

ENHANCING STUDENTS' SCIENCE PROCESS SKILLS THROUGH PJBL IN ACID-BASE TITRATION EXPERIMENT

Ayu Tri Khodizah^{1*}, Ni Pt. Pande Mirah Surya Dewi¹, Indah Langitasari²,
Irah Namirah²

¹Department of Chemistry Education, Faculty of Teacher Training and Education,
Universitas Lambung Mangkurat

Jl. Brigjen Hasan Basri, Banjarmasin 70123, Kalimantan Selatan, Indonesia

²Department of Chemistry Education, Faculty of Teacher Training and Education,
Universitas Sultan Ageng Tirtayasa

Jl. Ciwaru raya, Cipare, Kec.Serang, Kota Serang, 42117, Banten, Indonesia

*corresponding author: ayutrikhodizah@ulm.ac.id

Abstract. Science process skills (SPS) are essential competencies in 21st-century education. This study aimed to evaluate the effectiveness of the project-based acid-base titration project. A pre-experimental one-group pretest-posttest design was applied to 32 high school students in Serang City. Instruments included observation sheets and 28 essay items, validated by 10 experts using CVR (38 items retained, CVR ≥ 0.62) and tested for reliability (Cronbach's alpha = 0.542). Data were analyzed using the Shapiro-Wilk test, paired sample t-test, N-Gain, and effect size. Results showed a significant improvement in SPS, with pre- and post-test mean scores increasing from 40.00 to 74.34. The t-test yielded $t(31) = -21.417$, $p < 0.001$, and the effect size was high ($\mu = 0.97$). N-Gain analysis indicated moderate improvement in most indicators—such as planning steps (0.63), identifying patterns (0.65), and applying concepts (0.63)—but low gains in hypothesizing alternatives (0.04) and interpreting graphs (0.15). These findings suggest that PjBL is an effective strategy for developing SPS in practical chemistry contexts, preparing students for scientific reasoning and inquiry in the industrial era 4.0.

Keywords: acid-base titration, project-based learning, science process skills

INTRODUCTION

Chemistry education faces challenges as fundamental concepts must be developed in learning, while 21st-century skills and the Industrial Revolution 4.0 are also essential to cultivate. 21st-century skills generally refer to certain core competencies, such as collaboration, digital literacy, critical thinking, and problem-solving. Advocates assert that the need to educate students to thrive in a globalized world also entails students mastering content while generating, synthesizing, and gathering information from a variety of subjects and sources with an understanding and respect for diverse cultures (Hadinugrahaningsih et al., 2017). Chemistry topics are conceptual, combine various abstract concepts, and require laboratory activities or experiments to support theoretical explanations (Ural, 2016). However, students are accustomed to being taught to pass examinations by memorizing facts and disregarding concepts. Consequently, learning chemistry is challenging and less meaningful (Hadinugrahaningsih et al., 2017).

Acid-base material is one of the topics in chemistry that serves as foundational knowledge for studying subsequent materials, namely acid-base titration, buffer solutions, and salt hydrolysis. Acid-base material encompasses numerous concepts that students must comprehend, including macroscopic, microscopic, and symbolic aspects. The macroscopic aspect includes the identification and measurement of the pH of acid-base solutions using indicators (through color changes in universal

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indicators). Microscopic aspects include the proton (H^+) transfer mechanism and the transfer of electron pairs in acid-base reactions. Symbolic aspects include calculating algorithms to determine the concentration of H^+ and OH^- , the pH of acid-base solutions, and drawing acid-base titration curves (Wahyuni & Purwanto, 2020). Acid-base titration is a topic in chemistry that involves abstract and complex concepts, such as determining samples, pH, and ions in titration. Widarti et al. (2017) highlighted the abstract nature of acid-base titration concepts, such as pH and ion titration, as a significant barrier to student understanding. Acid-base titration is a chemistry topic that requires students to conduct experiment activities.

