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# Implementation of Project-Based Learning Based on Small-Scale Chemistry to Enhance Students' Science Process Skills in Acid-Base Learning

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**Abstract**

21st-century education necessitates that students master the '6C' skills. To this end, the Indonesian Independent Curriculum (Kurikulum Merdeka) emphasizes two core pillars: chemical comprehension and process skills. However, recent PISA scores indicate a decline in science performance, often attributed to suboptimal teaching models and limited laboratory infrastructure that inhibits practical learning. While Project-Based Learning (PjBL) and Small-Scale Chemistry (SSC) have been researched independently, their integrated application for acid-base topics within the Independent Curriculum remains unexplored, particularly as a solution to laboratory resource constraints. This quasi-experimental study analyzed the impact of the PjBL-SSC model on students' science process skills. The research subjects included classes XI MIPA 1 (n=33, experimental group) and XI MIPA 3 (n=37, control group) at MAN 2 Jepara. Data were gathered through tests, observations, interviews, and documentation, then analyzed using hypothesis testing and effect size measures. The results demonstrated a significant influence ($p = 0.000 < 0.05$), with the experimental class achieving a mean score of 88.85 compared to 70.51 in the control class - a 29.2% improvement. An effect size of 0.8 indicated a large influence, with the highest gains observed in the indicators for observing (86.4%), grouping (78.8%), and concluding (77.8%).

**Keywords**: Science process skills, Project-Based Learning, Small-Scale Chemistry

## 1. Introduction

Twenty-first-century education mandates the development of '6C' skills: critical thinking, collaboration, communication, creativity, culture, and connectivity (Montessori, 2023). These competencies are particularly vital in chemistry education (Aran, Ware, & Bambut, 2024), where instruction must transcend the mere explanation of concepts. Instead, students must develop scientific rigor, creativity, and a sense of responsibility toward chemistry-related problems (Sulistia, 2024). In the post-pandemic era, educational policy has transitioned from the simplified 2013 Curriculum to the 'Independent Curriculum' (Kurikulum Merdeka) (Mardatilla, Suryani, & Mawardi, 2023). This new framework empowers students to independently process their thoughts and take ownership of their knowledge acquisition (Surur, 2019).

The curriculum used in the current Indonesian education system is the independent curriculum. The independent curriculum is designed to be more in line with students' learning needs and interests (Khoirunnisa 2024). The independent curriculum can also be interpreted as a variety of intracurricular learning where the content delivered by the teacher is more optimal so that students can easily and have enough time to learn, deepen concepts and strengthen existing skills (Ministry of Education and Culture, 2022). The Independent Curriculum gives educators the freedom to create quality learning according to student needs and the learning environment (Anggraeni 2017). The independent curriculum focuses more on learning outcomes that focus on learning outcomes (CP), namely learning skills that students must achieve at each stage (Pratama 2024). In the implementation of this independent curriculum, chemistry learning is divided into 2 phases, namely phase E and phase F (Ministry of Education and Culture, 2022). Each phase in chemistry learning has 2 important elements that should not be ignored in every chemistry learning process. The first element is chemical understanding and the second element is process skills (Sitepu, DO, and Waruwu 2024).

The independent curriculum emphasizes Science Process Skills (SPS) to facilitate active science learning (Alfajri 2022). However, Indonesia's 2022 PISA science score declined to 383 points (rank 67/81), a 13-point decrease indicating implementation challenges in the independent curriculum (OECD 2023). This decline has serious implications: students with weak SPS struggle to apply chemistry concepts, hindering success in higher education and STEM careers, ultimately affecting national competitiveness in the knowledge economy. At MAN 2 Jepara, preliminary observations showed only 32% of students demonstrated adequate science process skills (mean: 58.4/100), with weaknesses in predicting (45.2), measuring (52.8), and concluding (54.6). The school's single chemistry laboratory serves 12 classes with sufficient equipment for only 20% of planned practicum activities, severely limiting hands-on learning opportunities. These challenges stem from multiple factors: difficulty adjusting to the curriculum's shift from competency-based to character-and-skills approaches (Anthony Firdaus et al. 2020; Mahmudah et al. 2024), suboptimal teaching methods that don't actively engage students (Santiawati et al. 2022), and the critical gap between curriculum expectations for hands-on investigation and resource-constrained classroom realities (Hofstein & Mamlok-Naaman 2007). Teachers must therefore employ innovative approaches to overcome both conceptual and practical barriers (Tsaniyyah et al. 2019).

This problem can be overcome by improving students' science process skills, which can be done by implementing the Project Based Learning (PjBL) model (Wismaningati et al. 2019). According to research conducted by (Safrina, 2018) it was proven that the application of the PjBL has a significant influence on students' science process skills. Project Based Learning models can involve students directly to solve the problems given (Sumarni, Wijayati, and Supanti 2019). Project Based Learning provides a forum for students to collaborate more deeply with other students (Rahmawati 2019). Project Based Learning is not limited by time and is limited to the planned learning time allocation. Teachers can monitor and guide students outside the classroom during the implementation of the project (Ni'mah and Rohmah 2023). The benefits of this learning provide solutions for students and teachers so that learning becomes more lively (Alhayat et al. 2023).

