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Building Better Science: A Framework for Discovery and Project-Based Learning in Thermal Physics Education

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Abstrak:
Project-based learning involves (1) students investigating important ideas and asking questions, (2) finding understanding in the process of investigating, (3) according to their needs and interests, (4) producing products and thinking creatively, (5) being critical and skilled in investigating and concluding material, and (6) connecting with real-world, authentic problems and issues. The Discovery Learning learning paradigm requires the instructor to supervise and steer student learning activities according to the goals—conditions like these desire to shift teaching and learning from teacher-centered to student-centered. R&D and experimentation are used in this study. After the research, statistics were used to compare student learning results from both practicum guides with distinct approach strategies. The Discovery practicum guide is the independent variable. Project-based learning and character qualities, whereas student learning results are the dependent variable. The average pretest score in Experimental Class I and II, Discovery Model practical guideIn a row, the Project-Based Learning Model is 53.00±8.65183375 and 56.00±11.91704748The average posttest score in Experimental Class I, Discovery model practical guide, and Experimental Class II, practical guideProject Based Learning Model: 86.00±9.045920836, 81.75±13.95110653. Establishing the normalized gain value of scientific learning outcomes in the class was important since students' average pretest and posttest scores in the science experiment differed. The Discovery Model practical guide is more successful for teaching and learning, particularly for heat and explanation information, than the Experimental Model. Project-based learning is best with the Discovery Model practical guide.

Keywords: Development; Discovery; Education; PBL; Practical Guidelines

Introduction

Indonesian education, particularly Junior High School (SMP), is crucial to students' natural science understanding and abilities. Natural science requires comprehending abstract principles and practical applications (Gunawan et al., 2017). Good learning helps students attain educational objectives, such as intellectual, moral, and social behaviour improvements (Lou et al. 2017;Craig and Marshall 2019;Maghfiroh et al. 2023). Learning resources and development help attain learning objectives. The scientific learning environment is a collection of knowledge gathered and refined via practicums that ask what, why, and how. Science learning has two parts: method and result (Ozdem-Yilmaz & Bilican, 2020). Science is a collection of natural science facts, ideas, and principles ;(Pizzolato and Persano Adorno 2020;Cai et al. 2021;Zulyusri et al. 2023). scientific involves abilities and attitudes needed to get and produce scientific products. This suggests that science learning must include cognitive, emotional

(scientific attitude), and psychomotor aspects (Begalli and Bilow 2019;Nurtanto, Fawaid, and Sofyan 2020);.

As educators, we often evaluate the curriculum and devise innovative strategies to address challenges in student learning. Educators may use three scientific methodologies to address the varied requirements of students in natural sciences: discovery/inquiry learning, project-based learning, and problem-based learning (Kalemkuş and Bulut-Özek 2024;Hujjatusnaini et al. 2022;Safaruddin et al. 2020). The strategy involves strategies used by educators to enhance student motivation and interest in science, aiming to improve academic accomplishment. Employing a scientific methodology in genuine learning and evaluation that incorporates the notion of assessment as an integral component of the learning process (Purwaningsih et al., 2020). The scientific approach to education must be enhanced by the adoption of a discovery-based learning paradigm (discovery learning/inquiry). To enhance students' capacity for contextual work, it is strongly advised that individuals and groups adopt a learning methodology centered on work-based problem-solving (problem-based learning) and project-based learning.

The aforementioned three sorts of scientific techniques are fundamental to constructivist learning. The methodologies established by Plato and Aristotle were subsequently used by John Dewey and Lev Vygotsky in twentieth-century education. The globally established concept of using student-centered constructivist learning approaches has given pupils several opportunity to develop their own knowledge. Students' unique skills, intellect, and creative thinking can only be realised via student-centered learning methodologies (Tsybulsky & Muchnik-Rozanov, 2019).