Experiment or practicum activities enable students to conduct several processes such as observing, comparing, formulating hypotheses, and preparing several experiments. Conducting these activities in the chemistry learning process can enhance students' science process skills (Nuswowati et al., 2020). Science process skills are intellectual competencies employed by scientists in the investigation of natural phenomena (Lepiyanto, 2017). Science Process Skills (SPS) aims to enhance students' sensitivity to learning experiences through the application of scientific methods. It assists students in comprehending the scientific phenomena under discussion, acquiring information, and increasing their sense of responsibility for their learning during laboratory experiment activities (Idris et al., 2022). Examine the connection between initial predictions and the actual outcomes observed, allowing students to develop a deeper understanding of scientific concepts and foster positive scientific attitudes through the investigative process they have experienced (Gultom, 2018). To further improve students' science process skills in acid-base titration material, the learning model must support experiment activities and effectively engage students in learning, thereby facilitating the enhancement of their science process skills. The appropriate learning model for this purpose is project-based learning (PjBL).

The Project-Based Learning (PjBL) steps, as delineated by Lucas (2005) and cited in Mariyaningsih & Hidayati (2018), are illustrated in Figure 1.

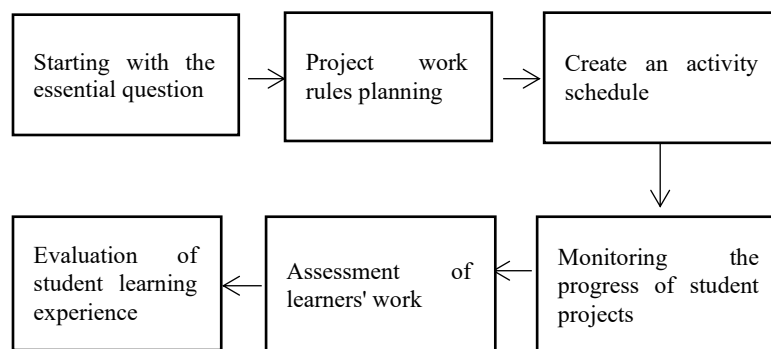


Figure 1. Steps of PjBL

Project-based learning is a student-centered approach that positions teachers as motivators and facilitators, wherein students are afforded the opportunity to work autonomously to construct their learning. It emphasizes problem-solving as a collaborative endeavor, utilizing problems as a primary means of collecting and integrating knowledge from student experiences in learning, and enhances students' creativity. Several factors contribute to this improvement, including the freedom for students to create and develop their ideas during project work, the encouragement and motivation to stay committed to their projects and to confidently ask and answer

questions, as well as the availability of tools and materials, even if they are limited in variety (Taqwilawaty *et al.*, 2024). The implementation of the PjBL model is anticipated to develop students' encouragement of the growth of creativity, independence, responsibility, confidence, critical thinking, and analytical skills in students (Hairunisa *et al.*, 2019), which align with science process skills, particularly problem-solving, communication, and cooperation. The further anticipated impact of implementing the PjBL model is an enhancement in science process skills that is beneficial for further studies and careers in science and technology professions, as necessitated in the industrial era 4.0. The project undertaken in this study involves an analysis of the groundwater conditions in each student's environment, specifically examining chemical parameters, namely, alkalinity. Alkalinity is defined as the buffer capacity against changes in water pH. The primary alkalinity formers are bicarbonate, carbonate, and hydroxide (Saxena & Sharma, 2016). The analysis of groundwater alkalinity utilizing the acid-base titration method encourages students to actively participate in the learning process, develop their scientific attitudes, and enhance their science process skills.

The implementation of the project-based learning model has been extensively applied by several researchers and has yielded positive outcomes, as reported by Milla *et al.* in 2019, demonstrating that the project-based learning model can improve science process skills in biology lessons at the secondary education level. This effect has also been observed at the lower secondary education level for chemistry subjects (Kızıkan & Bektaş, 2017). In addition to science process skills, the PjBL model can enhance academic achievement (Mahasneh & Alwan, 2018), learning motivation, and problem-solving skills (Chiang & Lee, 2016). With the application of PjBL for acid-base titration, students can be assigned to design and conduct experiments to determine the alkalinity of local water sources. This project requires them to apply their understanding of the concept of titration, collaborate with peers to develop a research plan, and communicate their findings, thereby directly engaging with and developing SPS. However, in the acid-base titration material, there has not been extensive application of the PjBL model to develop students' science process skills, necessitating the implementation of the PjBL model for science process skills in chemistry lessons, specifically in acid-base titration. Indeed, the acid-base titration material with this learning model resulted in an improvement in students' science process skills during the industrial period of 4.0.

