Physics Communication
Volume 9 Issue 1 Year 2025 Pages 46-52

P-ISSN 2528-5971 | E-ISSN 2528-598X
https://journal.unnes.ac.id/journals/pc
https://doi.org/10.15294/pc.v9i1.10809

Analysis of Student Self-Regulated Learning and Creative Thinking Through the Project-Based Learning Model on Renewable Energy Topics

Ratih Windyaningsiwi*, Sunyoto Eko Nugroho, Bambang Subali

Master of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia

*Correspondence to: *ratihwindyaningsiwi@students.unnes.ac.id*

Abstract: Self-regulated learning is essential for students to be proactive in their learning, and creative thinking is crucial for overcoming challenges and generating innovative solutions. Project-Based Learning (PjBL) has been proposed as an effective method for teaching subjects such as renewable energy, allowing students to apply concepts in a real-world context. However, challenges persist in implementing PjBL, including student adaptation and lack of structured materials. This study aims to assess the impact of the PjBL model on students' self-regulated learning and creative thinking, identify factors that promote self-regulated learning, and understand barriers to developing creative thinking. Conducted at SMA Negeri 11 Sarolangun, this study involved two experimental classes and one control class. Using a mixed-method approach with a sequential explanatory design, this research employed a quasi-experimental method with a non-equivalent control group design. Data were collected using questionnaires, creative thinking tests, and interviews, and analyzed using parametric statistical tests and qualitative descriptive analysis. The results showed that PjBL had a significant positive impact on self-regulated learning and creative thinking, with a supportive learning environment being a key factor. The t-test results showed a significant effect on self-regulated learning (0.002) and creative thinking (0.04), both below the 0.05 threshold. Effect size analysis indicated a high impact on self-regulated learning and moderate impact on creative thinking variable.

Keywords: Self-regulated Learning, Creative Thinking, Project-based Learning

Submitted: 2024-11-15. **Revised:** 2025-02-17. **Accepted:** 2025-02-20.

Introduction

In 2022, Indonesia changed its curriculum from the 2013 Curriculum to the Merdeka Curriculum. This curriculum is designed to be more flexible, focus on core material, and support the development of students' potential and abilities(Rahayu et al., 2022). The concept of Merdeka Belajar includes freedom of thought, innovation, self-regulated learning, creative thinking, and happiness (Suhartono, 2021). Self-regulated learning is one of the abilities that students need to participate in implementing the Merdeka Curriculum. Self-regulated learning is the quality and capability that students need to have in order to be able to proactively engage in the learning process, be encouraged to master various competencies, and manage knowledge with strong ownership (Aini & Taman, 2012; Romadona, 2019). The study conducted by Purwanto et al, (2019) emphasized the importance of teacher-designed learning to enhance students' self-regulated learning (SRL) capacity. They stated that the high number of students with low SRL capacity indicates a lack of contribution from teacher-organized learning activities in fostering students' SRL.

In addition to self-regulated learning, another important skill is student creative thinking. Creative thinking is one of the soft skills that involves expertise in facing challenges and finding solutions, either in the form of actions, approaches, or innovative ideas that are completely new baru (Resti, 2015; Erin et al., 2020). Independent and creative are two of the six skills outlined by the government in the Pancasila Education Profile (Kemendikbud, 2022).

Curriculum improvement is related to the adjustment of the learning process in the classroom to the needs of students, which is characterised by planned educational interactions between teachers and students. This process involves systematic planning, implementation and assessment (Pane et al, 2017).

Effective learning requires careful design, including activities, media, and teaching materials. Varied and innovative learning models, such as Project Based Learning (PjBL), are highly recommended in the Merdeka Curriculum. PjBL allows students to collaborate to create relevant and significant outcomes, as well as address real problems in their daily lives, providing hands-on experience and going beyond mere knowledge (Lestari et al, 2023).

Samudra et.al, (2014) analyzed the challenges students face in learning physics, including difficulties in understanding the subject due to the dense material, the need for memorization, and the mathematical analysis required. Difficulties in understanding physics were also identified as being caused by a lack of contextual learning, as well as issues related to students' talents, interests, and motivation in studying physics. This statement is supported by initial observations. Physics teachers at SMA N 11 Sarolangun reported that many students still struggle with physics learning. Physics is considered difficult because students are required to both discover concepts and solve mathematical problems simultaneously. As a result, teachers tend to guide students extensively, leading to a lack of self-regulated learning and creative thinking skills when solving problems.