Learning activities should be conducted interactively, inspiringly, engagingly, and challengingly, encouraging active student participation while allowing ample opportunity for initiative, creativity, and independence, aligned with students' talents, interests, and physical and psychological development (2013). Process norms for learning activities must be established via the execution of the present curriculum. Consequently, these process criteria are now being formulated inside the curriculum. Chen and Yang (2019) assert that laboratory activities play a crucial role in scientific education and demonstrate that students engaged in these activities get several advantages. Numerous research has been undertaken to assess the efficacy of laboratory experiments in scientific education in promoting cognitive, emotive, and practical objectives. In the laboratory, educators can foster students' physical, mental, and emotional engagement. Students have the chance to refine process skills to achieve optimal learning results. Directly encountered events may be ingrained in memory. The physical, mental, and emotional engagement of students is anticipated to be integrated into a learning environment that promotes self-confidence as well as inventive and creative behavior. Utilizing experimental techniques will enable the training and education of students to comprehend chemical ideas akin to those of a chemical scientist. Students engage in active learning by adhering to the phases of the educational process. Consequently, students will derive their own conceptions based on the outcomes achieved throughout the learning process.

The aspiration to provide optimal teaching and learning activities in the classroom, coupled with the extensive contents students must understand, sometimes hinders instructors from concentrating on the quality of student practicums. Teachers have several challenges in optimizing student practicum activities. Numerous studies have been undertaken, including: According to Krajcik and Czerniak (2018), obstacles in the implementation of practicums in schools include the lack of chemistry practicum guides to assist students, the absence of assessment guidelines for teachers regarding science process skills and scientific attitudes, and the high costs of chemistry practicum materials and equipment. The objective of this study is to 1) provide a practical guide based on discovery-type syntax and project-based learning. Obtain the

Discovery and Experimental-type practical guides for Project-Based Learning. The disparity in the substantial enhancement in learning outcomes achieved by the Discovery type and Problem type practical guides in Project-Based Learning. The efficacy of the learning process is facilitated by Discovery and Problem-based practical guides.

Literature Study

The integration of innovative teaching strategies, such as Discovery Learning (DL) and Project-Based Learning (PBL), has garnered attention in the realm of science education due to their potential to enhance students' cognitive, emotional, and psychomotor skills (Ozdem-Yilmaz & Bilican, 2020). These methodologies are rooted in constructivist theories that emphasize student-centered learning and interactive environments to foster deeper comprehension and critical thinking skills (Nurtanto et al., 2020). The article explores the efficacy of DL and PBL models in improving student outcomes in thermal physics education.

1. Importance of Science Education in Middle Schools

Middle school science education plays a critical role in equipping students with foundational scientific knowledge and problem-solving skills (Gunawan et al., 2017). A well-structured curriculum, supported by hands-on activities, can lead to significant improvements in student engagement and understanding of complex scientific concepts (Lou et al., 2017). Studies have shown that incorporating laboratory activities within the curriculum promotes cognitive, emotive, and practical learning goals (Chen & Yang, 2019).

2. Discovery Learning and Project-Based Learning Models

DL emphasizes active learning by allowing students to engage in problem-solving, hypothesis formulation, and experimentation. This approach fosters critical thinking and a deeper understanding of scientific principles (Ozdem-Yilmaz & Bilican, 2020). In contrast, PBL encourages students to tackle real-world problems through collaborative projects, promoting skills such as teamwork, creativity, and self-directed learning (Kalemkuş & Bulut-Özek, 2024). Research suggests that while both models enhance learning outcomes, DL has a more substantial impact on cognitive development due to its structured approach to conceptual understanding (Miller & Krajcik, 2019).

3. Efficacy of DL and PBL in Thermal Physics Education

The study found that the DL model was more effective than PBL in improving student learning outcomes in the context of thermal physics. Experimental data revealed that students using the DL practicum guide achieved a higher normalized gain in learning outcomes compared to those using the PBL guide (Begalli & Bilow, 2019). The structured nature of the DL guide facilitated uniform understanding among students, enabling them to grasp abstract concepts more effectively. In contrast, the PBL guide, while effective in enhancing psychomotor skills, fell short in providing the theoretical scaffolding required for comprehensive understanding (Zulyusri et al., 2023).

Implementing these models in classrooms poses challenges, such as limited resources and inadequate teacher training in laboratory management (Krajcik & Czerniak, 2018). To overcome these barriers, it is recommended that schools integrate both DL and PBL models, leveraging the strengths of each to provide a holistic learning experience. The combination of these methodologies can enhance students' cognitive abilities, foster creativity, and prepare them for real-world applications of science (Tsybulsky & Muchnik-Rozanov, 2019).

