IMPROVING HIGH SCHOOL STUDENT'S CONCEPTUAL UNDERSTANDING AND CREATIVITY SKILLS THROUGH PROBLEM-BASED (PrBL) AND PROJECT-BASED LEARNING (PjBL) IN PHYSICS

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ABSTRACT: *Developing students' 21st-century skills is one of the major goals of the Philippine education system. It has been a major problem in the education sector to integrate, innovate, and support learners in today's generation to develop a broad set of competencies necessary to compete in the global race of skills. This study aimed to improve students' conceptual understanding and creativity skills in physics using problem-based learning and project-based learning method. This study used a quasi-experimental pretest-posttest non-equivalent research design. Two heterogeneous classes were utilized as participants of the study. The first class intact class was designated as the first experimental group (n=42) utilizing problem-based learning, while the other intact class was designated as the second experimental group (n=36) using the project-based learning method. The creativity and conceptual understanding skills were measured using an open-ended questionnaire and scored using researcher-made rubrics with Krippendorff's alpha of 0.98 and 0.97, respectively. Results revealed significant improvement in conceptual understanding and creativity skills due to employing both teaching methods. Moreover, there is no significant difference in student's conceptual understanding and creativity skills as influenced by the two teaching methods. The absence of difference suggests that the two teaching methods contributed to the equal improvement of students' scores. Based on these results, it is suggested to use these teaching methods in other physics topics that require content and 21st-century skills mastery.*

Keywords: authentic learning, inquiry-based learning, innovative teaching, learner-centered, soft skills

1. INTRODUCTION

In a generation driven by innovation and complex technological and scientific challenges, it is indeed necessary to focus and nurture students' 21st-century skills [1], [2]. Creating and focusing on the alignment of transversal competencies on the curricula has been acknowledged globally and is known as essential skills, knowledge, attitudes, and values necessary to triumph in the worldwide skills race and competition. Of the different skills, conceptual understanding and creativity skills have often been left behind in the design and development of current curricula. Students possess creativity skills when they can come up with several feasible and clearly defined solutions, unique and insightful methods for a given scientific problem. On the other hand, students exhibit conceptual understanding when they can interpret and apply concepts, principles, and the process by making sense of data, text, and experience through images, analogies, and models.

The Australian Council for Educational Research commissioned by UNICEF and the Department of Education Philippines has explored and analyzed the integration of 21st-century skills as applied in the Philippines K to 12 programs. It was observed that there is a lack of explicitness in teaching the skills, the main focus of the lesson was more on subject content, and there was no discussion about the application of skills, the reflection on skills, and skills relative to learning [3]. This is similar to the assessment done by Care and Lou [4], which stated that one challenge reported by teachers and administrators in the Philippines is a shortage of assessment materials designed to target transversal competencies. Moreover, Pa-alisbo [5] revealed in his study conducted on the Department of Education-Cotabato District elementary educators that teachers are moderately competent in terms of 21st-century skills.

Focusing on creating an aligned 21st-century education system is one of the major responsibilities of the administrators and teachers here in the Philippines. The alignment and integration of the skills in teaching and learning are deemed necessary so that the students will be prepared for global competitiveness [6]. Similar to different schools abroad, the primary goal of the Philippine education system is to develop students' 21st-century skills such as conceptual understanding and creativity. Based on the latest NAT results and analysis of the Department of Education of the grade 6, 10, and 12 students, science had the lowest mean percentage score among other subjects [7, 8]. This goes to display that much should be done to improve the state and quality of science education in the Philippines. To achieve this, the education sector should equip the teachers with enough knowledge on teaching and assessing 21st-century skills and enforce a change in how educators should teach the learners in today's generation[9]. Based on an exhaustive literature review, Problem-based Learning (PrBL) and Project-based Learning (PjBL) can be utilized to improve student learning outcomes. These methods are of great advantage in pushing the class towards engaging the teaching and learning process and modifying the direction of teaching and learning from traditional, monotonous classroom practices into a much more modern and exciting environment [10]. Recently, Saldo and Walag [1] explored how PrBL and PjBL developed student's communication and collaboration skills.

The PrBL and PjBL are types of experiential and inquiry-based learning and teaching methods. These methods possess the same orientation: both consider learning in terms of authentic and constructivist approaches to education. These methods have been noted to powerfully engage the students to learn and actively participate in the learning process. Additionally, it is valuable and relevant to impact students' learning outcomes and academic performance positively. Thus, with these compelling reasons, this paper aimed to investigate the improvement of students' skills using PrBL and PjBL as teaching methods in Physics.

