PROJECT-BASED LEARNING AND RALLY TABLE: EFFECTS ON ELECTRICITY LEARNING OUTCOMES IN HIGH SCHOOL

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ABSTRACT
The implementation of Project-Based Learning (PjBL) in physics instruction is aligned with topics that have direct applications in daily life, such as electricity. One of the projects that students can undertake is constructing a simple household electrical installation. However, PjBL has a limitation in which students only focus on the project's final product rather than the underlying concepts required to complete it. This condition leads to decreased student engagement during the learning process, which may increase the probability of declining learning outcomes. This weakness can be addressed by integrating the Rally Table Strategy (RTS). Therefore, this study aims to measure the effectiveness of PjBL combined with RTS in improving the learning outcomes of 12th-grade students on electricity. The study employed a one-group pretest-posttest design with a sample of 72 students. The findings indicate an improvement in learning outcomes by 37%. In addition, classroom observations revealed that proper time allocation between regular learning activities and project work is essential to foster active student engagement throughout the learning process.

Keywords: Project-Based Learning, Rally Table Strategy, Learning Outcomes, Electricity

INTRODUCTION
Physics learning can be delivered directly through the lecture method; however, it provides limited opportunities for students to experience its application in daily life[1]. Over time, teachers are required to adjust their teaching practices to align with the latest curriculum implemented by the government[2]. Currently, the Merdeka Curriculum serves as

[1] Munir Tubagus et al., "Studi Komparatif Antara Pembelajaran Berbasis Proyek Dan Metode Ceramah Dalam Memperkuat Konsep Fisika Serta Kemampuan Pemecahan Masalah A Comparative Study Between Project-Based Learning and Lecture Methods in Strengthening Physics Concepts and Problem-S," Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam, 2024, https://mathedu.joln.my.id/index.php/edu/article/view/64.
[2] Enjelli Hehakaya and Delvyn Pollatu, "Problematika Guru Dalam Mengimplementasikan Kurikulum Merdeka," *Jurnal Pendidikan DIDAXEI* 3, no. 2 (2022): 394–408, https://e-journal.iaknambon.ac.id/index.php/DX/article/view/617.

the main reference for classroom learning[3]. This curriculum emphasizes student-centered learning, in which students' active participation in the classroom outweighs that of the teacher[4]. Student-centered learning itself is not entirely new, as it had already been initiated under the 2013 Curriculum prior to the adoption of the Merdeka Curriculum[5].

One of the learning models that applies a student-centered strategy is Project-Based Learning (PjBL)[6]. Recent syntheses indicate that project-based learning (PjBL) improves student achievement, motivation, and higher-order thinking across diverse contexts, especially when projects are carefully scaffolded and aligned with assessment[7]. Teachers can maximize PjBL's effectiveness by complementary cooperative structures that sustain conceptual dialogue during hands-on project work[8].

PjBL requires students to produce a final product as the outcome of a learning process conducted over one semester[9]. The implementation of PjBL has been carried out at SMA Negeri 1 Lawang in the subject area, which involves real-world problem-solving through product development. PjBL encourages students to explore, foster collaboration, and integrate multiple disciplines in addressing problems related to the learning topics[10]. The application of PjBL is particularly suitable for electricity-related issues, as it allows for in-depth discussion of a single concept while offering numerous opportunities for real-life

[3] Difana Leli Anggraini et al., "PERAN GURU DALAM MENGEMBANGAN KURIKULUM MERDEKA," *Jurnal Ilmu Pendidikan Dan Sosial* 1, no. 3 (December 1, 2022): 290–98, https://doi.org/10.58540/JIPSI.V1I3.53.

[4] Ni Nyoman et al., "IMPLEMENTASI PENDEKATAN TEACHING AT THE RIGHT LEVEL (TARL) TERINTEGRASI KONSEP UNDERSTANDING BY DESIGN (UBD) UNTUK MENINGKATKAN MOTIVASI BELAJAR SISWA SMA PADA PEMBELAJARAN BIOLOGI," *Widyadari* 25, no. 1 (April 12, 2024): 157–72, https://doi.org/10.59672/WIDYADARI.V25I1.3662; Nurhayati Nurhayati et al., "Implementasi Dan Tantangan Kurikulum Merdeka Di SMA: Strategi Pengajaran Berpusat Pada Siswa Untuk Pembelajaran Yang Lebih Fleksibel Dan Kreatif," *Jurnal Pendidikan* 13, no. 1 (January 14, 2025): 69–79, https://e-journal.unimudasorong.ac.id/index.php/jurnalpendidikan2/article/view/155.

[5] Anggina Resa, "Implmementasi Kurikulum Merdeka Berdasarkan Pendekatan Understanding by Design," *Jurnal Primary (Kajian Ilmu Pendidikan Dasar Dan Humaniora)* 4, no. 1 (April 28, 2023): 1–8, https://ejournal.universitaspgridelta.ac.id/index.php/psd/article/view/444; Qurota A'yun Ning Kamila et al., "Merdeka Belajar: Memahami Konsep Pembelajaran Masa Kini," *Journal of Information Systems and Management (JISMA)* 3, no. 2 (2024): 104–10, https://doi.org/10.4444/JISMA.V3I2.909.