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Research Methods

This research technique encompasses Research and Development (R&D) and experimentation. Upon conclusion of the research, a statistical analysis was conducted to assess the learning results of students using two distinct practicum guides with varying methodological approaches (Sugiyono, 2013). The independent variable serves as a reference for the practical tasks associated with the type. Investigate and categorize Project-Based Learning and character values, with the dependent variable being student learning results. The research design is shown below.

Sample Group	Pretest	Treatment	Posttest	Learning outcomes
Experiment 1 Discovery Type Practical Guide	T1	X1	T2	H1
Experiment 1 Practical Guide type project *Based Learning*	T1	X2	T2	H2

Population and Sample

The population is all SMP Negeri 3 Muara Tiga class VII students in the odd semester of 2024/2025. Cluster random sampling was used to sample two class VII courses.

Data Collection Techniques and Instruments

Researchers gather data using the test method. Data from:

1. Pre-test completed in both courses before beginning content. Both classes took a post-test after finishing the content and treatment.
2. The learning outcome exam is a multiple-choice test with five answers: A, B, C, D, and E. All learning test results address cognition (Sugiyono, 2013)

Two scores are given: one for the right response and zero for the erroneous answer. For analysis, test items are scored 0-100, giving them a weight of 100: 40 = 2.5.

Data Analysis Techniques

Data analysis methods for hypothesis testing:

1. Normality Check

   The Kolmogorov-Smirnov test in SPSS 16 tests normalcy. A result> 0.05 indicates regularly distributed data.

2. Homogeneity Test.

Test pretest homogeneity using a t-test. Start by testing the variance of both samples using SPSS Statistics Version 16.0 for Windows.

The qualitative data came from professional instructors' questionnaire replies and the quantitative data came from practical guidance trials. (Arikunto, 2003). Questionnaire data was analysed as follows: The collected data is a checklist summarised in a table. The 1-4 scale is not good, less good, excellent, and very good. Adjust the data analysis findings to match the eligibility statistics in the table. Conducting data analysis and drawing findings.

Results

Investigation into the creation of a handbook for 7th grade junior high school science practicals using the Discovery model and the Model Project-Based Learning, along with the Merdeka curriculum, including Research and Development (R&D) and Experiments. The study's conclusions include the creation of a handbook for scientific practicums for seventh-grade junior high schools, developed via the formulation of standard curricular experiments based on the Discovery and Experimental models. Project-based learning involves engaging in practical tasks aligned with the scientific curriculum for seventh-grade junior high school students.

The development process starts with the submission of scientific materials appropriate for curriculum implementation, followed by the compilation of practical experiments grounded on the principles of the Discovery Model and the Model. Project-based learning involves gathering information from science educators to choose a suitable school for research purposes. The scientific educators were solicited for their perspectives on the presence of science laboratory facilities, the state of the science laboratory, and the suitability of the class VII curriculum materials on heat and expansion for practical application.

The data indicates that the average science learning outcomes for students at SMP Negeri 3 Muara Tiga are derived from experimental class I, which utilised the Discovery model science practicum guide, and experimental class II, which also employed the same guide for Project-Based Learning. The mean pretest score was achieved in Experimental Class I using the Discovery Model practicum guide and in Experimental Class II employing the Discovery Model practicum guide. The Project Based Learning Model yields results of 53.00±8.65 and 56.00±11.92. The mean posttest score was achieved in Experimental Class I, using the Discovery model practical guide, and in Experimental Class II, employing the practical guide. The Project-Based Learning Model scores are 86.00 ± 9.045920836 and 81.75 ± 13.95110653.

The pretest and posttest data revealed a discrepancy in the average scores of students in the scientific experiment, necessitating the calculation of the normalised gain value for science learning outcomes in the class. Data homogeneity testing is conducted to ascertain if two datasets from distinct samples exhibit homogeneity. The homogeneity test is calculated using the SPSS 17.0 for Windows software, using Levene's test. If the significance level exceeds 0.05, the data is homogenous. Derived from the examinationLevene's Test for Equality of Variances indicates a significance value of 0.296, which is above the threshold of 0.05. Additionally, the Sig. (2-tailed) for experimental class I is 0.433, while for experimental class II it is 0.434. It may be inferred that the aforementioned data is homogenous.