This study investigated the development of students' conceptual understanding and creativity skills employing

problem-based learning and project-based learning methods in Physics. Specifically, this study answered these questions:

1. Is there an improvement in students' conceptual understanding and creativity skills as influenced by the two teaching methods?
2. How do students' scores in PrBL and PjBL compare in terms of:

a. conceptual understanding and
b. creativity?

2. MATERIALS AND METHODS

This study utilized a quantitative quasi-experimental research design, particularly pretest and posttest non-equivalent research design**.** Preliminary approval to the conduct of the study was first secured through a letter to conduct an experimental study to the Grade 10 Junior High School (JHS) students of the Integrated Basic Education Department (IBED) of San Isidro College through proper and appropriate channels. From the three grade 10 classes in the school year 2019-2020, two different sections were randomly taken as the study participants. One section (n=42) was designated as the first experimental group utilizing the PrBL method, while the other section (n=36) was designated as the second experimental group using the PjBL method. A test was constructed using six open-ended questions covering topics from the second quarter lessons of grade 10. The researcher-made instrument was presented to science education and physics experts for face and content validity. The creativity and conceptual understanding were measured using an open-ended questionnaire and scored using a researcher-made rubric with Krippendorff's alpha of 0.98 and 0.97, respectively [1]. The descriptive data were presented as mean and standard deviation, while the differences were tested using the analysis of covariance (ANCOVA) at a 0.05 level of significance.

3. RESULTS AND DISCUSSION

Creativity

Creativity skills refer to how students do their projects and how they find solutions for the problem. The creativity skills of the participants for PrbL and PjBL were investigated and are summarized in Table 1. As shown in Table 1, significant improvement in creativity skills was shown in both groups. This increase in creativity could be due to the opportunities provided to the students during the PBL sessions, wherein they were allowed and were given time to construct projects or propose solutions to solve real-life problems. As a result of the intervention given with the situation, the students understood events in a multi-dimensional way and improved their viewpoints [11]. According to Awang and Ramly [12], students gain creative thinking and professional skills as they tackle complex, interdisciplinary, and real-situation problems.

It is also revealed from the same data that the computed probability values in both the teaching methods are significant. This suggests that the students' pretest and posttest scores had increased significantly in creativity skills and improved as exposed to these teaching methods. The increase in creativity skills of the students may be attributed to the integration of technology in which they were allowed to research online about the given activities to analyze and design projects to provide solutions to the problem. Based on the findings of Chanlin [13], the ability to create and elaborate knowledge and the use of technology for supporting and reporting students' research work was observed and developed. Moreover, students' creativity and other life skills under project-based learning had increased positively. They were developed due to the group activities given to the students to finish a particular project and may be attributed to other experiences of the students like their extra-curricular activities, family, and personal life [14] [15].

Table 1. Pretest and Posttest Scores in Creativity

Method	Creativity		t (df)	p-value
	Pretest	Post-test		
PrBL	28.31±10.87	46.42±11.00	-36.37 (35)	0.001*
PjBL	24.79±5.91	42.68±6.02	-129.09 (33)	0.001*

*Significant at 0.05 level

As illustrated in Figures 1 and 2, the student's responses clearly show creative thinking. The students demonstrate confidence in carrying out procedures accurately, efficiently, and with clarity and organization. Besides, the students gave feasible and clearly defined solutions that are unique and insightful. According to Birgili [16], when students are presented with real-life problems to solve, they will have an opportunity to discover new knowledge and create innovative solutions based on their experiences. Relating to the students' answers, it is evident that they have acquired creative thinking since they have presented unique solutions that are realistic, efficient, and attainable. This could be an excellent start in developing students' creativity skills, which is vital in raising learners who might become scientists, designers, and engineers in the future. Furthermore, creativity is highlighted as a vital skill in the 21st-century that can enhance students' potential in finding and creating solutions to different real-world problems [17]. Therefore, it is a challenge for all teachers in today's generation to provide practical problems that are authentic for the students to unravel.