[6] Warda Rasidah et al., "Pengaruh Penggunaan Model Pembelajaran Project Based Learning Terhadap Penguasaan Materi IPA Pada Siswa," *JURNAL PENDIDIKAN MIPA* 12, no. 4 (December 1, 2022): 1072–78, https://doi.org/10.37630/JPM.V12I4.730; Deby Fauzi Asidiqi, "MODEL PROJECT BASED LEARNING (PjBL) DALAM MENINGKATKAN KREATIVITAS SISWA," *JURNAL PENDIDIKAN DASAR SETIA BUDHI (JPDS)* 7, no. 2 (January 25, 2024): 123–30, https://jurnal.usbr.ac.id/jpds/article/view/236.

[7] Lu Zhang and Yan Ma, "A Study of the Impact of Project-Based Learning on Student Learning Effects: A Meta-Analysis Study," *Frontiers in Psychology* 14 (2023): 1202728, https://doi.org/10.3389/FPSYG.2023.1202728.

[8] Xigui Yang, "A Historical Review of Collaborative Learning and Cooperative Learning," *Techtrends* 67, no. 4 (July 1, 2023): 1, https://doi.org/10.1007/S11528-022-00823-9.

[9] Damayanti Nababan, Alisia Klara Marpaung, and Angeli Koresy, "STRATEGI PEMBELAJARAN PROJECT BASED LEARNING (PJBL)," *Jurnal Pendidikan Sosial Dan Humaniora* 2, no. 2 (May 1, 2023): 706–19, https://publisherqu.com/index.php/pediaqu/article/view/178.

[10] W. Azura et al., "The Science Environment Technology Society (SETS) Based e-Module Development with Project Based Learning Model in Colloidal Learning," *Journal of Physics: Conference Series* 2157, no. 1 (January 1, 2022): 012046, https://doi.org/10.1088/1742-6596/2157/1/012046; Puput Lestari, Bakti Mulyani, and Dan Sri Mulyani, "Pengaruh Pendekatan SETS (Science, Environment, Technology, and Society) Berbasis Project Based Learning Pada Materi Asam Basa Terhadap Minat Kewirausahaan Siswa Kelas X SMK Kesehatan Donohudan Boyolali," *Jurnal Pendidikan Kimia* 11, no. 2 (December 28, 2022): 231–38, https://doi.org/10.20961/JPKIM.V11I2.66749.

applications that students can directly experience[11]. Several topics covered in the electricity study include static electricity, direct current (DC), magnetism, and alternating current (AC). A relevant product aligned with PjBL in these topics is the development of a simple household electrical installation[12].

However, implementing PjBL presents challenges. Students may focus primarily on the final product while neglecting the underlying physics concepts, and uneven participation or poor pacing can reduce conceptual gains[13]. Efforts to minimize these challenges can be made by readjusting and adapting the PjBL model[14].

Teachers have employed strategies to minimize these difficulties by clearly allocating time between students' project work and regular classroom learning activities[15]. This approach is expected to balance students' mastery of fundamental knowledge with the skills required for producing PjBL outcomes, enabling teachers to assess students' abilities more

[11] N. Diana, Yohannes, and Y. Sukma, "The Effectiveness of Implementing Project-Based Learning (PjBL) Model in STEM Education: A Literature Review," *Journal of Physics: Conference Series* 1882, no. 1 (May 13, 2021), https://doi.org/10.1088/1742-6596/1882/1/012146; C. Nurmaliah et al., "The Impact of Implementation of STEM Integrating Project-Based Learning on Students' Problem-Solving Abilities," *Journal of Physics: Conference Series* 1882, no. 1 (May 1, 2021): 012162, https://doi.org/10.1088/1742-6596/1882/1/012162; Y. Yunita et al., "The Effectiveness of the Project-Based Learning (PjBL) Model in Students' Mathematical Ability: A Systematic Literature Review," *Journal of Physics: Conference Series* 1882, no. 1 (May 13, 2021), https://doi.org/10.1088/1742-6596/1882/1/012080.

[12] Adhitya Rahardhian, "PENGARUH PEMBELAJARAN PJBL BERBASIS STEM TERHADAP KEMAMPUAN BERPIKIR KRITIS SISWA PADA MATERI LISTRIK DINAMIS," *JIPPF (Jurnal Inovasi Penelitian Dan Pembelajaran Fisika)* 3, no. 1 (2022), https://doi.org/10.26418/jippf.v3i1.50882; Susi Indria Wijayanti et al., "PENINGKATAN KREATIFITAS PESERTA DIDIK DALAM MERANGKAI LISTRIK SERI DAN PARALEL PADA SEBUAH DENAH RUMAH," *Journal of Lesson Study in Teacher Education* 1, no. 1 (2022): 1–6, https://doi.org/10.51402/JLSTE.V1I1.87.

[13] Shaban Aldabbus, "PROJECT-BASED LEARNING: IMPLEMENTATION & CHALLENGES," *International Journal of Education, Learning and Development* 6, no. 3 (2018): 71–79, https://www.researchgate.net/publication/328368222; Berta de la Torre-Neches et al., "Project-Based Learning: An Analysis of Cooperation and Evaluation as the Axes of Its Dynamic," *Humanities and Social Sciences Communications* 7, no. 1 (December 1, 2020): 1–7, https://doi.org/10.1057/S41599-020-00663-Z;SUBJMETA=160,4004,4014;KWRD=DEVELOPMENT+STUDIES,EDUCATION.