Based on initial observations made at SMA N 11 Sarolangun, it was detected that the low self-regulated learning and creative thinking of students in physics learning were caused by teachers who guided the learning process more because students complained about the difficulty of learning physics. This issue is not unique to SMA N 11 Sarolangun but reflects a broader trend in Indonesia. Research shows that self-regulated learning (SRL) and student creative thinking in Indonesia still face various challenges. Many students struggle to manage their learning activities, especially in online learning, due to low motivation and a lack of environmental support (Sari et al, 2021). This issue affects their academic achievement, as students with poor self-regulation tend to have difficulty understanding material deeply (Khoerunnisa et al., 2021). Therefore, it is crucial to enhance SRL so that students can become more independent learners and develop their creativity optimally.

Physics learning materials are closely related to everyday life, especially energy problems that have an impact on the environment. The increasing use of fossil energy causes greenhouse gas emissions and climate change (Setyono et al, 2021). Therefore, the use of renewable energy is taught from an early age to instil environmental awareness. Project-based learning (PjBL) allows students to understand and apply renewable energy concepts through practical activities, such as solar panel, wind turbine, or bioenergy projects. This method helps students understand renewable energy technologies, work in teams, solve problems, and think creatively, while developing environmental awareness and understanding the importance of transitioning to more sustainable energy sources.

This study aims to determine the effect of the PjBL model on self-regulated learning and creative thinking, determine the factors that encourage students' self-regulated learning, and determine the obstacles experienced by students in developing creative thinking.

Methods

The research was conducted at SMA Negeri 11 Sarolangun involving two classes as experimental groups and one class as a control group. The selection of experimental and control classes was carried out using simple random sampling to ensure an unbiased distribution of participants. This method allows each class to have an equal chance of being assigned as an experimental or control group. This research uses a Mixed Method with a concurrent embedded design strategy. The research design is a Quasi-experimental design with a Nonequivalent Control Group Design type. The control variable of this research is the PjBL learning model, while self-regulated learning and creative thinking are the dependent variables. Data collection techniques used in this study include questionnaires to measure self-regulated learning, tests to assess creative thinking, and interviews. Data analysis included both quantitative and qualitative data analysis. Quantitative data analysis techniques use parametric statistical tests, specifically the t-test, as the data were found to be normally distributed and homogeneous. If the data had not met these assumptions, a non-parametric test would have been used instead. Qualitative data analysis was carried out through

descriptive analysis. The material presented in the learning process is Renewable Energy Material. Learning activities use LKPD as teaching materials that help students in the learning process. In the LKPD, there are steps of learning activities that students must follow, including problems that must be solved through projects.

Results and Discussion

This study explores the effect of Project-Based Learning (PjBL) model on student's self-regulated learning and creative thinking in renewable energy material at SMA Negeri 11 Sarolangun. The focus of the research lies on evaluating the effectiveness of the PjBL model by comparing the experimental and control groups. Research activities were carried out in three meetings, each lasting 2 x 45 minutes, with the author as a teacher facilitating the learning process. Classes X.B and X.C acted as experimental groups, while X.A as the control group. This research uses a mixed method approach to analyse the factors that encourage the development of student's self-regulated learning and the obstacles experienced in developing creative thinking.

Before starting the research, validation of research instruments was carried out including teaching modules, student's self-regulated learning questionnaires, creative thinking test questions, and PjBL LKPD. The validity of this instrument is important to ensure the validity of the measuring instruments used in the study. Furthermore, a pretest was conducted to measure students' initial abilities in both aspects under study, namely self-regulated learning and creative thinking.

Normality and homogeneity tests were conducted on the initial data to ensure that the data were normally distributed and homogeneous. This is important to fulfil the basic assumptions in the statistical analysis that will be used. After ensuring the data met the requirements, the research was carried out for three meetings, with the experimental group using the PjBL model and the control group using conventional methods.

In the experimental group, the PjBL model was applied by involving students in a poster-making project about the process of making briquettes, while the control group did not use the PjBL model. The learning process in the experimental group began with an explanation of the material and followed by project work integrated in the Learner Worksheet (LKPD). This process aims to develop students' ability to think critically, creatively, and independently.