Project Based Learning emphasizes students' creativity and skills and teamwork skills, so that students can solve problems by creating a product (Sukmawijaya, Suhendar, and Juhanda 2019). Based on previous research from (Suhanda and Suryanto 2018) and (Permatasari et al., 2024) it is stated that the application of Project Based Learning can improve students' science process skills. The use of PjBL is not the only way to improve students' skills. Chemistry learning cannot be separated from practical activities that involve students directly in the learning process so that they can improve students' skills (Kartyka Nababan 2023). However, not all schools can carry out practical activities, some schools still do not have adequate tools and materials so that learning activities are rarely collaborated with practical activities (Restu and Arini 2020). Teachers can overcome this problem by using Small Scale Chemistry (SSC). SSC is carried out on a small scale using small amounts of chemicals and often using simple equipment to transfer from glass to plastic (Hidayah, Imaduddin, Yuliyanto, Gunawan, & Djunaidi, 2022a; Hidayah, Imaduddin, Yuliyanto, Gunawan, Djunaidi, & Tantayanon, 2022b). SSC the form of chemical practicums carried out in schools, carried out on a small scale, reducing the use of chemicals to minimize the use of chemicals and often using simple materials by switching from glass to smaller plastics (Istiqomah 2022).

The advantages of SSC include saving costs and time, increasing safety, easy to use and environmentally friendly. Instilling the ethics of resource conservation, improving students' understanding of scientific concepts, maintaining students' interest in the subject, directly involving students (Listyorini et al. 2019; Hidayah et al., 2022a, 2022b). It is proven in research conducted by (Harta et al., 2020) that the SSC experiment gave a fairly good average score related to students' science process skills. The problems that have been explained are strengthened by the results of observations and interviews conducted with chemistry teachers at MAN 2 Jepara, it was stated that students' science process skills are still low. This is caused by the transition from the 2013 curriculum to the independent curriculum. The 2013 Curriculum (K13) uses a competency approach while the independent curriculum uses a character and skills approach (Mahmudah et al., 2024). The use of K13 students tends to prioritize the competencies produced rather than the processes in it. This was also discussed in a study conducted by (Rahma, Putri, and Syarkowi 2023) it was also found that due to the Covid-19 pandemic, learning was not optimal, not supported by teaching aids and so on, so that students' science process skills were still lacking, especially with the changes to the independent curriculum currently being used. The learning system used is also still less varied, only with conventional learning, so that students' science process skills, especially in chemistry learning, have not increased optimally (Dewi Muliani and Citra Wibawa 2019).

Implementation of the PjBL model based on SSC this study will be applied to acid-base material. In general, students consider chemistry lessons difficult, memorization, have many formulas, and always face complicated calculations (Sudibawa, 2020). This is because chemistry lessons not only require concepts to be mastered by students, but also skills in them (Ma'isyah and Ardhana 2024). Acid-base material is one of the materials that not only requires chemical concepts, but also skills in its learning is acid-base material (Matsna, Rokhimawan, and Rahmawan 2023). Acid and base material is closely related to science process skills, especially in the context of chemistry and scientific methods (Artini and Wijaya 2020). Acid-base material requires thinking and explanation through reasoning, so that students can solve the problems faced. Acid-base material can be supported by simple experiments because acids and bases are often encountered in everyday life (Apriana 2020). Experiments carried out by students are very important because they can optimize the involvement of direct experience in the learning process, so that students can develop their abilities in using science process skills by observing, interpreting, using tools, materials and sources, and applying concepts and communicating the results of the experiment to teachers and friends (Qodiah, 2024). This study uses acid-base material because the material is closely related to science process skills (Juwita 2022). Acid-base material has been widely studied using SSC, but combining it with PjBL remains unexplored, so in this research provides evidence that PjBL can be combined with SSC especially applied to acid-base material so that there is an increase in students' science process skills (Wulandari, Ayu Mutmainnah, and Agustina 2022).

While previous research has explored Project-Based Learning (PjBL) and Social Smart City (SSC) frameworks in chemistry education, they have largely been examined in isolation. PjBL's efficacy in developing science process skills has been established by Sumarni et al. (2019) and Suhanda & Suryanto (2018); however, these studies were situated within the 2013 Curriculum and did not integrate SSC elements. Conversely, while Hidayah et al. (2022a, 2022b) and Harta et al. (2020) confirmed the viability of the SSC model, it was not embedded within a PjBL framework. Furthermore, contemporary studies on acid-base topics (Matsna et al., 2023; Wulandari et al., 2022; Juwita, 2022) failed to combine these approaches or address the specific context of the Independent Curriculum (Kurikulum Merdeka). Finally, although Mutawally (2021) and Rahmadani (2022) identified resource intensity as a barrier to PjBL, the literature lacks practical solutions to these constraints. Consequently, three critical gaps emerge: (1) a lack of systematic PjBL-SSC integration, (2) a dearth of research within the Independent Curriculum framework, and (3) unaddressed resource barriers hindering implementation in Indonesian schools.

This study uniquely integrates the PjBL-SSC model into the instruction of acid-base chemistry within the Independent Curriculum framework. It addresses common resource constraints through a cost-effective implementation of the Social Smart City (SSC) approach, provides a differential analysis of specific science process skill (SPS) indicators, and utilizes effect size to rigorously quantify pedagogical impact. Consequently, this research pioneers a feasible and scalable strategy for chemistry education in resource-limited Indonesian schools.

## 2. Methodology

This study employed four instruments validated by three experts (Aiken's V = 0.665, $\alpha = 0.677$): a 15-item science process skills test (7 multiple-choice, 8 essay) distributed across six indicators—observing (items 1,6,11), grouping (2,7,12), concluding (3,8), predicting (4,9), measuring (5,10,14), and communicating (13,15)—administered as pretest and posttest; a 4-point Likert observation sheet with inter-rater reliability $\kappa = 0.78$; semi-structured interviews with 9 students (3 high, 3 medium, 3 low achievers); and documentation of learning activities. The test was piloted with 38 Class XII students, with product-moment correlation confirming validity ($r > 0.320$). The independent variable was the PjBL-SSC model, dependent variable was science process skills, and controlled variables included teacher, material (acid-base), duration (4 meetings), and instruments.