[14] Malika Dian and Ayu Noviati, "Application of the Project Based Learning Model (PJBL)," *Social, Humanities, and Educational Studies (SHES): Conference Series* 4, no. 6 (September 1, 2021): 644–47, https://doi.org/10.20961/SHES.V4I6.68514; Manik Hatining, "Increasing Students' Learning Motivation in Limited Face-to-Face Learning through the PjBL (Project Based Learning) Model)," *Social, Humanities, and Educational Studies (SHES): Conference Series* 4, no. 5 (October 8, 2022): 1228–37, https://doi.org/10.20961/SHES.V4I5.66184; Muhammad Nur Huda and Yunia Tiara Riski, "Analisis Kelebihan Dan Kekurangan Kurikulum Prototipe," *JAMBURA Elementary Education Journal* 4, no. 2 (March 22, 2023): 89–96, https://doi.org/10.37411/JEEJ.V4I2.1473; Nababan, Marpaung, and Koresy, "STRATEGI PEMBELAJARAN PROJECT BASED LEARNING (PJBL)."

[15] Sri Wahyu Widyaningsih and Irfan Yusuf, "Implementation of Project-Based Learning (PjBL) Assisted by E-Learning through Lesson Study Activities to Improve the Quality of Learning in Physics Learning Planning Courses.," *International Journal of Higher Education* 9, no. 1 (2020): 60–68, https://doi.org/10.5430/ijhe.v9n1p60; Diana, Yohannes, and Sukma, "The Effectiveness of Implementing Project-Based Learning (PjBL) Model in STEM Education: A Literature Review"; Ignatia Esti Sumarah et al., *Pembelajaran Berbasis Proyek Berdasarkan Gaya Belajar Vark: Untuk Peserta ... - Ignatia Esti Sumarah, Rusmawan, Cipta Gilang Kencana, Kristophorus Divinanto Adi Yudono, Chrisnutajati Waninghiyu, Agata Mustika Kusuma Dewi - Google Books*, ed. Ignatia Esti Sumarah (Yogyakarta : Sanata Dharma University Press, 2022), https://books.google.co.id/books?hl=en&lr=&id=jPHAEAAAQBAJ&oi=fnd&pg=PA1&dq=keseimbangan+belajar+di+kelas+dan+proyek&ots=nysEL7y7vv&sig=ih_SdbZywYOLd2lvBbxEcnGYEkc&redir_esc=y#v=onepage&q=keseimbangan belajar di kelas dan proyek&f=false.

objectively and in a structured manner[16]. In practice, however, students still face challenges in understanding the basic concepts of the subject matter and often demonstrate low motivation during regular classroom learning[17]. This issue can be identified through a 52% decrease in the proportion of students actively responding during lessons[18]. Furthermore, reduced student engagement in answering teachers' questions can also be observed in their behaviors, such as waiting for answers from the teacher or peers instead of attempting to respond independently, avoiding eye contact to escape being called on, providing irrelevant answers that reflect superficial understanding, and similar patterns[19]. The decline in classroom engagement further increases the likelihood of lower learning outcomes, as students' problem-solving abilities in fundamental topics fall short of the targeted learning objectives.

Meta-analytic work on cooperative and active-learning approaches suggests that structured cooperative practices and frequent, guided peer interactions substantially increase cognitive and social learning outcomes relative to unstructured group work[20]. One instructional strategy whose advantages can address the shortcomings of the PjBL model is the Rally Table Strategy (RTS). RTS is a cooperative learning strategy in which all students are actively involved regardless of differences in ability, and its implementation incorporates play elements[21]. This strategy not only requires students to be skillful and quick in solving problems but also encourages them to complement each other's knowledge with peers during the problem-solving process. Thus, the RTS serves as an alternative to minimize the weaknesses of PjBL, as it offers several advantages: students within a group are actively

[16] Wening Patmi Rahayu, Hidayatin Hidayatin, and Madziatul Churiyah, "Development of a Project-Based Learning Assessment System to Improve Students' Competence," *Jurnal Pendidikan Ekonomi Dan Bisnis (JPEB)* 8, no. 2 (October 1, 2020): 86–101, https://doi.org/10.21009/JPEB.008.2.1; Parno et al., "Impact of The STEM Approach with Formative Assessment in PjBL on Students' Critical Thinking Skills," *Journal of Physics: Conference Series* 2165, no. 1 (January 1, 2022): 012044, https://doi.org/10.1088/1742-6596/2165/1/012044; Vijayalakshmi M, Preeti Patil, and Girish Karikatti, "Effective Assessment Strategies for Project-Based Learning," *Journal of Engineering Education Transformations* 36 (December 1, 2022): 154–60, https://journaleet.in/index.php/jeet/article/view/244.

[17] Edi Rozal et al., "The Effect of Project-Based Learning through YouTube Presentations on English Learning Outcomes in Physics," *AL-ISHLAH: Jurnal Pendidikan* 13, no. 3 (December 6, 2021): 1924–33, https://doi.org/10.35445/ALISHLAH.V13I3.1241.

[18] Tira Selviana Putri, Muliati Syam, and Laili Komariyah, "Penerapan Model Project Based Learning (PjBL) Di SMAN 1 Muara Pahu Kelas XI Pada Materi Fluida Statis," *Jurnal Literasi Pendidikan Fisika (JLPF)* 1, no. 02 (November 20, 2020): 152–64, https://doi.org/10.30872/jlpf.v1i02.232.