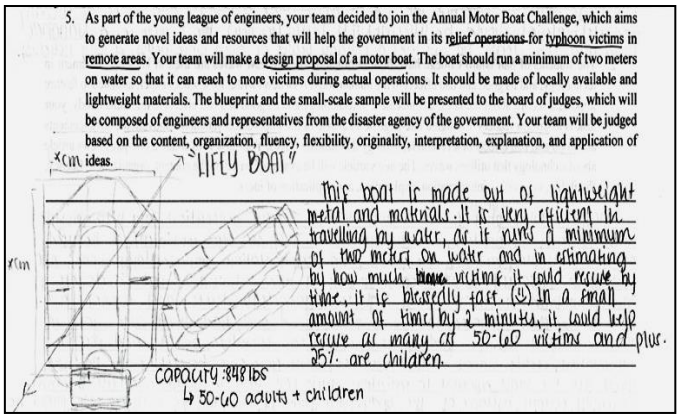

Figure 1. Student's response in question number 5

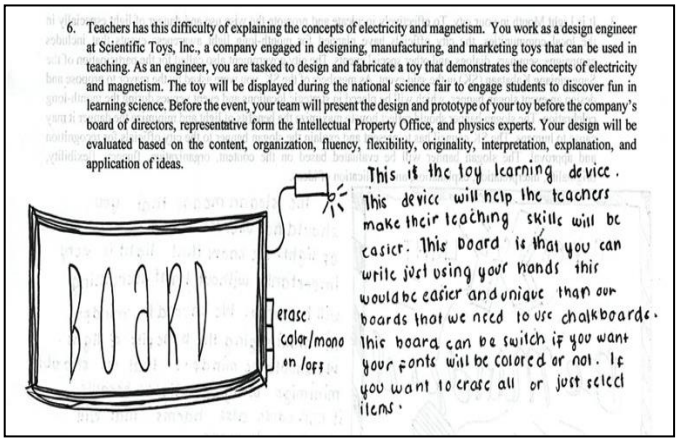

Figure 2. Student's response in question number 6

The differences in the pretest and posttest scores of the students in creativity for the two teaching methods were investigated using one-way ANCOVA and are shown in Table 2. This suggests no significant difference in students' creativity skills as influenced by the two teaching methods. This means that students' scores in the two experimental groups were not significantly different from one another.

Table 2. One-way ANCOVA Table Examining the Difference in Creativity Skills for the Two Teaching Methods

Source	Sum of Squares	df	Mean Square	F	p-value
Group (Treatment effect)	7.467	1	7.467	1.457	.232^{NS}
Error	343.480	67	5.127		
Total	350.947	68			

*Significant at 0.05 level, ^{NS}Not significant

Students' creative thinking skills increased by using the problem-based learning method [18], [19]. Likewise, implementing project-based learning in the class could improve their creativity skills like flexibility, novelty, and originality [20]. It was also revealed a significant favorable influence of project-based learning on the affective development of creativity, including adventurousness, curiosity, imagination, and challenge [21]. Besides, it was also revealed that PBL affects students' creativity and critical thinking [22]. This could have been the reason for the absence of difference for both of the teaching methods. This further implies that the lack of difference between the two teaching methods would mean that both groups may have equally developed the creative skills.

Conceptual Understanding

Conceptual understanding skills refer to what the students have known in basic science concepts. The conceptual understanding for the two teaching methods was examined and are summarized in Table 3. As shown, significant improvement was shown in conceptual understanding skills for both groups. The students' pretest scores in conceptual understanding are similar in both of the teaching methods. This increase in conceptual understanding skills for the two teaching methods could be due to the brainstorming and exploratory activities are given where the students were allowed to research and present their outputs in class. This is also shown in the report [23] that more expert-like views about the subject tended to obtain higher conceptual understanding. It was also emphasized the importance of considering students' beliefs in physics, for it is also related to conceptual understanding that may significantly affect their learning [24].

In addition, the pretest and posttest scores of the students had increased positively in conceptual understanding. This further highlights that the students improved their conceptual understanding skills as exposed to problem-based learning and project-based learning methods. This may also be due to the range of students' abilities and differences between students' groupmates, various real-world problems presented, and sophisticated gadgets they own that could help them research and further understand the topic. Students' conceptual understanding of a topic can also be attributed to the undertaking of multiple projects utilizing the project-based learning method, advanced analysis tools, and the differences between students' cohorts [25]. This is similar to the results [26], wherein project-based learning methods improved students' understanding of the concepts improved through team-format activities.