The research proceeded through three phases from November 2023 to January 2024. The preparation phase involved developing and validating teaching modules, piloting instruments, and conducting reliability tests. The implementation phase consisted of four 90-minute meetings. In the experimental class (XI MIPA 1, n=33): Meeting 1 involved pretest, introduction to acid-base concepts, and group formation; Meeting 2 focused on project design using LKPD to plan natural indicator creation with SSC equipment; Meeting 3 implemented SSC practicum where students created indicators from local materials (turmeric, hibiscus, dragon fruit, carrot, pandan), tested solutions, and recorded observations. The SSC approach drastically reduces chemical use up to 1000 times compared to conventional laboratories and uses simple plastic equipment (Hidayah et al., 2022a), while maintaining the same chemical principles as macro-scale experiments. Meeting 4 included project presentations and posttest. In the control class (XI MIPA 3, n=37). Meeting 1 consisted of pretest and lecture. Meeting 2 featured teacher demonstration; Meeting 3 involved review and exercises. Meeting 4 concluded with posttest. Three trained observers recorded students' science process skills throughout both implementations. The data analysis phase employed SPSS 25 for descriptive statistics, normality tests (Kolmogorov-Smirnov), homogeneity tests (Levene's), independent samples t-tests (α = 0.05), and effect size calculations (Cohen's d), while interview transcripts underwent thematic analysis.

The test instruments and teaching modules before being applied in this study were tested for validity and reliability. The teaching modules were tested for content validity by experts and then the data was processed using the formula Aiken's V, the use of this formula is done because it can show the suitability of the question items with the indicators to be measured. The results of the analysis of the teaching module are 0.665 which shows that the results of the validation of the teaching module obtained are included in the high category, which states that the teaching module has high content suitability and is suitable for use in research. While the validity test of the question instrument was carried out by testing the questions that had been made on class XII MIPA 2 students with a total of 38 students who had previously received acid-base material. carried out by analyzing student answers using correlation analysis product moment with the help of SPSS. The results of the validity calculation in the table can be seen that 15 questions with r count > r table are 15 questions that are declared valid and 5 questions with r count < r table are declared invalid so that the questions that can be used for research are 15 questions.

Reliability testing is used to measure the consistency or otherwise of the instrument used in research to measure the influence of variable X on variable Y. The results of the reliability test of the question instrument can be seen that Cronbach's alpha on the question instrument is higher than the basic value, namely 0.677 > 0.60, these results prove that the question instrument created is declared reliable.

## 3.Results

### 3.1 Pretest on students' science process skills in acid-base materials

Performance in the control class was distributed across four categories: 'Good' (76–85) with 10.81% (4 students), 'Sufficient' (56–75) with 59.46% (22 students), 'Poor' (40–55) with 16.22% (6 students), and 'Very Poor' (≤40) with 13.51% (5 students). In contrast, the experimental class spanned five categories: 'Very Good' (86–100) at 3.03% (1 student), 'Good' (76–85) and 'Sufficient' (56–75) both at 39.39% (13 students each), 'Poor' (41–55) at 3.03% (1 student), and 'Very Poor' (≤40) at 15.16% (5 students).

**Table 1.** Pretest on students' science process skills in acid-base materials

| No | Range Score | Category | Control class | | Experimental class | |
|---|---|---|---|---|---|---|
| | | | Amount student | Percentage | Amount student | Percentage |
| 1 | 86-100 | Very Good | 0 | 0% | 1 | 3.03% |
| 2 | 76-85 | Good | 4 | 10.81% | 13 | 39.39% |
| 3 | 56-75 | Enough | 22 | 59.46% | 13 | 39.39% |
| 4 | 40-55 | Not enough | 6 | 16.22% | 1 | 3.03% |
| 5 | ≤40 | Very Not enough | 5 | 13.51% | 5 | 15.16% |
| Amount | | | 37 | 100% | 33 | 100% |

### 3.2 Posttest on students' science process skills in acid-base materials

Posttest results for the control class were distributed across four categories: 'Very Good' (86–100) with 13.52% (5 students), 'Good' (76–85) with 24.32% (9 students), 'Sufficient' (56–75) with 51.35% (19 students), and 'Poor' (40–55) with 10.81% (4 students). In contrast, the experimental class spanned only three categories, with a significant majority reaching 'Very Good' (69.70%, 23 students), followed by 'Good' (21.21%, 7 students) and 'Sufficient' (9.09%, 3 students).

**Table 2.** Posttest on students' science process skills in acid-base materials

| No | Range Score | Category | Control class | | Experimental class | |
|---|---|---|---|---|---|---|
| | | | Amount student | Percentage | Amount student | Percentage |
| 1 | 86-100 | Very Good | 5 | 13.52% | 23 | 69.70% |
| 2 | 76-85 | Good | 9 | 24.32% | 7 | 21.21% |
| 3 | 56-75 | Enough | 19 | 51.35% | 3 | 9.09% |
| 4 | 40-55 | Not enough | 4 | 10.81% | 0 | 0% |
| 5 | ≤40 | Very Not enough | 0 | 0% | 0 | 0% |
| Amount | | | 37 | 100% | 33 | 100% |

Descriptive analysis revealed that the experimental group (n=33) achieved a mean gain of 20.09 points (29.2%), doubling the 9.16-point gain (14.9%) of the control group (n=37). Outcomes were also more consistent in the experimental group, as evidenced by a decline in standard deviation (10.35 to 8.70) versus an increase in the control group (11.42 to 12.18). Posttest distributions favored the experimental class, where 69.7% of students scored in the 'Very Good' range, compared to only 13.5% in the control class. This suggests that the PjBL-SSC model is highly effective for both overall achievement and the reduction of performance disparities.