RESEARCH METHOD

This research employs a pre-experimental method with a one-group pretest-posttest research design (Creswell, 2012). The subjects comprised 32 twelfth-grade science students (17 females and 15 males) from a high school in Serang City. Participants were selected using purposive sampling based on their prior exposure to the acid-base titration concept. The study began with a pre-test to determine students' initial science process skills, followed by a Project-Based Learning (PjBL) intervention, and ended with a post-test to assess students' progress.

Table 1. Science process skills categories

Score (%)	Category
0-25	Very low
26-50	Low
51-75	Medium
76-100	High

(Rahayu & Anggraeni, 2017)

The intervention was conducted in two sessions, each lasting 100 minutes. The Project-Based Learning (PjBL) model was implemented through a sequence of six structured stages: (1) formulating essential questions, (2) designing the project, (3) planning the project schedule, (4) executing the project, (5) evaluating the outcomes, and (6) reflecting on the learning experience (Larmer et al., 2015). Students were organized into small groups to engage in a contextual project addressing water pollution resulting from elevated alkalinity levels. They examined the impact of alkalinity on water pipes and household items, correlating it with the concept of acid-base titration. Throughout the sessions, the instructor facilitated each stage by guiding the formulation of problems, overseeing the planning and execution of experiments, and leading class discussions. The Science Process Skills (SPS) observation sheet was employed during practical sessions—particularly during project execution—to assess indicators such as identifying variables, hypothesizing, planning experiments, and interpreting results. Additionally, a set of 28 essay-based test items was administered as pre- and post-tests to evaluate the cognitive aspects of students' SPS. The scoring rubric and performance level descriptors are presented in Table 1.

The test instrument underwent content validation by 10 experts (5 chemistry education lecturers and 5 senior high school chemistry teachers), using the Content Validity Ratio (CVR) method. Of the 42 initial items, 38 were retained, having met the minimum acceptable CVR value of 0.62. Reliability testing using Cronbach's Alpha yielded a value of 0.542, categorized as moderate, thus indicating that the test instrument was sufficiently reliable.

SPS test questions to assess the enhancement of students' science process skills following the implementation of the PjBL model are analyzed through N-Gain value analysis. N-Gain is a metric utilized to assess the enhancement in science process skills subsequent to the implementation of the PjBL model. The determination of the N-Gain value can be ascertained through the following formula:

$$\text{N-Gain} = \frac{\text{posttest value} - \text{pretest value}}{\text{max value} - \text{pretest value}} 100\%$$

N-Gain analysis was used to measure the improvement in SPS, with classification criteria shown in Table 2. Normality of the data was examined using the Shapiro-Wilk test, and hypothesis testing was conducted through a paired sample t-test using IBM SPSS 16.0. Additionally, effect size calculations were employed to evaluate the strength of the PjBL intervention, as shown in Table 3.

Table 2. Criteria for increasing the N-Gain value

N-Gain score	Criteria
< 0.30	Low
0.30-0.70	Medium
>0.70	High

Situmorang et al., (2015)

Table 3. Effect size classification

Effect size (μ)	Category
$\mu \leq 0.15$	Very low
$0.15 < \mu \leq 0.40$	Low
$0.40 < \mu \leq 0.75$	Medium
$0.75 < \mu \leq 1.10$	High
$\mu \geq 1.10$	Very high

Dinçer, (2015)

The study also employed effect size calculations to ascertain the magnitude of influence exerted by the implementation of the PjBL model on the development of students' science process skills. Effect size is a quantitative measure of the strength of the relationship between two variables, independent of sample size, and indicates the magnitude of the difference or association (Diani et al., 2016). The results of the effect size calculations were classified as presented in Table 3. The research procedures that were implemented are illustrated in Figure 2.