Table 3. Pretest and Posttest Scores in Conceptual Understanding

Method	Conceptual Understanding		t (df)	p-value
	Pretest	Post-test		
PrBL	29.23±10.35	47.64±10.47	-34.89 (35)	0.001
PjBL	26.68±5.87	44.62±6.00	-113.81 (33)	0.001

*Significant at 0.05 level

As revealed in Figures 6 and 7, students' answers demonstrate conceptual understanding. The students' responses show accurate, extensive, and deep understanding in interpreting the problem through analogies and examples. Likewise, it is very evident in the answers of the students that they have understood the problem since they have supported and justified their answers or solutions with enough reasoning grounded from concepts and principles. The gain in students' conceptual understanding can be attributed to the strategies and activities given to the students, which are real-life [27]. Since the students' activities are hands-on utilizing PBL, they will have the chance to correct their misconceptions and improve their school performance. Finally, based on another work [28], hands-on activities can build students' understanding of the concept and construct their own knowledge.

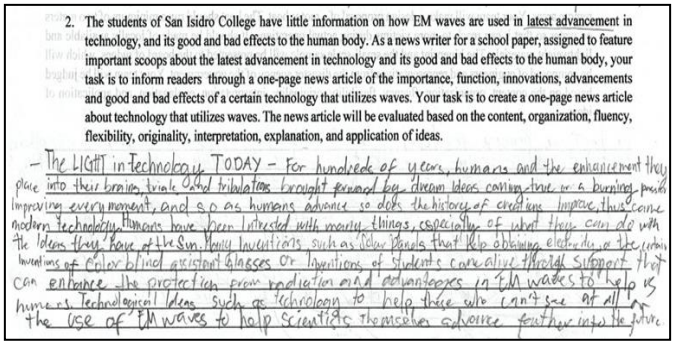

Figure 3. Student's response in question number 2

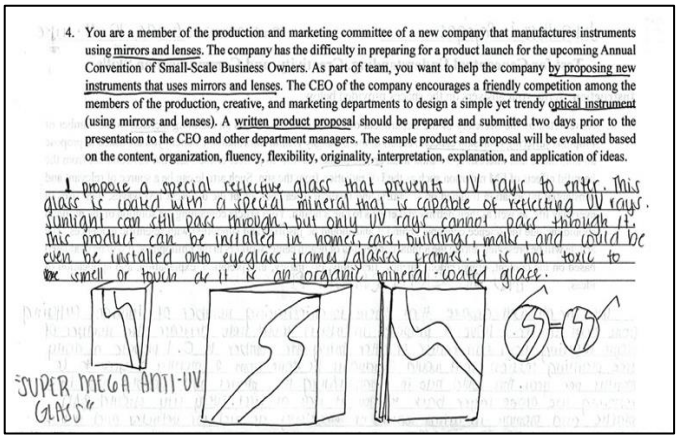

Figure 4. Student's response in question number 4

Table 4. One-way ANCOVA Table Examining the Difference in Conceptual Understanding Skills for the Two Teaching Methods

Source	Sum of Squares	df	Mean Square	F	p-value
Group (Treatment effect)	11.191	1	11.191	1.939	.168^{NS}
Error	386.689	67	5.771		
Total	397.88	68			

*Significant at 0.05 level, ^{NS}Not significant

As shown in Table 4, there is no significant difference in student's conceptual understanding skills as influenced by the two teaching methods. This suggests that students' scores in the two experimental groups were not significantly different from one another. These findings are consistent with the results that, through essay tests, the students' classical comprehension of conceptual understanding had improved utilizing problem-based learning [29]. Likewise, the problem-based method effectively enhances the conceptual understanding of the students since they are actively involved in learning, and it is expected that it facilitates students to develop an understanding of scientific concepts such as designing, predicting, concluding, and constructing a hypothesis [30]. Moreover, in a study [31] to investigate the effect of project-based learning environments on students' conceptual understanding of recycling, it was found that the project-based learning environment had a positive effect on students' conceptual understanding of recycling. This could have been the reason for the absence of difference for both of the teaching methods. This further implies that the lack of difference between the two teaching methods could mean that both groups may have equally developed the conceptual understanding skills.