[19] Kris Kimbark, Michelle L. Peters, and Tim Richardson, "Effectiveness of the Student Success Course on Persistence, Retention, Academic Achievement, and Student Engagement," *Community College Journal of Research and Practice* 41, no. 2 (February 1, 2017): 124–38, https://doi.org/10.1080/10668926.2016.1166352; Hao Lei, Yunhuo Cui, and Wenye Zhou, "Relationships between Student Engagement and Academic Achievement: A Meta-Analysis," *Social Behavior and Personality* 46, no. 3 (2018): 517–28, https://doi.org/10.2224/SBP.7054; Jorge Díez, "Lack of Interest? Self and Peer Assessment as a Means to Improve Students' Engagement," *Innovations in Education and Teaching International* 60, no. 2 (March 4, 2023): 218–26, https://doi.org/10.1080/14703297.2021.2013288;PAGE:STRING:ARTICLE/CHAPTER.

[20] Zhang and Ma, "A Study of the Impact of Project-Based Learning on Student Learning Effects: A Meta-Analysis Study"; Marselius Sampe Tondok, Suryanto Suryanto, and Rahkman Ardi, "Building Bridges in Diverse Societies: A Meta-Analysis of Field Experimental Cooperative Learning Studies on Intergroup Relations in Educational Settings," *Societies 2024, Vol. 14, Page 221* 14, no. 11 (October 27, 2024): 221, https://doi.org/10.3390/SOC14110221.

[21] Adhar Adhar, "MENINGKATKAN HASIL BELAJAR MATEMATIKA MELALUI MODEL PEMBELAJARAN RALLY TABLE PADA SISWA KELAS VIIIB MTS 'SAINS' ALGEBRA KOTA SORONG," *SOSCIED* 2, no. 2 (November 5, 2019): 76–88, https://doi.org/10.32531/JSOSCIED.V2I2.171.

engaged in solving complex problems that are broken down into smaller steps, ensuring participation from lower-achieving students, while also promoting more equitable contributions through game-based task completion[22].

Previous studies have demonstrated improvements in students' learning outcomes through the independent implementation of the RTS[23]. This study combines PjBL with RTS to minimize the limitations inherent in PjBL. The integration of RTS into PjBL has a strong theoretical and empirical rationale: PjBL provides authentic tasks and learning contexts, whereas RTS offers recurring micro-interactions that help maintain conceptual focus and promote peer scaffolding during project implementation[24]. Therefore, this study hypothesizes that implementing PjBL combined with RTS will yield a statistically significant improvement in the learning outcomes of 12th-grade students on electricity.

RESEARCH METHODS

This study employed a pre-experimental method with a one-group pretest–posttest design as presented in Table 1[25]. This method was selected to examine the effect of implementing PjBL integrated with RTS on students' learning outcomes in electricity. The study involved one experimental group without a control group[26]. A pretest was administered to assess students' prior knowledge, followed by implementing the PjBL-RTS treatment over three physics learning sessions. The PjBL-RTS activities were conducted through several learning stations around the school environment, where students worked in pairs to solve electricity-related problems within a specified time limit. After the treatment was completed, a posttest was administered to measure the improvement in students' learning outcomes.

Table 1. One group pretest-posttest design

Pretest	Treatment	Posttest
O_1	X	O_2

This study involved 72 twelfth-grade students from SMAN 1 Lawang as the research sample. The sampling technique employed was saturated sampling, in which the sample size is equivalent to the total population[27]. The independent variable in this study was the PjBL model integrated with the RTS, while the dependent variable was the students' learning outcomes.

[22] Adhar...
[23] Adhar...
[24] Yang, "A Historical Review of Collaborative Learning and Cooperative Learning"; Melissa Dancy et al., "Physics Instructors' Knowledge and Use of Active Learning Has Increased over the Last Decade but Most Still Lecture Too Much," *Physical Review Physics Education Research* 20, no. 1 (2024): 10119, https://doi.org/10.1103/PhysRevPhysEducRes.20.010119.
[25] R. B. Johnson and L. B. Christensen, *Educational Research: Quantitative, Qualitative, and Mixed Approaches - R. Burke Johnson, Larry B. Christensen - Google Books*, ed. R. Burke Johnson and Larry B Christensen, *Sage* , 8th ed. (California: Sage, 2025), https://books.google.co.id/books?hl=en&lr=&id=juYaEQAAQBAJ&oi=fnd&pg=PT21&dq=Educational+research:+Quantitative,+qualitative,+and+mixed+approache&ots=3pEpvgCq2X&sig=J5kMWopZw7NVqjN3HiEKwaotHY0&redir_esc=y#v=onepage&q=Educational research%3A Quantitative%2C qualitative%2C and mixed approache&f=false.
[26] Richard A Swanson and Elwood F Holton III, *Research in Organizations: Foundations and Methods of Inquiry* (San Francisco, California: Berrett-Koehler Publishers, Inc., 2005).
[27] Johnson and Christensen, *Educational Research: Quantitative, Qualitative, and Mixed Approaches - R. Burke Johnson, Larry B. Christensen - Google Books*.

The test instrument consisted of 30 multiple-choice questions covering topics on dynamic electricity, static electricity, magnetic induction, and alternating current. The instrument was content-validated by experts to ensure its validity, followed by a trial with 72 students and a reliability test. The effectiveness of the treatment was analyzed based on the pretest and posttest results, with the difference between the two scores serving as the effectiveness index of the treatment condition.

The data analysis technique employed in this study consisted of prerequisite testing and hypothesis testing[28]. The prerequisite test used the Kolmogorov-Smirnov test to assess the normality of the data. The hypothesis test utilized a significance test of mean differences with the assistance of IBM SPSS software to determine the effect of implementing PjBL integrated with RTS on the learning outcomes of 12th-grade students in the topic of electricity.