Discussion

This research is to evaluate the efficacy of the Discovery Model practical guide and Project-Based Learning Model on the topic of Heat for seventh-grade science enthusiasts in the first semester. The effectiveness is shown by the improvement in student learning outcomes after the use of the practicum guide, which was

earlier assessed for normalcy to see if the study population of each variable was normally distributed. Data that followed a normal distribution were analysed to assess student learning outcomes; this normally distributed data was used for the study involving Experimental Class I and Experimental Class II, conducted using the Kolmogorov-Smirnov test in SPSS Version 17.0. The data processing findings indicate that the significance value for normality is 0.269, which above 0.05; hence, it may be inferred that the data follows a normal distribution.

Utilising two classes as samples, designated as experimental class I and experimental class II, prior to the implementation of the practical guide, reveals that the comprehension levels of both experimental classes are homogeneous. This is evidenced by Levene's Test conducted in the SPSS program, yielding a significant value of 0.433, which exceeds 0.05.

The percentage data on the enhancement of learning outcomes reveals 75.9% for experimental class I and 60.7% for experimental class II. The data indicates that experimental class I, utilising the Discovery Model practical guide, exhibited a greater percentage increase in learning outcomes than experimental class II, which employed the Project Based Learning Model practical guide. This suggests that the efficacy of the Discovery Model practical guide surpasses that of the Project Based Learning Model practical guide.

The analysis of questionnaires distributed to the validation team, comprising teachers and lecturers, reveals that the average evaluation of the prepared practicum guide indicates a superior assessment for the Project Based Learning model compared to the Discovery model. During implementation, students using the Project Based Learning model practicum guide exhibit a lesser average gain in learning outcomes compared to those employing the Discovery model practicum guide. Students in experimental class I using the Discovery Model practicum guide adhere strictly to the established processes, employing the offered tools and resources, which facilitates a uniform comprehension of the practicum tasks among the students. Each student should conduct practicums in accordance with the established processes outlined in the handbook. Based on the learning results of students in the experimental class I, those using the Discovery model practicum guide exhibit uniform scores, indicating no significant difference in learning across the students.

Factors affecting the enhancement of student learning results include the limited assistance of the Project Learning model practicum for theoretical comprehension and the many questions included in the examination. The Project Based Learning model practicum prioritises students' psychomotor skills above the Discovery model practicum guide.

Consequently, it is preferable for the execution of practical work in junior high schools to integrate the Discovery Model and Project-Based Learning Model, with the objective of enhancing students' psychomotor skills, and cognitive abilities, and fostering a more dynamic learning process in practical activities.

Conclusion

Create model syntax-based practical guidelines Models and discovery Project-based learning. The Discovery Model practical guide is based on laboratory tools and materials, while the Project Based Learning model practical guide must be designed independently from preparing the tools and materials, and students must discover their surroundings. Data research at the school demonstrates that the Discovery and Practical Models have different learning outcomes. Project Based Learning on the heat and decomposition material at SMP Negeri 3 Muara Tiga class VII semester 1 using the Merdeka curriculum shows that experimental class I using the Discovery model practical guide has an average value of 79.00, which

increases learning outcomes by 75.9%, and experimental class II using the Model practicum guide has an average value of 67.50, which increases learning outcomes by 60%.

Students who utilise the Discovery practical guide score higher than those who use the Experimental one.Project-based learning. Based on the debate, the Discovery Model practical guide is more successful for teaching and learning, particularly for heat and analytical content, than the Model practical guide. Project-based learning is best with the Discovery Model practical guide.