3.3 Observation Results on the influence of PjBL-SSC on students' science process skills in acid-base materials

**Table 3. Observation Results**

| No | KPS Indicator | Control Class | | Experimental Class | |
|---|---|---|---|---|---|
| | | Percentage | Category | Percentage | Category |
| 1 | Observing | 76.4% | Good | 86.4% | Very Good |
| 2 | Grouping | 56.8% | Enough | 78.8% | Good |
| 3 | Conclude | 51.3% | Not enough | 77.8% | Good |
| 4 | Predicting | 54.1% | Not enough | 68.7% | Enough |
| 5 | Measure | 62.7% | Enough | 66.7% | Enough |
| 6 | Communicating | 76% | Good | 77.7% | Good |
| Average | | 62.8% | Enough | 76.1% | Good |

Observational data indicated that the experimental class outperformed the control class across all six indicators of science process skills. The experimental class achieved an overall average of 76.1% (Good), whereas the control class averaged 62.8% (Sufficient). The most significant disparities were observed in 'Concluding,' where the experimental class reached 77.8% (Very Good) compared to the control class's 51.3% (Poor), and 'Grouping,' with scores of 78.8% (Good) and 56.8% (Sufficient), respectively. Additionally, the experimental class maintained higher scores in 'Observing' (86.4% vs. 76.4%) and 'Predicting' (68.7% vs. 54.1%), although 'Predicting' proved to be the most challenging area for both groups.

Interestingly, measuring and communicating skills showed minimal differences between classes. Both groups achieved similar scores in measuring (experimental: 66.7%; control: 62.7%) and communicating (experimental: 77.7%; control: 76.0%), suggesting these foundational skills develop consistently regardless of teaching approach. The stronger performance in concluding and grouping among experimental students likely reflects the nature of Project Based Learning, where students regularly practiced organizing information and drawing evidence-based conclusions from their natural indicator experiments. The persistent difficulty with predicting in both classes indicates that hypothesis formulation requires more explicit instructional support than either approach currently provides.

3.4 Normality test on the influence of PjBL-SSC on students' science process skills in acid-base materials

Normality was assessed using the One-Sample Kolmogorov-Smirnov test in SPSS. The data are considered normally distributed if the significance value (0.05) is greater than 0.05, whereas a value less than 0.05 indicates that the data are not normally distributed.

**Table 4. Data Normality Test Results**

| Mark Pretest and Posttest | Sig. Value | Information |
|---|---|---|
| Pretest Control Class | 0.637 > 0.05 | Normal |
| Posttest Control Class | 0.443 > 0.05 | Normal |
| Pretest Experimental Class | 0.699 > 0.05 | Normal |
| Posttest Experimental Class | 0.103 > 0.05 | Normal |

The significance values for the control class were 0.637 (pretest) and 0.443 (posttest), while the experimental class yielded values of 0.699 (pretest) and 0.103 (posttest). Because all these values are greater than 0.05, the data for both groups are considered normally distributed.

3.5 Homogeneity test on the influence of PjBL-SSC on students' science process skills in acid-base materials

After the data is normally distributed, a homogeneity test is carried out to determine whether the pairs being tested have differences that represent variances that are classified as homogeneous. The data being tested is said to be homogeneous if the significance value is > 0.05 with a significance level of 5%. The data being tested for homogeneity are data pretest And posttest experimental class and control class.

**Table 5. Homogeneity Test Results**

| Mark Pretest And Posttest | Sig. Value | Information |
|---|---|---|
| Pretest Control Class and Experimental Class | 0,624 > 0,05 | Homogeneous |
| Posttest Control Class and Experimental Class | 0,063 > 0,05 | Homogeneous |

Homogeneity testing yielded significance values of 0.624 for the pretest and 0.063 for the posttest. Since both values exceed the 0.05 threshold, the variances of the control and experimental classes are considered homogeneous. Following the successful results of both normality and homogeneity tests, the data meet the necessary assumptions for parametric hypothesis testing using the t-test.

3.6 Hypothesis testing (t-test) on the influence of PjBL-SSC on students' science process skills in acid-base materials

Hypothesis testing was conducted using an independent samples t-test to determine if there was a significant difference between the means of the two independent groups. As the data satisfied the preliminary requirements of normality and homogeneity, the use of this parametric test was appropriate.

**Table 6. Hypothesis Test Results**

| Variables | N | Mean | t value | Tabel | df | SD | Sig.(2-tailed) |
|---|---|---|---|---|---|---|---|
| Class Control | 37 | 70.51 | 7.066 | 1.668 | 68 | 12.175 | 0.000 |
| Class Experiment | 33 | 88.85 | | | | 8.704 | |

The independent samples test revealed a significant difference in science process skills between the experimental and control classes, with a Sig. (2-tailed) value of 0.000 ($p < 0.05$). The calculated t-value was 7.066, which significantly exceeds the critical t-table value of 1.668 (at df = 68 and alpha = 0.05). Because the calculated t-value is greater than the table value (7.066 > 1.668) and the p-value is less than 0.05, the null hypothesis ($H_0$) is rejected and the alternative hypothesis ($H_a$) is accepted. This confirms that the Project-Based Learning model integrated with Small-Scale Chemistry (PjBL-SSC) significantly improves students' science process skills in acid-base material.

3.7 Size Test on the influence of PjBL-SSC on students' science process skills in acid-base materials

Effect Size aims to determine how big the differences are between two different groups in a research study (Khairunnisa et al. 2022).

$$ES = \frac{(Xpost-Xpre)E-(Xpost-Xpre)C}{SDpreC+SDpreE+SDpreC} = 0.8$$

The effect size calculation yielded a result of 0.8, which is interpreted as a moderate effect. Consequently, it can be concluded that the Small-Scale Chemistry-based Project-Based Learning (PjBL-SSC) model has a moderate influence on the improvement of students' science process skills.