RESEARCH RESULTS AND DISCUSSION

The 30-item pretest and posttest were administered to students and subsequently tested for reliability using IBM SPSS software. The results of the reliability test are presented in Table 2.

Table 2. Reliability test result

Cronbach's Alpha	N of Items
0.678	30

Based on the reliability test results, Cronbach's Alpha was 0.678, which is greater than 0.600. Therefore, it can be concluded that the test instrument was reliable. Furthermore, the improvement in students' learning outcomes can be seen from the pretest and posttest scores, as presented in Table 3.

Table 3. Pretest and posttest scores

	Pre	Post
Mean	45.06	66.49
N	72	72
Std. Deviation	12.950	8.876
Minimum	23	40
Maximum	83	85
Sum	3244	4787
Variance	167.715	78.789

Based on Table 3, the average score before the treatment was 45.06, with the highest score achieved by students being 83 and the lowest score being 23. After the treatment, the average score increased to 66.49, with the highest score of 85 and the lowest score of 40. These results indicate an improvement in students' learning outcomes from the initial stage to the final stage after the treatment. Furthermore, the students' test results were examined for distribution using the Kolmogorov–Smirnov normality test, as the sample size exceeded 30. The results of the normality test are presented in Table 4.

[28] Johnson and Christensen.

Table 4. Kolmogorov-Smirnov normality test

	Kolmogorov-Smirnov[a]		
Statistic		**df**	**Sig.**
Pre	.131	72	.004
Post	.084	72	.200*

Based on the results of the normality test, the pretest obtained a significance value of 0.004 < 0.05, indicating that the data were not normally distributed. Meanwhile, the posttest obtained a significance value of 0.200 > 0.05, indicating that the data were normally distributed. Referring to the non-normal distribution of the pretest data, a non-parametric test using the Wilcoxon test was conducted. The results of the Wilcoxon test are presented in Table 5.

Table 5. Wilcoxon test of pretest and posttest data

N			**Mean Rank**	**Sum of Ranks**
Post - Pre	Negative Ranks	7a	8.57	60.00
	Positive Ranks	65[b]	39.51	2568.00
	Ties	0c		
	Total	72		

a. Post < Pre
b. Post > Pre
c. Post = Pre

The results of the Wilcoxon test for the pretest and posttest showed that there were 7 students with negative ranks, indicating a decrease in learning outcomes. Meanwhile, 65 students had positive ranks, indicating improved learning outcomes. No students obtained the same scores on both the pretest and posttest. The Wilcoxon test statistics are presented in Table 6.

Table 6. Wilcoxon test result

	Post - Pre
Statistic test	0.000

The results of the Wilcoxon test presented in Table 6 show a significance value of 0.000. Since the significance value is < 0.05, this indicates a significant difference between the pretest and posttest results. Therefore, it can be concluded that *implementing PjBL integrated with RTS effectively influenced students' learning outcomes in the topic of electricity*. The average pretest and posttest scores increased, indicating an overall improvement in students' learning outcomes following the implementation of PjBL-RTS. This improvement was further evidenced by 65 students achieving mastery in accordance with the learning objectives.

The present study's findings are consistent with recent international research demonstrating that structured active-learning interventions produce meaningful gains in conceptual understanding and exam performance in STEM subjects. In particular, systematic reviews and meta-analyses of project-based and active-learning approaches report moderate

to significant positive effects on learning outcomes when instruction includes frequent formative interactions and scaffolding[29].

Integrating RTS into PjBL addresses a common weakness of unstructured project work. Students can become task-driven rather than concept-driven. RTS supplies repeated, brief opportunities for students to verbalize reasoning, receive peer feedback, and correct misconceptions in situ; this micro-interactional structure mirrors elements shown in cooperative-learning meta-analyses to enhance both cognitive and social outcomes[30].

PjBL can support students' critical and creative thinking skills by developing a simple household electrical installation project. In addition, RTS can enhance students' fundamental knowledge of electricity, as reflected in improving their learning outcomes. RTS reinforces students' basic understanding of electricity concepts through game-based learning activities that involve discussion and collaboration. Beyond cognitive improvement, this study also revealed positive social impacts, such as increased student participation in answering questions during class and greater overall engagement.

Observational data from this study also emphasize the importance of instructional pacing. Balancing the project duration and the RTS session ensures that conceptual and practical learning are both achieved. International evidence indicates that simply assigning projects is insufficient; teachers must design checkpoints and embed guided interactions to maintain cognitive engagement and prevent decline in conceptual focus during open-ended work[31]. Thus, the synergy observed here aligns with broader findings that active and cooperative learning are most effective when intentionally structured and monitored[32]. Moreover, increased engagement was observed in class, supporting the prior finding that active participation correlates positively with academic achievement[33].

CONCLUSION

Based on the findings of this study, it can be concluded that the combination of the PjBL model with the RTS has proven effective in improving students' physics learning outcomes in electricity topics. The improvement in students' learning outcomes before and after the treatment with the RTS reached 37%. In addition, the RTS successfully stimulated student engagement in classroom discussions and in responding to conceptual questions. Students became more active in the learning process, as the strategy required them to collaboratively solve group problems. Therefore, integrating the PjBL model with the RTS can be applied as an effective approach to enhance students' learning outcomes.