Reference

Begalli, M., & Bilow, U. (2019). Sharing LHC Research and Discovery with High School Students. In M. Pietrocola (Ed.), *Upgrading Physics Education to Meet the Needs of Society* (pp. 69–84). Springer International Publishing. https://doi.org/10.1007/978-3-319-96163-7_4

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. (2021). Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, *52*(1), 235–251. https://doi.org/10.1111/bjet.13020

Chen, C.-H., & Yang, Y.-C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, *26*, 71–81. https://doi.org/10.1016/j.edurev.2018.11.001

Craig, T. T., & Marshall, J. (2019). Effect of project-based learning on high school students' state-mandated, standardized math and science exam performance. *Journal of Research in Science Teaching*, *56*(10), 1461–1488. https://doi.org/10.1002/tea.21582

Gunawan, G., Sahidu, H., Harjono, A., & Suranti, N. M. Y. (2017). Efektivitas Penerapan Model Project Based Learning Berbantuan Media Virtual terhadap Kreativitas Fisika Peserta Didik. *Jurnal Cakrawala Pendidikan*, *36*(2). https://doi.org/10.21831/cp.v36i2.13514

Hujjatusnaini, N., Corebima, A. D., Prawiro, S. R., & Gofur, A. (2022). The Effect of Blended Project-based Learning Integrated with 21st-Century Skills on Pre-Service Biology Teachers' Higher-order Thinking Skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 104–118. https://doi.org/10.15294/jpii.v11i1.27148

Kalemkuş, F., & Bulut-Özek, M. (2024). The effect of online project-based learning on metacognitive awareness of middle school students. *Interactive Learning Environments*, *32*(4), 1533–1551. https://doi.org/10.1080/10494820.2022.2121733

Krajcik, J. S., & Czerniak, C. M. (2018). *Teaching Science in Elementary and Middle School: A Project-Based Learning Approach* (1st ed.). Routledge. https://doi.org/10.4324/9781315205014

Lou, S.-J., Chou, Y.-C., Shih, R.-C., & Chung, C.-C. (2017). A Study of Creativity in CaC2 Steamship-derived STEM Project-based Learning. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(6). https://doi.org/10.12973/eurasia.2017.01231a

Maghfiroh, S., Wilujeng, I., Jumadi, J., & Masyitha, D. (2023). Development of Physics E-Module Based on Discovery Learning to Improve Students' Scientific Literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 452–458. https://doi.org/10.29303/jppipa.v9i2.1733

Miller, E. C., & Krajcik, J. S. (2019). Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 7. https://doi.org/10.1186/s43031-019-0009-6

Nurtanto, M., Fawaid, M., & Sofyan, H. (2020). Problem Based Learning (PBL) in Industry 4.0: Improving Learning Quality through Character-Based Literacy Learning and Life Career Skill (LL-LCS). *Journal of Physics: Conference Series*, *1573*(1), 012006. https://doi.org/10.1088/1742-6596/1573/1/012006

Ozdem-Yilmaz, Y., & Bilican, K. (2020). Discovery Learning—Jerome Bruner. In B. Akpan & T. J. Kennedy (Eds.), *Science Education in Theory and Practice* (pp. 177–190). Springer International Publishing. https://doi.org/10.1007/978-3-030-43620-9_13

Permendikbud. (2013). *Peraturan Menteri Pendidikan dan Kebudayaan Nomor 59 Tahun 2014 Tentang Kurikulum 2013 Sekolah Menengah Atas/Madrasah Aliyah*.

Pizzolato, N., & Persano Adorno, D. (2020). Informal physics teaching for a better society: A mooc-based and context-driven experience on learning radioactivity. *Journal of Physics: Conference Series*, *1512*(1), 012040. https://doi.org/10.1088/1742-6596/1512/1/012040

Purwaningsih, E., Sari, S. P., Sari, A. M., & Suryadi, A. (2020). The Effect of STEM-PjBL and Discovery Learning on Improving Students' Problem-Solving Skills of Impulse and Momentum Topic. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 465–476. https://doi.org/10.15294/jpii.v9i4.26432

Safaruddin, S., Ibrahim, N., Juhaeni, J., Harmilawati, H., & Qadrianti, L. (2020). The Effect of Project-Based Learning Assisted by Electronic Media on Learning Motivation and Science Process Skills. *Journal of Innovation in Educational and Cultural Research*, *1*(1), 22–29. https://doi.org/10.46843/jiecr.v1i1.5

Sugiyono, D. (2013). *Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D.*

Tsybulsky, D., & Muchnik-Rozanov, Y. (2019). The development of student-teachers' professional identity while team-teaching science classes using a project-based learning approach: A multi-level analysis. *Teaching and Teacher Education*, *79*, 48–59. https://doi.org/10.1016/j.tate.2018.12.006

Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature Study: Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555