Renewable energy is a crucial topic in science education due to its relevance to environmental issues and sustainability. Sources such as solar, wind, hydro, biomass, and geothermal energy not only provide alternatives to fossil fuels but also open opportunities for innovation in their management. In the context of learning, an approach that allows students to explore and understand renewable energy in depth is *Project-Based Learning* (PjBL). Through PjBL, students not only gain theoretical knowledge about renewable energy but also engage in real-world projects that require them to think critically and creatively to solve real-life problems.

The implementation of PjBL in renewable energy topics has a significant impact on *self-regulated learning*. In this model, students are given the autonomy to manage their own projects, from designing and gathering information to completing projects related to renewable energy. For instance, in a project involving the creation of a prototype solar power generator or biogas production from organic waste, students must strategize their learning, determine the necessary steps, and evaluate the outcomes. This process enhances students' ability to learn independently, as they become accustomed to actively seeking solutions without relying too much on the teacher. Research has shown that PjBL effectively enhances self-regulated learning because students are more motivated to manage their time, plan their work, and develop their understanding through independent exploration (Mabruro, 2023).

Furthermore, PjBL also has a strong influence on the development of *creative thinking*. In renewable energy projects, students are challenged to find innovative solutions for utilizing energy in more environmentally friendly ways. Such activities encourage them to think beyond conventional approaches, try different strategies, and test new ideas. A study by Kurniawan et al. (2024) found that students who

engaged in PjBL on renewable energy topics showed significant improvements in creative thinking because their projects were exploratory and required innovation (Dinantika et al, 2019).

After the learning period was completed, a posttest was conducted to re-measure student's self-regulated learning and creative thinking. The results show that the application of the PjBL model has a significant impact on increasing student's self-regulated learning and student creative thinking. This result is obtained from the t-test results through SPSS, if the Sig. value is smaller than 0.05 then H_0 is rejected, meaning that PjBL has an effect on self-regulated learning and creative thinking. Table 1 shows the results of the t-test of student self-regulated learning and creative thinking data.

Table 1. Results of The T-Test Of Student Self-regulated learning and Creative thinking Data.

	Self-regulated learning	**Creative thinking**
Sig.	0,002	0,04
Conclusion	Influence	Influence

From Table 1, it is known that the Sig. value of self-regulated learning is 0.002 <0.05 and the Sig. value of creative thinking is 0.04 <0.05, so both are declared to have an influence.

Data from the self-regulated learning questionnaire showed an increase in motivation, responsibility, and ability to learn independently. The PjBL model proved to be effective in motivating students to learn independently, by building their own knowledge through making real products. This indicates that PjBL is effective in improving students' ability to organise and direct their own learning process (Priyambudi et al, 2021). The increase in student's self-regulated learning scores can be seen in Figure 1.

In addition, the PjBL model also had a positive effect on students' creative thinking. A t-test of the creative thinking essay question results revealed that students who followed this model showed significant improvement in creative thinking skills. Projects that require problem solving and collaboration make an important contribution to the development of students' creative thinking (Rafik et al, 2022). In addition to the t-test results, the effect size calculation using Cohen's d shows a value of 1,37 for self-regulated learning and 0.55 for creative thinking. According to Cohen's (1988) interpretation, these values indicate that PjBL has a high on self-regulated learning and medium effect on creative thinking variables. This strengthens the evidence that PjBL has a fairly significant positive impact on students' self-regulated learning and creative thinking skills.

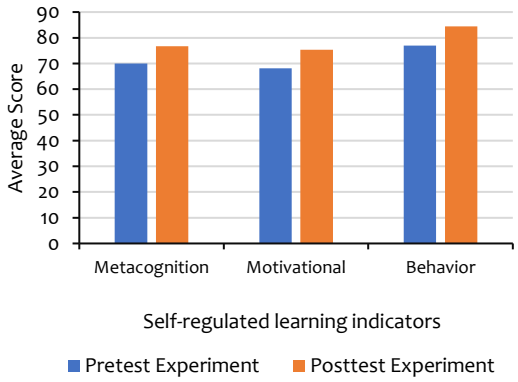

Figure 1. Increase in Self-Regulated Learning Scores for Each Indicator in the Experimental Class

This moderate effect size may be attributed to several factors. First, the intervention duration, which lasted only three sessions, may not have been sufficient for students to fully develop their self-regulated learning and creative thinking skills. A longer implementation period could potentially yield a greater effect. This aligns with research indicating that the application of Project-Based Learning (PjBL) over a longer period can significantly enhance students' self-regulated learning and creative thinking abilities (Susilowaty, 2020).