However, observations during the research process indicated that proper time allocation between regular lessons and project activities is required to support students' engagement throughout the learning process. In addition, the limited number of participants in this study restricts the generalizability of the findings. Therefore, future studies are encouraged to involve a larger number of students as research subjects. Furthermore, including both experimental and control classes in subsequent research designs would

[29] Zhang and Ma, "A Study of the Impact of Project-Based Learning on Student Learning Effects: A Meta-Analysis Study."
[30] Tondok, Suryanto, and Ardi, "Building Bridges in Diverse Societies: A Meta-Analysis of Field Experimental Cooperative Learning Studies on Intergroup Relations in Educational Settings."
[31] Dancy et al., "Physics Instructors' Knowledge and Use of Active Learning Has Increased over the Last Decade but Most Still Lecture Too Much."
[32] Zhang and Ma, "A Study of the Impact of Project-Based Learning on Student Learning Effects: A Meta-Analysis Study."
[33] Lei, Cui, and Zhou, "Relationships between Student Engagement and Academic Achievement: A Meta-Analysis."

provide a more comprehensive evaluation of the effectiveness of the PjBL model combined with the RTS in enhancing students' learning outcomes.

REFERENCES

Adhar, Adhar. "MENINGKATKAN HASIL BELAJAR MATEMATIKA MELALUI MODEL PEMBELAJARAN RALLY TABLE PADA SISWA KELAS VIIIB MTS 'SAINS' ALGEBRA KOTA SORONG." *SOSCIED* 2, no. 2 (November 5, 2019): 76–88. https://doi.org/10.32531/JSOSCIED.V2I2.171.

Aldabbus, Shaban. "PROJECT-BASED LEARNING: IMPLEMENTATION & CHALLENGES." *International Journal of Education, Learning and Development* 6, no. 3 (2018): 71–79. https://www.researchgate.net/publication/328368222.

Anggraini, Difana Leli, Marsela Yulianti, Siti Nur Faizah, Anjani Putri, and Belawati Pandiangan. "PERAN GURU DALAM MENGEMBANGAN KURIKULUM MERDEKA." *Jurnal Ilmu Pendidikan Dan Sosial* 1, no. 3 (December 1, 2022): 290–98. https://doi.org/10.58540/JIPSI.V1I3.53.

Asidiqi, Deby Fauzi. "MODEL PROJECT BASED LEARNING (PjBL) DALAM MENINGKATKAN KREATIVITAS SISWA." *JURNAL PENDIDIKAN DASAR SETIA BUDHI (JPDS)* 7, no. 2 (January 25, 2024): 123–30. https://jurnal.usbr.ac.id/jpds/article/view/236.

Azura, W., A. Silalahi, M. Zubir, and Nurfajriani. "The Science Environment Technology Society (SETS) Based e-Module Development with Project Based Learning Model in Colloidal Learning." *Journal of Physics: Conference Series* 2157, no. 1 (January 1, 2022): 012046. https://doi.org/10.1088/1742-6596/2157/1/012046.

Dancy, Melissa, Charles Henderson, Naneh Apkarian, Estrella Johnson, Marilyne Stains, Jeffrey R. Raker, and Alexandra Lau. "Physics Instructors' Knowledge and Use of Active Learning Has Increased over the Last Decade but Most Still Lecture Too Much." *Physical Review Physics Education Research* 20, no. 1 (2024): 10119. https://doi.org/10.1103/PhysRevPhysEducRes.20.010119.

Dian, Malika, and Ayu Noviati. "Application of the Project Based Learning Model (PJBL)." *Social, Humanities, and Educational Studies (SHES): Conference Series* 4, no. 6 (September 1, 2021): 644–47. https://doi.org/10.20961/SHES.V4I6.68514.

Diana, N., Yohannes, and Y. Sukma. "The Effectiveness of Implementing Project-Based Learning (PjBL) Model in STEM Education: A Literature Review." *Journal of Physics: Conference Series* 1882, no. 1 (May 13, 2021). https://doi.org/10.1088/1742-6596/1882/1/012146.

Díez, Jorge. "Lack of Interest? Self and Peer Assessment as a Means to Improve Students' Engagement." *Innovations in Education and Teaching International* 60, no. 2 (March 4, 2023): 218–26. https://doi.org/10.1080/14703297.2021.2013288;PAGE:STRING:ARTICLE/CHAPTER.

Hatining, Manik. "Increasing Students' Learning Motivation in Limited Face-to-Face Learning through the PjBL (Project Based Learning) Model)." *Social, Humanities, and Educational Studies (SHES): Conference Series* 4, no. 5 (October 8, 2022): 1228–37. https://doi.org/10.20961/SHES.V4I5.66184.

Hehakaya, Enjelli, and Delvyn Pollatu. "Problematika Guru Dalam Mengimplementasikan Kurikulum Merdeka." *Jurnal Pendidikan DIDAXEI* 3, no. 2 (2022): 394–408. https://e-journal.iaknambon.ac.id/index.php/DX/article/view/617.

Huda, Muhammad Nur, and Yunia Tiara Riski. "Analisis Kelebihan Dan Kekurangan Kurikulum Prototipe." *JAMBURA Elementary Education Journal* 4, no. 2 (March 22,

2023): 89–96. https://doi.org/10.37411/JEEJ.V4I2.1473.

Johnson, R. B., and L. B. Christensen. *Educational Research: Quantitative, Qualitative, and Mixed Approaches - R. Burke Johnson, Larry B. Christensen - Google Books*. Edited by R. Burke Johnson and Larry B Christensen. *Sage* . 8th ed. California: Sage, 2025. https://books.google.co.id/books?hl=en&lr=&id=juYaEQAAQBAJ&oi=fnd&pg=PT21&dq=Educational+research:+Quantitative,+qualitative,+and+mixed+approache&ots=3pEpvgCq2X&sig=J5kMWopZw7NVqjN3HiEKwaotHY0&redir_esc=y#v=onepage&q=Educational research%3A Quantitative%2C qualitative%2C and mixed approache&f=false.