4. CONCLUSION

The students' conceptual understanding and creativity skills have increased positively after using the two teaching methods. This means that when these teaching strategies are utilized, students can develop their conceptual understanding and creativity skills due to the different real-world scenarios given to propose and construct solutions as answers to the problems. Also, no significant differences were found in students' scores for the two skills as influenced by the two teaching methods. This could be because both problem-based and project-based learning methods are inquiry-based teaching methods that are student-centered, problem-focused, self-directed, self-reflective, and the teacher serves as a facilitator. Problem-based learning and project-based learning as teaching methods have significantly developed the students' conceptual understanding and creativity in physics. Educators, therefore, may utilize inquiry-based teaching methods that are learner-centered to develop students' 21st-century skills, especially conceptual understanding and creativity skills.

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REFERENCES

[1] I. J. P. Saldo and A. M. P. Walag, "Utilizing Problem-Based and Project-Based Learning in Developing Students ' Communication and Collaboration Skills in Physics," *American Journal of Educational Research*, vol. 8, no. 5, pp. 232–237, 2020, doi: 10.12691/education-8-5-1.

[2] D. J. C. Tindowen, J. M. Bassig, and J.-A. Cagurangan, "Twenty-First-Century Skills of Alternative Learning System Learners," *SAGE Open*, vol. 7, no. 3, p. 215824401772611, Jul. 2017, doi: 10.1177/2158244017726116.

[3] C. Scoular, *Analysis of 21st century skills integration as applied in the Philippines K to 12 program. Final report*, no. March. 2020.

[4] E. Care and R. Lou, *Network on Education Quality Monitoring in the Asia-Pacific*, 4th ed. ACTRC Newsletter. Retrieved from https://us13.campaign-archive.com/?u=6b505ede9feb1d6772f41c3d2&id=f62c6b8a5a&e=df0a1192f0, 2016.

[5] M. A. C. Pa-alisbo, "The 21st Century Skills and Job Performance of Teachers," *Tojet - The Turkish Online Journal of Educational Technology*, vol. 8, no. 32, pp. 7–12, 2017.

[6] NAEP, "21st Century Skills , Education & Competitiveness," *A resources and Policy guide*, 2014.

[7] Department of Education, "2018 National Achievement Test (NAT) 6, 10, & 12 Results and analysis." 2019.

[8] A. M. P. Walag, M. T. M. Fajardo, P. G. Bacarrisas, and F. M. Guimary, "Are our Science Teachers Scientifically Literate? An Investigation of Science Teachers' Scientific Literacy in Cagayan de Oro City, Philippines," *Science International*, vol. 32, no. 2, pp. 179–182, 2020.

[9] M. A. A. C. Bug-os, A. M. P. Walag, and M. T. M. Fajardo, "Science Teacher's Personal and Subject-Specific Self-Efficacy in Teaching Science: The Case of El Salvador City, Philippines," *Science International*, vol. 33, no. 3, pp. 179–186, 2021.

[10] K. H. Tseng, F. K. Chiang, and W. H. Hsu, "Interactive processes and learning attitudes in a web-

based problem-based learning (PBL) platform," *Computers in Human Behavior*, vol. 24, no. 3, pp. 940–955, 2008, doi: 10.1016/j.chb.2007.02.023.

[11] E. Ersoy and N. Başer, "The Effects of Problem-based Learning Method in Higher Education on Creative Thinking," *Procedia - Social and Behavioral Sciences*, vol. 116, pp. 3494–3498, 2014, doi: 10.1016/j.sbspro.2014.01.790.

[12] H. Awang and I. Ramly, "Creative thinking skill approach through problem-based learning," pp. 635–640, 2008.

[13] L. J. ChanLin, "Technology integration applied to project-based learning in science," *Innovations in Education and Teaching International*, vol. 45, no. 1, pp. 55–65, 2008, doi: 10.1080/14703290701757450.

[14] S. Mihardi, M. B. Harahap, and R. A. Sani, "The Effect of Project Based Learning Model with KWL Worksheet on Student Creative Thinking Process in Physics Problems," *Journal of Education and Practice*, vol. 4, no. 25, pp. 188–200, 2013.

[15] S. Wurdinger and M. Qureshi, "Enhancing College Students' Life Skills through Project Based Learning," *Innovative Higher Education*, vol. 40, no. 3, pp. 279–286, 2015, doi: 10.1007/s10755-014-9314-3.