## 4. Discussion

The predetermined class samples were given different treatments, in the control class a conventional learning model was used, while in the experimental class a conventional learning model was used PjBL based on SSC. Treatment in each class is explained as follows:

4.1 Control Class Using Conventional Learning Model

The control class utilized a conventional learning model that emphasized teacher-led lectures; students primarily listened to explanations supplemented by acid-base practicum demonstrations. This group participated in three meetings, beginning with a pretest to assess their initial abilities. Following the pretest, the teacher introduced acid-base concepts using trigger questions. Students responded effectively to these prompts, supporting the findings of Pandu, Purnamasari, and Nuvitalia (2023), who state that trigger questions can enhance students' confidence and skill in expressing opinions. During the second meeting, the conventional lecture method was used to explain acid-base indicators. This was accompanied by a demonstration of practicum activities to develop observation skills, where students directly observed the differences between acidic and basic solutions using natural indicators.

4.2 Demonstration activities

During these demonstrations, most students showed significant interest and engagement. This observation aligns with research by Prasetyo et al. (2022), which suggests that practicum-based learning methods increase student enthusiasm. As the teacher explained the material, several science process skills were integrated into the lesson, specifically observation, classification, measurement, and prediction. Additionally, students were encouraged to ask questions to clarify their understanding. However, only four students actively participated in this questioning phase. Since asking questions is a key indicator of the 'communication' science process skill, this low participation suggests that students' interpersonal communication skills remain limited. This is consistent with Suryaningsih (2023), who found that low interpersonal communication skills often hinder students' ability to express opinions during academic discussions.

Based on the results of the observation regarding the concluding indicator, the control class got a less category because when students were asked to conclude the learning outcomes, no one spoke until they were asked directly by the teacher. This happens because students still cannot understand the material that has been delivered by the teacher, in other words, students' communication skills in science process skills are still low. Supported by research conducted by (Putra and Pebriana 2022) which states that students are less able to communicate their learning outcomes during learning activities.

The last meeting was a summative test (posttest) to measure the results of students' science process skills after learning is carried out and to compare them with the pretest results as an analysis of the influence of the applied learning model and a review of the material that has been explained by the teacher.

The experimental class utilized the Project-Based Learning (PjBL) model integrated with Small-Scale Chemistry (SSC). This approach was specifically designed to enhance students' science process skills, consistent with research by Rohayati and Ibrahim (2019), which demonstrated that PjBL effectively improves these skills. The intervention spanned four sessions; the first session included a pretest, an introductory lecture on acid-base concepts, and an orientation to SSC practicum activities. Subsequently, the teacher organized students into groups of five or six and instructed them to discuss the provided Student Worksheets (LKPD). Most students displayed high enthusiasm while completing these worksheets, supporting the findings of Jalal et al. (2021) that the use of LKPD can significantly increase student interest in learning.

In this activity, there are indicators of science process skills that appear, namely observing, students are asked to solve existing problems, find sources of information to design their projects in the form of making natural indicators to identify acidic solutions and basic solutions. LKPD discussion activities can be seen in the following picture.

The effect size calculation yielded a result of 0.8, which is interpreted as a moderate effect. Consequently, it can be concluded that the Small-Scale Chemistry-based Project-Based Learning (PjBL-SSC) model has a moderate influence on the improvement of students' science process skills.

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Figure 1. LKPD Discussion Activity in Experimental Class

At the second meeting, the teacher monitored the students' project activities that had been designed by the students at the previous meeting until the project was completed. The project carried out by the students was in the form of a practical work-based activity. Small Scale Chemistry, practical work using SSC used as an alternative to the lack of facilities and infrastructure in the laboratory by using tools made of plastic instead of glass and can be done anywhere (Hidayah et al. 2022b). In this activity, there are indicators of science process skills that appear in the form of grouping because in this practical activity what is done is identifying acid solutions and base solutions using natural indicators which will then be grouped from samples that have been brought by students which are acid solutions and base solutions, each group designs a natural indicator that will be used and differs between one group and another and then designs the results of the project that has been implemented. The natural indicators made by students are indicators from carrots, turmeric, hibiscus, pandan, and dragon fruit. Students are very enthusiastic in the small scale practical activities, each group is busy doing the project they have designed previously. This was also conveyed by (Jalal, Muhsinin, and Suryaningsih 2017) that practical activities make students more active, enthusiastic and motivated to learn. Practical activities can be seen in the following picture:

Figure 2. Small Scale Chemistry Practicum Implementation

Students conducting acid-base identification using natural indicators (turmeric, hibiscus, carrot, pandan, and dragon fruit) with SSC equipment during Meeting 3. Note the use of plastic droppers and small-volume containers instead of conventional glassware, demonstrating cost-effective laboratory practice. This activity develops 'grouping' and 'measuring' indicators of science process skills.

Small Scale Chemistry practicum activities are new to students because they have not been widely implemented by teachers due to limited knowledge, information and creativity of teachers (Hidayah et al., 2022a). Students are very enthusiastic about carrying out practicum activities and have fun with their respective groups. Drops of solution and indicators that are reacted amaze students and always want to try because the results obtained are different. Before the practicum process begins, students are asked to predict the results that will be obtained through project planning activities which are one of the indicators of science process skills, namely predicting, and when the practicum activities are carried out by students, other indicators that appear are measuring, through natural indicators that have been made by students, students can easily analyze the differences in the treatment of natural indicators with the reaction of acid and base solution samples provided and can measure the pH of the solution using pH indicator paper. Students still have difficulty measuring the results of the practicum because they are not used to using laboratory equipment. This finding aligns with Hidayah et al. (2022b), who reported that students experienced difficulties in determining tools for small-scale chemistry and operating small-sized equipment, though they showed good inference abilities on experimental results. Similarly, Hidayah et al. (2022a) found that pre-service teachers faced challenges with the accuracy of small-scale measurements but appreciated the ease of understanding chemical concepts through accessible practicum activities. In line with research conducted by (Candra and Hidayati 2020) which states that students' difficulties during practicum activities are the lack of students' habituation in using laboratory equipment.