Kamila, Qurota A'yun Ning, MASDUKI ASBARI, EULIS DARMAYANTI, and Nuraida. "Merdeka Belajar: Memahami Konsep Pembelajaran Masa Kini." *Journal of Information Systems and Management (JISMA)* 3, no. 2 (2024): 104–10. https://doi.org/10.4444/JISMA.V3I2.909.

Kimbark, Kris, Michelle L. Peters, and Tim Richardson. "Effectiveness of the Student Success Course on Persistence, Retention, Academic Achievement, and Student Engagement." *Community College Journal of Research and Practice* 41, no. 2 (February 1, 2017): 124–38. https://doi.org/10.1080/10668926.2016.1166352.

la Torre-Neches, Berta de, Mariano Rubia-Avi, Jose Luis Aparicio-Herguedas, and Jairo Rodríguez-Medina. "Project-Based Learning: An Analysis of Cooperation and Evaluation as the Axes of Its Dynamic." *Humanities and Social Sciences Communications* 7, no. 1 (December 1, 2020): 1–7. https://doi.org/10.1057/S41599-020-00663-Z;SUBJMETA=160,4004,4014;KWRD=DEVELOPMENT+STUDIES,EDUCATION.

Lei, Hao, Yunhuo Cui, and Wenye Zhou. "Relationships between Student Engagement and Academic Achievement: A Meta-Analysis." *Social Behavior and Personality* 46, no. 3 (2018): 517–28. https://doi.org/10.2224/SBP.7054.

Lestari, Puput, Bakti Mulyani, and Dan Sri Mulyani. "Pengaruh Pendekatan SETS (Science, Environment, Technology, and Society) Berbasis Project Based Learning Pada Materi Asam Basa Terhadap Minat Kewirausahaan Siswa Kelas X SMK Kesehatan Donohudan Boyolali." *Jurnal Pendidikan Kimia* 11, no. 2 (December 28, 2022): 231–38. https://doi.org/10.20961/JPKIM.V11I2.66749.

M, Vijayalakshmi, Preeti Patil, and Girish Karikatti. "Effective Assessment Strategies for Project-Based Learning." *Journal of Engineering Education Transformations* 36 (December 1, 2022): 154–60. https://journaleet.in/index.php/jeet/article/view/244.

Nababan, Damayanti, Alisia Klara Marpaung, and Angeli Koresy. "STRATEGI PEMBELAJARAN PROJECT BASED LEARNING (PJBL)." *Jurnal Pendidikan Sosial Dan Humaniora* 2, no. 2 (May 1, 2023): 706–19. https://publisherqu.com/index.php/pediaqu/article/view/178.

Nurhayati, Nurhayati, Khairunnisa, Suryani Tarigan, and Mariani Lubis. "Implementasi Dan Tantangan Kurikulum Merdeka Di SMA: Strategi Pengajaran Berpusat Pada Siswa Untuk Pembelajaran Yang Lebih Fleksibel Dan Kreatif." *Jurnal Pendidikan* 13, no. 1 (January 14, 2025): 69–79. https://e-journal.unimudasorong.ac.id/index.php/jurnalpendidikan2/article/view/155.

Nurmaliah, C., T. N. Azmi, Safrida, Khairil, and W. Artika. "The Impact of Implementation of STEM Integrating Project-Based Learning on Students' Problem-Solving Abilities." *Journal of Physics: Conference Series* 1882, no. 1 (May 1, 2021): 012162. https://doi.org/10.1088/1742-6596/1882/1/012162.

Nyoman, Ni, Serma Adi, Dewa Nyoman Oka, and I Ketut Surata. "IMPLEMENTASI

PENDEKATAN TEACHING AT THE RIGHT LEVEL (TARL) TERINTEGRASI KONSEP UNDERSTANDING BY DESIGN (UBD) UNTUK MENINGKATKAN MOTIVASI BELAJAR SISWA SMA PADA PEMBELAJARAN BIOLOGI." *Widyadari* 25, no. 1 (April 12, 2024): 157–72. https://doi.org/10.59672/WIDYADARI.V25I1.3662.

Parno, D. A. Nur'aini, S. Kusairi, and M. Ali. "Impact of The STEM Approach with Formative Assessment in PjBL on Students' Critical Thinking Skills." *Journal of Physics: Conference Series* 2165, no. 1 (January 1, 2022): 012044. https://doi.org/10.1088/1742-6596/2165/1/012044.

Rahardhian, Adhitya. "PENGARUH PEMBELAJARAN PJBL BERBASIS STEM TERHADAP KEMAMPUAN BERPIKIR KRITIS SISWA PADA MATERI LISTRIK DINAMIS." *JIPPF (Jurnal Inovasi Penelitian Dan Pembelajaran Fisika)* 3, no. 1 (2022). https://doi.org/10.26418/jippf.v3i1.50882.

Rahayu, Wening Patmi, Hidayatin Hidayatin, and Madziatul Churiyah. "Development of a Project-Based Learning Assessment System to Improve Students' Competence." *Jurnal Pendidikan Ekonomi Dan Bisnis (JPEB)* 8, no. 2 (October 1, 2020): 86–101. https://doi.org/10.21009/JPEB.008.2.1.