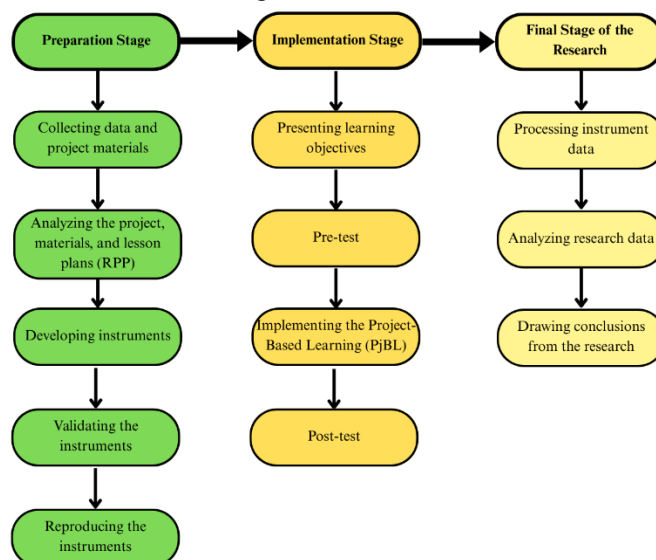


Figure 2. Research procedures

RESULT AND DISCUSSION

The acquisition of science process skills (SPS) is crucial for students to meet the demands of scientific and technological advancement. In contemporary education, students are expected to actively construct knowledge and independently solve problems, necessitating mastery of SPS, such as observing, hypothesizing, planning experiments, and interpreting data. Project-Based Learning (PjBL) is recognized as an effective model for fostering these skills by engaging students in contextual projects derived from everyday phenomena, thereby maintaining their engagement throughout the learning process. In this study, students' science process skills were evaluated through both direct observation and essay-based assessments. During the intervention, observers utilized an SPS observation sheet to document students' practical abilities. Figure 3 presents the percentage of students' performance in each science process skill (SPS) based on observational data. The highest percentages were recorded for the indicators of observing (86%) and hypothesizing (80%), followed by planning experiments (80%) and using tools/materials (75%). These results reflect strong engagement and competence in practical tasks during the project.

To complement the observational findings, Figure 4 and Table 4 summarize the normalized gain (N-Gain) scores for each SPS indicator obtained from the pre- and post-test results. This quantitative measure highlights the extent of improvement in various cognitive aspects of SPS. The table reveals moderate gains in most indicators, such as defining experimental steps (N-Gain = 0.63) and interpreting observations (0.65), while certain indicators, such as identifying multiple explanations (0.04) and interpreting graphs (0.15), showed limited progress. These differences

indicate varying levels of conceptual mastery and instructional effectiveness across different indicators.

Figure 3 and Table 4 provide a detailed overview of the students' conceptual improvement for each science process skill indicator. By combining these quantitative data with observational results (Figure 3), a more comprehensive understanding of students' development during PjBL implementation can be achieved.

To quantitatively measure the effectiveness of the PjBL model, a pre-test and post-test design was employed. The Shapiro-Wilk test confirmed normal data distribution for both the pre-test (Sig = 0.216) and post-test (Sig = 0.089), as shown in Table 5. This justified the use of a paired sample t-test to evaluate the statistical significance of the learning gains. The paired sample t-test results (Table 6) revealed a significant difference between the pre-test and post-test scores ($t(31) = -21.417$, $p < 0.001$), indicating that the implementation of PjBL had a statistically significant impact on students' science process skills.