At the third meeting, students presented the results of the projects they had done. This is one of the indicators of science process skills, namely communicating. In addition, the indicator of concluding appears at this time, namely students are asked to conclude the results of their own projects and the results of the entire project and the teacher helps provide reinforcement for what has been conveyed by the students. Each group presented the results of their projects well, but most of them were delivered by female students. Through presentation activities, students can improve their speaking skills and self-confidence (Goeyardi 2022).

Figure 3. Project Results Presentation Activity

During the fourth meeting, student groups presented their natural indicator project findings to the class. This activity fostered the 'communicating' and 'concluding' indicators of science process skills, as it required students to articulate their procedures, results, and evidence-based conclusions. To further support the learning process, the presentations included peer feedback and teacher reinforcement.

At the fourth meeting, the teacher gave students the opportunity to ask questions about things they still did not understand from the project that had been carried out and to share the experiences they had gained after that, many students were enthusiastic about sharing their experiences in carrying out the project, then a summative test was carried out (posttest) to measure student outcomes after learning is carried out and compare them with the pretest results as an analysis of the influence of the applied learning model.


Figure 4. Posttest Administration

Students completing the 15-item science process skills test after four meetings of PjBL-SSC instruction. The posttest was conducted simultaneously for both control and experimental classes to ensure consistency and measure the final science process skills achievement across six indicators: observing, grouping, concluding, predicting, measuring, and communicating.

4.3 Discussion of Science Process Skills Test Results

The assessment of science process skills involved a 15-item instrument administered as both a pretest and a posttest. This instrument, focusing on acid-base material, was rigorously tested for validity and reliability prior to use. Analysis of the test results revealed a distinct performance gap between the control class and the experimental class using the SSC-based PjBL model. In the pretest, the control class achieved an average score of 61.35, while the experimental class averaged 68.76. In the posttest, the control class improved to 70.51, whereas the experimental class reached significantly higher at 92.76. These results demonstrate that the experimental group outperformed the control group. This superiority is attributed to the PjBL-SSC model, which provided students with hands-on opportunities to manage projects both individually and collaboratively. By directly engaging in project creation, students developed a deeper understanding of identifying acid-base solutions using natural indicators found in their environment.

The project activities took the form of a practicum facilitated by Small-Scale Chemistry (SSC). The adoption of SSC was essential to address the school's limited laboratory facilities and infrastructure. Although conducted on a reduced scale, SSC maintains the same chemical principles as conventional practicums. According to Supatmi (2022), small-scale practicums are more effective than conventional methods at enhancing students' science process skills. This effectiveness stems from the direct, individual experience students gain, allowing them to personally engage with facts, theories, and concepts to achieve a deeper understanding. This approach contrasts with the conventional model used in the control class, which relied primarily on teacher-led demonstrations. Furthermore, Kasdum (2019) confirms that Project-Based Learning (PjBL) significantly influences science process skills. Hariningsih and Zainuddin (2022) identify several factors affecting these skills, including students' foundational abilities, attitudes, motivation, and the availability of equipment. By merging PjBL with SSC, this study addressed these variables: PjBL fostered student engagement and motivation, while SSC overcame the limitations of laboratory resources. Consequently, the PjBL-SSC model proved highly effective in improving students' science process skills.

The magnitude of the impact of the PjBL-SSC model was measured using an effect size calculation. The resulting value of 0.8 falls within the moderate category based on standard interpretation scales. Consequently, it can be concluded that the application of PjBL based on SSC has a moderate influence on improving students' science process skills. While this model demonstrates the potential to significantly enhance these skills, its impact may be less pronounced compared to other instructional models that yield higher effect size scores.

4.4 Discussion of Science Process Skills Indicators in the Application of Project Based Learning Model Based on Small Scale Chemistry

Observations were conducted to assess students' science process skills throughout the PjBL-SSC learning process. Analysis of the observation sheets yielded an average score of 86.4%, placing student performance in the 'very good' category. This high level of achievement is attributed to the model's emphasis on direct interaction with study objects during small-scale practicums. These activities, designed to encourage student agency, fostered high levels of engagement and enthusiasm. These findings align with research by Fitriana (2021), which suggests that observation activities are effective tools for describing student attention and classroom participation. Furthermore, interview data from students across high, medium, and low performance categories corroborated these results, as participants reported no significant difficulties during the observation phase. Ultimately, this learning model serves as a viable alternative to stimulate student interest and prevent boredom in the classroom.

Observations regarding the 'grouping' indicator resulted in an average score of 78.8%, falling into the 'good' category. This high level of performance occurred because students were able to categorize their findings immediately during the practicum. Specifically, by identifying acid-base solutions using natural indicators they had prepared themselves, students could easily classify substances based on their experimental outcomes. These findings align with research by Rohmatul et al. (2022), which suggests that proficient grouping skills enable students to record and organize observation data systematically. Interview data corroborated these results, revealing that only one student in the low-achievement category experienced difficulty organizing the observation table.

Similarly, the 'concluding' indicator achieved an average value of 77.8%, also classified as 'good.' Because students conducted the experiments personally, they gained a firsthand understanding of the results, which facilitated the formulation of evidence-based conclusions. This is consistent with the findings of Nuraufa, Aziz, and Fatiatun (2024), who noted that practical activities significantly enhance students' ability to draw accurate conclusions. Interview responses further supported this, showing that despite the complexity of the task, only two students reported challenges in synthesizing their final results.