External factors such as classroom dynamics, variations in student engagement, and differences in teacher facilitation could have contributed to the observed effect size. Future research with a longer intervention period and additional support mechanisms may help enhance the impact of PjBL on student learning outcomes (Mabruro, 2023).

Factors that encourage the development of students' self-regulated learning in PjBL include projects that are interesting and relevant to real life, the use of LKPD as a learning guide, good time management, and collaboration with classmates. Relevant projects make learning more meaningful for students, while LKPD helps students to learn in a structured manner. This is in line with the research of Sari et al. (2020) which states that PjBL-based LKPD helps facilitate the learning process by making learning more structured and increasing students' active participation.

Collaboration with classmates has proven to be very beneficial in developing student's self-regulated learning. Students support each other and exchange ideas, which helps them see the problem from different points of view. It also helps students develop communication and teamwork skills (Kokotsaki et al, 2016). This finding is supported by the research of Ellingsen et al (2021) who stated that group management and active self-management positively influence each other and improve the team's ability to innovate. Bell (2010) asserted that collaboration in PjBL helps students develop social skills and the ability to work together, while Kokotsaki et al (2016) highlighted the importance of interaction between students in enhancing learning and creative thinking in the context of PjBL.

However, some barriers were also identified in the development of students' creative thinking. The main barriers included lack of confidence and challenges in group collaboration. Some students felt uncomfortable to speak freely. Students with low creative thinking often feel inferior and lack the courage to express ideas. This is in line with Marasabessy (2019) findings that a lack of confidence can prevent individuals from exploring and developing creative ideas. Similarly, research by Nugraha et al (2023) highlights that self-confidence plays a crucial role in fostering creative flexibility, as students who struggle with confidence tend to limit their creative exploration. Additionally, Khotimah (2025) identified challenges in implementing Project-Based Learning (PjBL), such as time constraints, limited resources, and a lack of teacher training, all of which can impact group collaboration and hinder students' creative development. Therefore, teacher and peer support are essential in overcoming these obstacles, allowing students to maximize their creative potential.

Support from teachers and classmates proved important in overcoming barriers to creative thinking. A learning environment that supports experimentation and new ideas, as well as active support from the group, helps students overcome challenges and maximise their creative potential. Effective collaboration within the group allows students to better develop creative ideas.

Overall, this research proves the effectiveness of the PjBL learning model in improving student's self-regulated learning and creative thinking in learning IPAS (Physics). This is in line with previous research by Putra (2016), Kasiyanti et al (2022), Dinawati et al (2024), Fitri et al (2021), and Rafik et al (2022) which also showed the positive effect of PjBL on students' self-regulated learning and creative thinking.

Conclusion

The study showed that the application of the Project-Based Learning (PjBL) model significantly increased students' self-regulated learning, with the t-test results showing a Sig. value of 0.002, which is smaller than 0.05, indicating a significant effect. In addition, the t-test on the creative thinking post-test question also shows a Sig. value of 0.04, which is also smaller than 0.05, indicating that PjBL has a positive effect on students' creative thinking. The effect size analysis revealed that the impact of PjBL on self-regulated learning was high, while the effect on creative thinking was moderate.

These findings have important implications for educational practice. Teachers can optimize the implementation of PjBL by creating a more structured yet flexible learning environment, encouraging collaboration, and integrating LKPD effectively as a learning resource. Additionally, fostering a classroom culture that builds students' confidence and providing continuous support from peers and teachers can help

overcome barriers in developing creative thinking.

However, this study has limitations. The sample size was relatively small, which may affect the generalizability of the findings. Moreover, the measurement of creative thinking was based on post-test scores, which may not fully capture the complexity of students' creative abilities. The limited time available for PjBL implementation also influenced the quality of learning, as students may have needed more time to explore concepts deeply and develop their projects more comprehensively. Future research could explore a larger sample, use more diverse assessment methods, and allocate a longer duration for PjBL to gain deeper insights into its long-term impact on student learning outcomes.