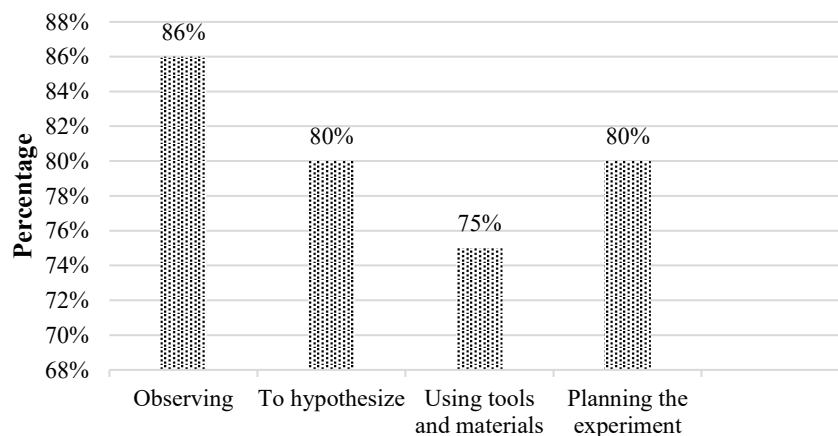


Figure 3. Graph of SPS observation results

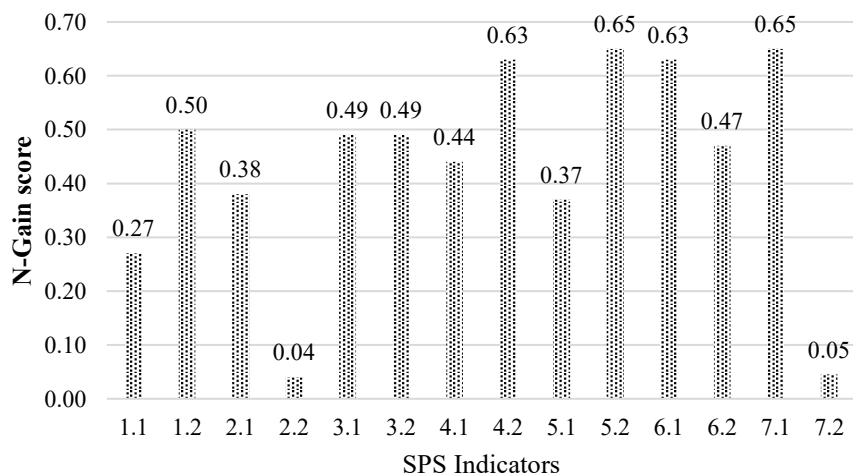


Figure 4. N-Gain graph on SPS indicators

Description of Figure 4:

1.1) Employing multiple senses; 1.2) Utilizing relevant data; 2.1) Formulating a research hypothesis; 2.2) Recognizing multiple explanations for an event; 3.1) Understanding the rationale behind tool/material usage; 3.2) Knowing how to handle tools and materials; 4.1) Identifying necessary tools/materials/sources; 4.2) Defining work steps; 5.1) Linking observational outcomes; 5.2) Identifying patterns in observations; 6.1) Applying new concepts to explain phenomena; 6.2) Using learned concepts in novel situations; 7.1) Representing experimental data with tables; 7.2) Interpreting graphs, tables, or diagrams

Table 4. N-Gain scores for each science process skill indicator

SPS Category	Indicator	N-Gain	Category
1. Observing	1.1 Employing multiple senses	0.27	Low
	1.2 Utilizing relevant data	0.50	Moderate
2. Hypothesizing	2.1 Formulating a research hypothesis	0.38	Moderate
	2.2 Recognizing multiple explanations for an event	0.04	Low
3. Planning an experiment	3.1 Understanding the rationale behind tool/material usage	0.49	Moderate
	3.2 Knowing how to handle tools and materials	0.49	Moderate
4. Using Tools and Materials	4.1 Identifying necessary tools/material/source	0.44	Moderate
	4.2 Defining work steps	0.63	Moderate
5. Interpreting	5.1 Linking observational outcomes	0.37	Moderate
	5.2 Identifying patterns in observations	0.65	Moderate
6. Applying Concepts	6.1 Applying new concepts to explain phenomena	0.63	Moderate
	6.2 Using learned concepts in novel situations	0.47	Moderate
7. Communicating	7.1 Representing experimental data with tables	0.65	Low
	7.2 Interpreting graphs, tables, or diagrams	0.05	Moderate

Table 5. Shapiro-wilk normality test results

Data	df	Sig
Pre-test	32	0.216
Post-test	32	0.089

Table 6. Paired sample t-test results

Data	T	Sig (2-tailed)
Pair 1 Pre-test – Post-test	-21,417	0.000

Furthermore, the effect size was calculated to be 0.97 (Table 7), which falls into the high category. This suggests that the observed improvement is not only statistically significant but also educationally meaningful, reflecting a strong influence of PjBL on students' skill development. These findings are consistent with previous research highlighting that the PjBL approach promotes active learning, critical thinking, and collaborative problem-solving. The structured phases of PjBL (from questioning to reflecting) enable students to develop scientific reasoning while applying knowledge in real-world contexts. The combination of observational and test-based evidence in this study supports the conclusion that PjBL significantly enhances students' science process skills during the learning process.

Table 7. Effect size calculation results

Effect size (μ) score	Category
0,97	High

A detailed explanation of each SPS indicator and its respective improvement score is presented below, highlighting how the PjBL model contributed to skill development across various phases of learning.