The observation results on the communication indicator obtained an average percentage value of 77.7% with a good category. This is because students who directly carry out practical activities will find it much easier to communicate their results to other students and teachers compared to students who do not do practical. This statement is supported by the results of interviews from 2 questions asked, only 2 students still had difficulty when students compiled the results of the practical report, while other students did not experience difficulties. The results of research conducted by (Syafmitha, Selaras, and Fadilah 2024) show that the application of the PjBL model can improve students' ability to communicate in the very good and increasing category.

The 'predicting' indicator achieved an average score of 68.7%, falling into the 'sufficient' category. Hamidah (2023) posits that the project-planning phase of PjBL typically allows students to predict project timelines and outcomes effectively, often resulting in performance in the 'very good' category. However, in this study, students remained in the 'sufficient' category due to a lack of foundational knowledge and limited prior practical skills. Interview data supported this finding: three students reported difficulty anticipating experimental outcomes before the trial began, and three others struggled to predict data that had not yet been observed.

Similarly, the 'measuring' indicator received an average value of 66.7%, also categorized as 'sufficient.' These results align with research by Tawil (2020), which indicates that measurement remains a relatively weak area in students' science process skills. This lower score may be attributed to students' limited experience with practical tools, which hinders their mastery of measurement techniques. Qualitative interviews confirmed these observations, as three students explicitly noted difficulties in accurately measuring experimental results during the practicum.

The experimental class's superior performance stems from several interconnected mechanisms. SSC practicum provided hands-on experiences where students directly manipulated materials and observed color changes in natural indicators they created themselves, developing observing skills through active engagement rather than passive observation (Piaget, 1954). The project framework gave these observations authentic purpose—solving how to identify acids and bases using local materials—connecting with experiential learning principles (Dewey, 1938). Individual access to plastic containers meant each student could practice measuring and observing, unlike limited conventional glassware. The project cycle itself (predict-observe-reflect) required repeated practice in grouping and concluding, explaining why these skills showed strongest improvements.

Observing (86.4%) benefited from multiple opportunities to examine color changes at individual pace. Grouping and concluding improved through classification tasks and presentation justifications. Predicting remained challenging (68.7%) despite improvement, indicating need for explicit hypothesis formulation instruction. Measuring showed minimal class differences (66.7% vs. 62.7%), suggesting tool familiarity depends less on pedagogy than on dedicated practice. Communicating developed similarly (77.7% vs. 76.0%) as both classes had discussion opportunities.

The effect size of 0.8 aligns with Suhanda and Suryanto's (2018) 18-point gains and exceeds typical brief interventions, possibly due to independent curriculum's process skills emphasis. Unlike previous studies that examined PjBL (Suhanda & Suryanto, 2018) or SSC (Hidayah et al., 2022a, 2022b) separately, this integration achieved moderate-to-large effects by solving PjBL's resource demands without sacrificing pedagogical benefits. Teachers can implement PjBL-SSC with minimal facilities using local materials, though predicting and measuring need additional scaffolding. Schools should invest in cost-effective SSC equipment alongside teacher training in PjBL facilitation. Curriculum developers can create topic-specific SSC project templates for other chemistry topics, particularly those with observable phenomena and locally available materials.

Like any research, this study has limitations worth noting. The most obvious is scope—we worked with just two classes at one school, which means we should be cautious about assuming these results would apply everywhere. Different schools face different challenges, and what worked at MAN 2 Jepara might need adjustment elsewhere. The timeline was also quite short. Four meetings gave us enough time to see initial improvements in science process skills, but we don't know if these gains lasted. Did students still demonstrate strong observing and grouping skills months later? We can't say from this data alone.

Our assessment approach, while thorough, could have been richer. We relied heavily on tests and structured observations, which are useful but don't capture everything about how students think scientifically. Looking at students' actual project work more closely, or interviewing more than nine students, might have revealed additional insights.

We also couldn't control for everything that might have influenced results. The same teacher taught both classes, so we can't separate the model's effects from the teacher's effectiveness. And we didn't systematically track things like student motivation or how much support they got at home. Finally, we only tested this with acid-base material. Other chemistry topics might work differently with PjBL-SSC, especially those needing different equipment or presenting different safety considerations.

The experimental class's superior performance stems from several interconnected mechanisms rooted in established learning theories. SSC practicum provided hands-on experiences where students directly manipulated materials and observed color changes in natural indicators they created themselves, developing observing skills through active engagement rather than passive observation (Piaget, 1954). The project framework gave these observations an authentic purpose—solving how to identify acids and bases using local materials—connecting with experiential learning principles (Dewey, 1938). Individual access to plastic containers meant each student could practice measuring and observing, unlike the limited conventional glassware, where students must wait for equipment access. The project cycle itself (predict-observe-reflect-present) required repeated practice in grouping and concluding, explaining why these skills showed the strongest improvements (78.8% and 77.8% respectively). The differential improvements across indicators reveal important instructional implications: Observing (86.4%) benefited from multiple opportunities to examine color changes at individual pace; grouping and concluding improved through classification tasks and presentation justifications requiring students to articulate evidence-based reasoning. However, predicting remained challenging (68.7%) despite improvement over control class (54.1%), indicating that hypothesis formulation requires more explicit instructional scaffolding than the current PjBL-SSC implementation provided. Measuring showed minimal class differences (66.7% vs. 62.7%), suggesting tool familiarity depends less on pedagogical approach than on dedicated, instrument-specific practice beyond the four-meeting timeframe. Communicating developed similarly in both classes (77.7% vs. 76.0%) as both had discussion opportunities, though in different formats—project presentations versus teacher-led discussions.