References

Bell, S. (2010). *Project-Based Learning for the 21st Century : Skills for*. 39–43. https://doi.org/10.1080/00098650903505415

Dinantika, H. K., Suyanto, E., & Nyeneng, I. D. P. (2019). Pengaruh Penerapan Model Pembelajaran Project Based Learning Terhadap Kreativitas Siswa Pada Materi Energi Terbarukan. *Titian Ilmu: Jurnal Ilmiah Multi Sciences*, *11*(2), 73–80. https://doi.org/10.30599/jti.v11i2.473

Dinawati, S., & Arianti, A. (2024). Peningkatan Kreativitas dan Hasil Belajar Siswa Kelas V pada Mata Pelajaran Bahasa Indonesia dengan Model PjBL. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *09*, 3218–3229. https://doi.org/10.23969/jp.v9i2.13767

Ellingsen, P., Tonholm, T., Johansen, F. R., & Andersson, G. (2021). Learning from problem-based projects in cross-disciplinary student teams. *Education Sciences*, *11*(6). https://doi.org/10.3390/educsci11060259

Erin, A., Cahyani, M., Mayasari, T., & Sasono, M. (2020). *Efektivitas E-Modul Project Based Learning Berintegrasi STEM Terhadap Kreativitas Siswa SMK*. *4*(1), 15–22. https://doi.org/10.20527/jipf.v4i1.1774

Fitri, L., Yuliana, D., & Jaya, F. (2021). Pengaruh Project Based Learning Terhadap Kreativitas Siswa Pada Mata Pelajaran Simulasi Digital. *Jurnal Pendidikan Teknologi Informasi …*, *4*, 39–48. https://ojs.cbn.ac.id/index.php/jukanti/article/view/270

Kasiyanti, Hayati, K. N., & Aisyah, S. (2022). Efektivitas Model Project Based Learning Terhadap Kemandirian Dan Disiplin Belajar Siswa Sekolah Dasar. *Didaktik : Jurnal Ilmiah PGSD FKIP Universitas Mandiri*, *08*(2796–2815). https://doi.org/10.36989/didaktik.v8i2.600

Kemendikbud. (2022). *Profil Pelajar Pancasila*. http://ditpsd.kemdikbud.go.id/hal/profil-pelajar-pancasila

Khoerunnisa, N., Rohaeti, E. E., & Ningrum, D. S. ayu. (2021). Gambaran Self Regulated Learning Siswa Terhadap Pembelajaran Daring Pada Masa Pandemi Covid 19. *FOKUS (Kajian Bimbingan & Konseling dalam Pendidikan)*, *4*(4), 298. https://doi.org/10.22460/fokus.v4i4.7433

Khotimah, K. (2025). Analisis Penerapan Pendidikan Berbasis Proyek Untuk Mewujudkan Pendidikan Inklusi di Era Modern. *LEARNING : Jurnal Inovasi Penelitian Pendidikan dan Pembelajaran*, *5*(1), 1–23. https://doi.org/10.51878/learning.v5i1.4310

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning : a review of the literature. *Improving Schools*. https://doi.org/10.1177/1365480216659733

Lestari, S., & Putro, A. A. Y. (2023). *Choaching Untuk Meningkatkan Kemampuan Guru Dalam Menerapkan Pembelajaran Berbasis Proyek (Project Based Learning)*. Jombang : Kun Fayakun. http://repository.upy.ac.id/id/eprint/4052

Mabruro, V. I. (2023). Kemampuan Berpikir Kreatif Peserta Didik Ditinjau dari Self-Regulated pada Model Pembelajaran Project Based Learning dengan Pendekatan Realistik. *PRISMA, Prosiding Seminar Nasional Matematika*, 551–556. https://journal.unnes.ac.id/sju/index.php/prisma/article/view/66788

Marasabessy, Z. A. (2019). Membentuk Kreativitas Dalam Dunia Kerja. *Suhuf*, *31*(1), 58–71. https://doi.org/10.23917/suhuf.v31i1.9005

Nugraha, I. R. R., Supriadi, U., & Firmansyah, M. I. (2023). Efektivitas Strategi Pembelajran Project Based Learning dalam meningkatkan Kreativitas Siswa. *Jurnal Penelitian dan Pendidikan IPS*, *17*(1), 39–47. https://doi.org/10.21067/jppi.v17i1.8608