Observing

The observing skill includes utilizing as many senses as possible and using relevant facts. In this study, students engaged in multiple Project-Based Learning (PjBL) phases—formulating key questions, planning, and conducting experiments where they used visual and auditory senses, particularly during discussions and titration activities. However, the N-Gain score for using senses was low (0.27), likely due to limited real-life interaction with lab tools. In contrast, students effectively gathered relevant data using qualitative and quantitative observations, with a moderate N-Gain of 0.50. Overall, the observing skill was well-developed through hands-on learning, in line with findings by Fitriyani et al., (2017), who highlighted PjBL's strength in engaging students through direct observation and measurement.

Hypothesizing

The hypothesizing skill consists of formulating research hypotheses and recognizing multiple possible explanations. During the project planning phase, students developed hypotheses based on the groundwater alkalinity case study, resulting in a moderate N-Gain of 0.38. However, their ability to generate multiple explanations remained low (N-Gain 0.04) due to insufficient stimulation to explore alternative ideas beyond the worksheet. These findings reflect challenges in hypothesis generation when students have limited prior knowledge and resources. Rustaman (2005) emphasizes that guiding students through pattern recognition and posing exploratory questions is crucial for strengthening their hypothesizing skills.

Planning an experiment

Planning an experiment involves determining the necessary tools, materials, and procedures. Students discussed and identified the appropriate instruments and steps for conducting an acid-base titration to assess water alkalinity. This phase resulted in moderate N-Gain scores for both selecting resources (0.44) and outlining procedures (0.63), indicating that collaborative planning helped foster critical thinking and experimental design. The absence of explicitly listed materials in the worksheet encouraged students to analyze the problem more deeply.

Using Tools and Materials

Before conducting experiments, students must understand the tools and materials used and how to operate them. Two main indicators in this aspect are understanding why and how to use tools and materials. Students showed a moderate N-Gain (0.49) in understanding the reasons behind selecting tools and materials, developed during the project planning phase through discussions and research. Their ability to properly use tools and materials also scored a moderate N-Gain (0.49), evident during the project monitoring phase, especially in titration experiments where accurate usage directly impacted data collection. Observations showed 75% mastery in this skill, indicating the effectiveness of the planning and monitoring stages in enhancing this aspect.

Interpreting

Interpreting data is essential for turning observations into meaningful insights. The first indicator, connecting observations, was developed during the monitoring phase when students related experimental changes (e.g., color shifts during titration) to theoretical concepts, achieving an N-Gain of 0.37 (Wenno, 2008). The second, identifying patterns in a series of observations, emerged during the planning and monitoring phases. Students analyzed experimental data to determine the alkalinity of groundwater, leading to a moderate N-gain of 0.65 and demonstrating their ability to

draw conclusions based on observed patterns. The overall interpretation skill was evident, with 78% of students reaching a high proficiency level through these activities.

Applying Concepts

This skill refers to students' ability to use learned concepts in new contexts. The first indicator, using concepts to explain new phenomena, appeared during the essential question phase and monitoring phase. Students formulated hypotheses about water alkalinity and verified them through titration, resulting in an N-Gain of 0.63. The second indicator, applying learned concepts in new situations, was developed during data analysis when students calculated water alkalinity using titration formulas, gaining an N-Gain of 0.47. These two indicators are interrelated and together enhanced students' conceptual application skills, with 84% scoring high in observations.

Communicating

Communication skills were practiced through data representation and project presentations. The first indicator, representing experimental data in tables, was developed during project monitoring, where students recorded their findings in structured formats and scored a moderate N-Gain of 0.65. The second indicator, interpreting tables or graphs, was less developed (N-Gain 0.15) as activities lacked emphasis on reading titration graphs and translating data into verbal or written forms. Nevertheless, communication skills were still evident, with 80% of students demonstrating high performance through report writing and classroom presentations.

The steps of Project-Based Learning (PjBL) are closely tied to the development of scientific process skills. PjBL begins with identifying real-world questions or problems, encouraging students to formulate hypotheses and design systematic investigations. Through planning and conducting experiments, students engage in observation, measurement, and data analysis, fostering critical inquiry and problem-solving abilities. As students analyze findings and develop solutions or products, they enhance their analytical, organizational, and application skills. Presenting results and receiving feedback strengthen communication and reflective practices. These steps not only promote mastery of subject matter but also equip students with the scientific skills essential for addressing complex challenges in the industrial era 4.0, which demands critical thinking, collaboration, and adaptability in technologically advanced contexts.