Rasidah, Warda, Tri Wahyuningsih, Erna Suhartini, Yudo Dwiyono, Andi Asrafiani Arafah, and Universitas Mulawarman. "Pengaruh Penggunaan Model Pembelajaran Project Based Learning Terhadap Penguasaan Materi IPA Pada Siswa." *JURNAL PENDIDIKAN MIPA* 12, no. 4 (December 1, 2022): 1072–78. https://doi.org/10.37630/JPM.V12I4.730.

Resa, Anggina. "Implmementasi Kurikulum Merdeka Berdasarkan Pendekatan Understanding by Design." *Jurnal Primary (Kajian Ilmu Pendidikan Dasar Dan Humaniora)* 4, no. 1 (April 28, 2023): 1–8. https://ejournal.universitaspgridelta.ac.id/index.php/psd/article/view/444.

Rozal, Edi, Rizki Ananda, Aminah Zb, Mohammad Fauziddin, and Fauzan Sulman. "The Effect of Project-Based Learning through YouTube Presentations on English Learning Outcomes in Physics." *AL-ISHLAH: Jurnal Pendidikan* 13, no. 3 (December 6, 2021): 1924–33. https://doi.org/10.35445/ALISHLAH.V13I3.1241.

Selviana Putri, Tira, Muliati Syam, and Laili Komariyah. "Penerapan Model Project Based Learning (PjBL) Di SMAN 1 Muara Pahu Kelas XI Pada Materi Fluida Statis." *Jurnal Literasi Pendidikan Fisika (JLPF)* 1, no. 02 (November 20, 2020): 152–64. https://doi.org/10.30872/jlpf.v1i02.232.

Sumarah, Ignatia Esti, Rusmawan, Cipta Gilang Kencana, Kristophorus Divinanto Adi Yudono, Chrisnutajati Waninghiyu, and Agata Mustika Kusuma Dewi. *Pembelajaran Berbasis Proyek Berdasarkan Gaya Belajar Vark: Untuk Peserta ... - Ignatia Esti Sumarah, Rusmawan, Cipta Gilang Kencana, Kristophorus Divinanto Adi Yudono, Chrisnutajati Waninghiyu, Agata Mustika Kusuma Dewi - Google Books*. Edited by Ignatia Esti Sumarah. Yogyakarta : Sanata Dharma University Press, 2022. https://books.google.co.id/books?hl=en&lr=&id=jPHAEAAAQBAJ&oi=fnd&pg=PA1&dq=keseimbangan+belajar+di+kelas+dan+proyek&ots=nysEL7y7vv&sig=ih_SdbZywYOLd2lvBbxEcnGYEkc&redir_esc=y#v=onepage&q=keseimbangan belajar di kelas dan proyek&f=false.

Swanson, Richard A, and Elwood F Holton III. *Research in Organizations: Foundations and Methods of Inquiry*. San Francisco, California: Berrett-Koehler Publishers, Inc., 2005.

Tondok, Marselius Sampe, Suryanto Suryanto, and Rahkman Ardi. "Building Bridges in Diverse Societies: A Meta-Analysis of Field Experimental Cooperative Learning

Studies on Intergroup Relations in Educational Settings." *Societies 2024, Vol. 14, Page 221* 14, no. 11 (October 27, 2024): 221. https://doi.org/10.3390/SOC14110221.

Tubagus, Munir, Eka Feby, Ronauli Lubis, Iain Manado, and Sulawesi Utara. "Studi Komparatif Antara Pembelajaran Berbasis Proyek Dan Metode Ceramah Dalam Memperkuat Konsep Fisika Serta Kemampuan Pemecahan Masalah A Comparative Study Between Project-Based Learning and Lecture Methods in Strengthening Physics Concepts and Problem-S." Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam, 2024. https://mathedu.joln.my.id/index.php/edu/article/view/64.

Widyaningsih, Sri Wahyu, and Irfan Yusuf. "Implementation of Project-Based Learning (PjBL) Assisted by E-Learning through Lesson Study Activities to Improve the Quality of Learning in Physics Learning Planning Courses." *International Journal of Higher Education* 9, no. 1 (2020): 60–68. https://doi.org/10.5430/ijhe.v9n1p60.

Wijayanti, Susi Indria, Muhammad Akhirudin, Asri Cahyaningsih, and Mts Muhammadiyah Batang. "PENINGKATAN KREATIFITAS PESERTA DIDIK DALAM MERANGKAI LISTRIK SERI DAN PARALEL PADA SEBUAH DENAH RUMAH." *Journal of Lesson Study in Teacher Education* 1, no. 1 (2022): 1–6. https://doi.org/10.51402/JLSTE.V1I1.87.

Yang, Xigui. "A Historical Review of Collaborative Learning and Cooperative Learning." *Techtrends* 67, no. 4 (July 1, 2023): 1. https://doi.org/10.1007/S11528-022-00823-9.

Yunita, Y., D. Juandi, Y. S. Kusumah, and S. Suhendra. "The Effectiveness of the Project-Based Learning (PjBL) Model in Students' Mathematical Ability: A Systematic Literature Review." *Journal of Physics: Conference Series* 1882, no. 1 (May 13, 2021). https://doi.org/10.1088/1742-6596/1882/1/012080.

Zhang, Lu, and Yan Ma. "A Study of the Impact of Project-Based Learning on Student Learning Effects: A Meta-Analysis Study." *Frontiers in Psychology* 14 (2023): 1202728. https://doi.org/10.3389/FPSYG.2023.1202728.