Pane, A., & Dasopang, M. D. (2017). Belajar dan Pembelajaran. *Jurnal Kajian Ilmu-ilmu Keislaman*, *03*(2), 333–352. https://doi.org/10.24952/fitrah.v3i2.945

Priyambudi, B., Suroya B, A., Safitri, D., Susilo, H., Nathalia, & Sudrajat, K. (2021). Implementasi Model Discovery Learning Menggunakan Lesson Study Untuk Meningkatkan Kemampuan Komunikasi Dan Kolaborasi. *SNOWBEL 2019 Seminar Nasional dan Workshop Biologi-IPA dan Pembelajarannya ke-4*, 630.

Purwanto, E., & Formen, A. (2019). *Could Self-Regulated Learning b e Taught t o Students ?* *335*(ICESSHum),

818–823. https://doi.org/10.2991/icesshum-19.2019.128
Putra, H. D. (2016). Pengaruh Project Based Learning terhadap Hasil Belajar Tematik. *Prosiding Seminar Pendidikan Nusantara 2016*, 6(4), 4083–4091.
Rafik, M., Febrianti, V. P., Nurhasanah, A., & Muhajir, S. N. (2022). Telaah Literatur: Pengaruh Model Pembelajaran Project Based Learning (PjBL) terhadap Kreativitas Siswa Guna Mendukung Pembelajaran Abad 21. *Jurnal Pembelajaran Inovatif*, 5(1), 80–85. https://doi.org/10.21009/jpi.051.10
Rahayu, R., Rosita, R., Rahayuningsih, Y. S., & Hernawan, A. H. (2022). Implementasi Kurikulum Merdeka Belajar di Sekolah Penggerak. *Jurnal Basicedu*, 6(4), 6313–6319. https://doi.org/10.31004/basicedu.v6i4.3237
Romadona, D. D., & Hestiwidayani. (2019). Deskripsi Kemandirian Belajar Siswa SMA Kelas X pada Mata Pelajaran Fisika. *Jurnal Pendidikan Matematika dan Sains*, 7(1), 27–30. https://doi.org/10.21831/jpms.v7i1.27910
Samudra, G. B., Suastra, I. W., & Suma, K. (2014). Permasalahan-Permasalahan Yang Dihadapi Siswa SMA Di Kota Singaraja dalam Mempelajari Fisika. *Jurnal Pendidikan dan Pembelajaran IPA Indonesia*, 4(1), 1–7. https://ejournal-pasca.undiksha.ac.id/index.php/jurnal_ipa/article/view/1093/841
Sari, L., Taufina, & Fachruddin, F. (2020). Pengembangan Lembar Kerja Peserta Didik (LKPD) dengan Menggunakan Model PJBL di Sekolah Dasar. *Jurnal Basicedu*, 4(4), 813–820. https://doi.org/10.31004/basicedu.v4i4.434
Sari, N. Ka. A. R., & Indrayani, L. (2021). Self-Regulated Learing Siswa Kelas XI IPS Pada Mata Pelajaran Ekonomi di SMA Negeri 3 Singaraja. *Jurnal Pendidikan Ekonomi Undiksha*, 13(2), 319. https://doi.org/10.23887/jjpe.v13i2.34930
Setyono, A. E., & Kiono, B. F. T. (2021). Dari Energi Fosil Menuju Energi Terbarukan: Potret Kondisi Minyak dan Gas Bumi Indonesia Tahun 2020 – 2050. *Jurnal Energi Baru dan Terbarukan*, 2(3), 154–162. https://doi.org/10.14710/jebt.2021.11157
Suhartono, O. (2021). Kebijakan Merdeka Belajar dalam Pelaksanaan Pendidikan di Masa Pandemi Covid-19. *Ar-Rosikhun: Jurnal Manajemen Pendidikan Islam*, 1(1), 8–19. https://doi.org/10.18860/rosikhun.v1i1.13897
Susilowaty, N. (2020). Pengaruh model pembelajaran Project based Learning terhadap peningkatan kemampuan self-regulated learning Mahasiswa Universitas Advent Indonesia. *Jurnal Padegogik*, 3(1), 71–80. https://doi.org/10.35974/jpd.v3i1.2235