CONCLUSION

This study aimed to examine the effectiveness of the Project-Based Learning (PjBL) model in enhancing students' science process skills (SPS) through a contextual acid-base titration project. The implementation of PjBL led to a statistically significant improvement in students' SPS, as evidenced by a paired sample t-test result of $t(31) = -21.417$, $p < 0.001$. The pre-test and post-test mean scores increased meaningfully, and the calculated effect size ($\mu = 0.97$) was categorized as high, indicating a strong practical impact of the intervention. Quantitative analysis using N-Gain scores revealed moderate improvement across most SPS indicators, particularly in defining work steps (N-Gain = 0.63), interpreting observational patterns (0.65), and applying new concepts (0.63). However, some indicators, such as recognizing multiple explanations (0.04) and interpreting graphs (0.15), showed limited gains, indicating areas requiring further instructional support. These findings confirm that the PjBL model is effective in developing students' science process skills, including observing, hypothesizing, planning experiments, using tools, interpreting results,

applying concepts, and communicating findings. The structured phases of PjBL, combined with collaborative and contextual learning tasks, facilitate critical thinking, problem-solving, and the application of scientific knowledge—skills that are essential for academic achievement and real-world scientific literacy.

REFERENCES

- Chiang, C. L., & Lee, H. (2016). The Effect of Project-Based Learning on Learning Motivation and Problem-Solving Ability of Vocational High School Students. *International Journal of Information and Education Technology*, 6(9), 709–712. <https://doi.org/10.7763/ijiet.2016.v6.779>
- Creswell, J. W. (2012). *Educational Research*. Pearson Education.
- Diani, R., Yuberti, Y., & Syafitri, S. (2016). Uji Effect Size Model Pembelajaran Scramble dengan Media Video Terhadap Hasil Belajar Fisika Peserta Didik Kelas X MAN 1 Pesisir Barat. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 5(2), 265. <https://doi.org/10.24042/jipfalbiruni.v5i2.126>
- Dinçer, S. (2015). Effects of computer assisted learning on students achievements in Turkey : A meta-analysis. *Journal of Turkish Science Education*, 12(1), 99–118. <https://doi.org/10.12973/tused.10136a>
- Fitriyani, R., Haryani, S., & Susatyo, E. (2017). Pengaruh Model Inkuiri Terbimbing Terhadap Keterampilan Proses Sains pada Materi Kelarutan dan Hasil Kali Kelarutan,. *Jurnal Inovasi Pendidikan Kimia*, 11(2), 1957–1970.
- Gultom, E. C. (2018). Penerapan model pembelajaran Predict, Observe, Explain (POE) pada materi larutan elektrolit dan non elektrolit untuk meningkatkan keterampilan proses sains, sikap ilmiah dan kemampuan kognitif siswa. *Quantum: Jurnal Inovasi Pendidikan Sains*, 9(1), 76-83. <https://dx.doi.org/10.20527/quantum.v9i1.4864>
- Hadinugrahaningsih, T., Rahmawati, Y., & Ridwan, A. (2017). *Developing 21st century skills in chemistry classrooms: Opportunities and challenges of STEAM integration*. 030008. <https://doi.org/10.1063/1.4995107>
- Hairunisa, Arif Rahman Hakim, & Nurjumiati. (2019). Studi Pengaruh Model Pembelajaran Berbasis Proyek (Project Based Learning) Terhadap Kreativitas Mahasiswa Program Studi PGSD Pada Mata Kuliah Konsep Dasar IPA. *JURNAL PENDIDIKAN MIPA*, 9(2), 93–96. <https://doi.org/10.37630/jpm.v9i2.190>
- Idris, N., Talib, O., & Razali, F. (2022). Strategies in Mastering Science Process Skills in Science Experiments: A Systematic Literature Review. *Jurnal Pendidikan IPA Indonesia*, 11(1), 155–170. <https://doi.org/10.15294/jpii.v11i1.32969>
- Kızıkan, O., & Bektaş, O. (2017). The Effect of Project Based Learning on Seventh Grade Students' Academic Achievement. *International Journal of Instruction*, 10(01), 37–54. <https://doi.org/10.12973/iji.2017.1013a>
- Larmer, J., Mergendoller, J., & Boss, S. (2015). *Setting the Standard for Project Based Learning*. www.bie.org
- Lepiyanto, A. (2017). Analisis Keterampilan Proses Sains Pada Pembelajaran Berbasis Praktikum. *BIOEDUKASI (Jurnal Pendidikan Biologi)*, 5(2), 156. <https://doi.org/10.24127/bioedukasi.v5i2.795>
- Mahasneh, A. M., & Alwan, A. F. (2018). The Effect of Project-Based Learning on Student Teacher Self-efficacy and Achievement. *International Journal of Instruction*, 11(3), 511–524. <https://doi.org/10.12973/iji.2018.11335a>