[16] B. Birgili, "Creative and Critical Thinking Skills in Problem-based Learning Environments," *Journal of Gifted Education and Creativity*, vol. 2, no. 2, pp. 71–71, 2015, doi: 10.18200/jgedc.2015214253.

[17] T. de C. Nakano and S. M. Wechsler, "Creativity and innovation: Skills for the 21st century," *Estudos de Psicologia (Campinas)*, vol. 35, no. 3, pp. 237–246, 2018, doi: 10.1590/1982-02752018000300002.

[18] R. B. Rudibyani, "Improving Students' Creative Thinking Ability Through Problem Based Learning Models on Stoichiometric Materials," *Journal of Physics: Conference Series*, vol. 1155, no. 1, 2019, doi: 10.1088/1742-6596/1155/1/012049.

[19] W. Wahyu, K. Kurnia, and R. N. Eli, "Using problem-based learning to improve students' creative thinking skills on water purification," *AIP Conference Proceedings*, vol. 1708, no. February 2016, 2016, doi: 10.1063/1.4941158.

[20] S. K. Ummah, A. Inam, and R. D. Azmi, "Creating manipulatives: Improving students' creativity through project-based learning," *Journal on Mathematics Education*, vol. 10, no. 1, pp. 93–102, 2019, doi: 10.22342/jme.10.1.5093.93-102.

[21] S. J. Lou, Y. C. Chou, R. C. Shih, and C. C. Chung, "A study of creativity in CaC 2 steamship-derived STEM project-based learning," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 6, pp. 2387–2404, 2017, doi: 10.12973/EURASIA.2017.01231A.

[22] R. D. Anazifa and Djukri, "Project- based learning and problem- based learning: Are they effective to improve student's thinking skills?," *Jurnal Pendidikan IPA Indonesia*, vol. 6, no. 2, pp. 346–355, 2017, doi: 10.15294/jpii.v6i2.11100.

[23] M. Sahin, "The impact of problem-based learning on engineering students' beliefs about physics and conceptual understanding of energy and momentum," *European Journal of Engineering Education*, vol. 35, no. 5, pp. 519–537, 2010, doi: 10.1080/03043797.2010.487149.

[24] M. Sahin, "Effects of problem-based learning on university students' epistemological beliefs about physics and physics learning and conceptual understanding of Newtonian Mechanics," *Journal of Science Education and Technology*, vol. 19, no. 3, pp. 266–275, 2010, doi: 10.1007/s10956-009-9198-7.

[25] M. Jollands and R. Parthasarathy, "Developing engineering students' understanding of sustainability using project based learning," *Sustainability (Switzerland)*, vol. 5, no. 12, pp. 5052–5066, 2013, doi: 10.3390/su5125052.

[26] İ. Ilter, "A study on the efficacy of project-based learning approach on Social Studies Education: Conceptual achievement and academic motivation," *Educational Research and Reviews*, vol. 9, no. 15, pp. 487–497, 2014, doi: 10.5897/err2014.1777.

[27] P. Phanphech, T. Tanitteerapan, and E. Murphy, "Explaining and enacting for conceptual understanding in secondary school physics," *Issues in Educational Research*, vol. 29, no. 1, pp. 180–204, 2019.

[28] Nurjanah, J. A. Dahlan, and Y. Wibisono, "Development of media model based on hands-on activity to improve conceptual understanding abilities of junior high school students in Bandung district," *Journal of Physics: Conference Series*, vol. 1280, no. 4, 2019, doi: 10.1088/1742-6596/1280/4/042001.

[29] S. Wardani, S. Nurhayat, and P. C. Hardiyanti, "The Effectiveness of Problem Based Learning Model to Improve Conceptual Understanding and Intrapersonal Skill," *International Journal of Science and Research (IJSR)*, vol. 6, no. 5, pp. 1576–1580, 2017.

[30] S. N. Pratiwi, C. Cari, N. S. Aminah, and H. Affandy, "Problem-Based Learning with Argumentation Skills to Improve Students' Concept Understanding," *Journal of Physics: Conference Series*, vol. 1155, no. 1, 2019, doi: 10.1088/1742-6596/1155/1/012065.

[31] T. Ş. Çoruhlu and S. E. Nas, "The impact of project-based learning environments on conceptual understanding: The 'Recycling' concept," *Asia-Pacific Forum on Science Learning and Teaching*, vol. 19, no. 1, pp. 1–23, 2018.