- Mariyaningsih, N., & Hidayati, M. (2018). *Bukan Kelas Biasa Teori dan Praktik Berbagai Model dan Metode Pembelajaran Menerapkan Inovasi Pembelajaran di Kelas-Kelas Inspiratif*. Kekata Publisher.
- Milla, D., Jufri, A. W., & Soeprianto, H. (2019). THE EFFECTIVENESS OF PROJECT-BASED LEARNING FOR BIOLOGY CLASS IN DEVELOPING THE SCIENCE PROCESSING SKILLS AND CREATIVITY OF HIGH SCHOOL STUDENTS. *Unnes Science Education Journal*, 8(1), 25–30. <https://doi.org/10.15294/usej.v8i1.15485>
- Nuswowati, M., Azzahra, A., & Purwanti, E. (2020). The effectiveness of nature-based practicum worksheet on acid-base titration material towards students' science process skills. *Journal of Physics: Conference Series*, 1567(2), 022040. <https://doi.org/10.1088/1742-6596/1567/2/022040>
- Rahayu, A. H., & Anggraeni, P. (2017). ANALISIS PROFIL KETERAMPILAN PROSES SAINS SISWA SEKOLAH DASAR DI KABUPATEN SUMEDANG. *JURNAL PESONA DASAR*, 5(2), 22–33.
- Rustaman, N. Y. (2005). *Strtategi Belajar Mengajar Biologi*. UM Press.
- Saxena, R., & Sharma, H. (2016). An Approach towards the Determination of Alkalinity in Water, Its Experimental Consideration & Comparison with Traditional Method: An Overview. *International Journal of Applied Sciences*, 5(3), 122–128. <https://doi.org/10.21013/jas.v5.n3.p3>
- Situmorang, R. M., Muhibbuddin, & Khairil. (2015). PENERAPAN MODEL PEMBELAJARAN PROBLEM BASED LEARNING UNTUK MENINGKATKAN HASIL BELAJAR SISWA PADA MATERI SISTEM EKSKRESI MANUSIA. *Jurnal EduBio Tropika*, 2.
- Taqwilawaty, I., Azizahwati, A., & Sahal, M. (2024). INCREASING STUDENT CREATIVITY THROUGH A PROJECT BASED LEARNING MODEL ASSISTED BY LOCAL WISDOM ON VIBRATIONS AND WAVES MATERIAL CLASS 8 MTs. *Quantum: Jurnal Inovasi Pendidikan Sains*, 15(1), 140–149. <https://dx.doi.org/10.20527/quantum.v15i1.17848>
- Ural, E. (2016). The Effect of Guided-Inquiry Laboratory Experiments on Science Education Students' Chemistry Laboratory Attitudes, Anxiety and Achievement. *Journal of Education and Training Studies*, 4(4), 217–227. <https://doi.org/10.11114/jets.v4i4.1395>
- Wahyuni, T. S., & Purwanto, K. K. (2020). Students' conceptual understanding on acid-base titration and its relationship with drawing skills on a titration curve. *Journal of Physics: Conference Series*, 1440(1), 012018. <https://doi.org/10.1088/1742-6596/1440/1/012018>
- Wenno, I. H. (2008). Praktikum Fisika dengan Menggunakan LKS Competence Based Process Skills sebagai Alat Evaluasi. *Jurnal Kependidikan*, 1, 93–110.
- Widarti, H. R., Permanasari, A., & Mulyani, S. (2017). Undergraduate Students' Misconception on Acid-Base and Argentometric Titrations: a Challenge To Implement Multiple Representation Learning Model With Cognitive Dissonance Strategy. *International Journal of Education*, 9(2), 105. <https://doi.org/10.17509/ije.v9i2.5464>