The effect size of 0.8 positions this study within the moderate-to-large range, aligning with Suhanda and Suryanto's (2018) 18-point gains while exceeding typical brief interventions, possibly due to the independent curriculum's explicit process skills emphasis creating favorable conditions for skill development. Unlike previous studies that examined PjBL (Suhanda & Suryanto, 2018) or SSC (Hidayah et al., 2022) separately, this integration achieved moderate-to-large effects by addressing PjBL's resource demands through SSC's cost-effective approach without sacrificing pedagogical benefits, demonstrating that resource-limited schools can achieve comparable or superior outcomes through strategic integration. The practical implications are significant: Teachers can confidently implement PjBL-SSC with minimal facilities using locally available materials (turmeric, hibiscus, dragon fruit, carrot, pandan) and plastic containers, though additional scaffolding is needed for predicting and measuring skills through structured prediction templates and dedicated instrument practice sessions. Schools should prioritize investment in cost-effective

SSC equipment sets over expensive conventional glassware, alongside teacher professional development in PjBL facilitation skills.

Curriculum developers can create topic-specific SSC project templates for other chemistry topics with observable phenomena and locally available materials, enabling systematic implementation across the curriculum. However, several limitations warrant acknowledgment: The study's scope was limited to two classes (n=70) at one school, requiring cautious generalization to diverse contexts; the four-meeting duration demonstrated initial improvements but long-term retention remains unmeasured; assessment relied primarily on tests and structured observations rather than richer portfolio analysis; the same teacher taught both classes, preventing complete separation of model effects from teacher effectiveness; and the study tested only acid-base material, with other chemistry topics potentially requiring different adaptations. Despite these limitations, the robust effect size, strong theoretical grounding, and practical feasibility position PjBL-SSC as a promising, evidence-based approach for chemistry education in resource-constrained Indonesian schools operating under the independent curriculum framework.

Like any research, this study has limitations worth noting. The most obvious is the scope and generalizability. We worked with just two classes (n=70) at one school (MAN 2 Jepara), which means we should be cautious about assuming these results would apply everywhere. Different schools face different challenges, and what worked at MAN 2 Jepara might need adjustment elsewhere. Duration was also quite short. Four meetings gave us enough time to see initial improvements in science process skills, but we don't know if these gains lasted. Did students still demonstrate strong observing and grouping skills months later? We can't say from this data alone.

Our assessment approach, while thorough, could have been richer. We relied heavily on tests and structured observations, which are useful but don't capture everything about how students think scientifically. Looking at students' actual project work more closely, or interviewing more than nine students, might have revealed additional insights. We also couldn't control for everything that might have influenced results. The same teacher taught both classes, so we can't completely separate the model's effects from the teacher's effectiveness (controlled variables). And we didn't systematically track things like student motivation or how much support they got at home. Finally, topic specificity is a limitation we only tested this with acid-base material. Other chemistry topics might work differently with PjBL-SSC, especially those needing different equipment or presenting different safety considerations. Despite these limitations, the robust effect size (0.8), strong alignment with learning theories, and practical feasibility make PjBL-SSC a promising approach for chemistry education in resource-limited Indonesian schools operating under the independent curriculum framework.

## 5. Conclusion and Suggestions

Based on the research findings, the t-test yielded a significant value of 0.000 ($p < 0.05$), leading to the rejection of the null hypothesis ($H_0$) and the acceptance of the alternative hypothesis ($H_a$). This indicates that the PjBL-SSC model significantly influences the improvement of students' science process skills. Furthermore, the calculated effect size of 0.8, categorized as 'moderate' according to Cohen's criteria, confirms that the application of Project-Based Learning based on Small-Scale Chemistry provides a meaningful impact on these skills. The PjBL-SSC model serves as a viable alternative for educators seeking to enhance students' science process skills. Additionally, it offers a practical solution for schools facing limited laboratory facilities and infrastructure, ensuring that high-quality practical learning activities remain accessible to students.

## 6. References


Alfajri, N. A. (2022). Analysis of Students' Science Process Skills in Distance Learning at State Junior High Schools in Lebak Regency.

Alhayat, A., Mukhidin, M., Utami, T., & Yustikarini, R. (2023). The Relevance of the Project-Based Learning (PjBL) Model to the "Independent Learning Curriculum" (Kurikulum Merdeka). *DWIJA CENDEKIA: Jurnal Riset Pedagogik*, 7(1), 105.

Anggraeni, W. (2017). Using Two-Tier Diagnostic Test Instruments. Wiwiek Anggraeni.

Firdaus, A., Miranda, Y., & Sinaga, S. (2020). Implementation of the PjBL Model to Improve Science Process Skills and Scientific Attitudes of Grade VIII Junior High School Students. *Journal of Environment and Management*, 1(3), 259-266.

Candra, R., & Hidayati, D. (2020). The Application of Practicums to Improve Students' Process and Performance Skills in the Science Laboratory. *Edugama: Jurnal Kependidikan Dan Sosial Keagamaan*, 6(1), 26-37. https://doi.org/10.32923/edugama.v6i1.1289

Dewey, J. (1938). Experience and Education. New York: Macmillan Company.

Harta, J., et al. (2020). Developing Small Scale Chemistry Practicum Module to Identify Students' Ability in Predict-Observe-Explain (POE) Implementation. *JKPK (Jurnal Kimia dan Pendidikan Kimia)*, 5(1), 91.

Hidayah, F. F., Imaduddin, M., Yuliyanto, E., Gunawan, G., & Djunaidi, M. C. (2022a). Introducing the Small-Scale Chemistry Approach Through Inquiry-Based Laboratory Activities For Pre-Service Teachers. *EduChemia (Jurnal Kimia dan Pendidikan),* 7(1), 14-35. https://doi.org/10.30870/educhemia.v7i1.13084

Hidayah, F. F., Imaduddin, M., Yuliyanto, E., Gunawan, G., Djunaidi, M. C., & Tantayanon, S. (2022b). "Counting Drops and Observing Color": Teachers' and Students' First Experiences in Small-Scale Chemistry Practicum of Acid-Base Solutions. *Journal of Technology and Science Education*, 12(1), 244-258. https://doi.org/10.3926/jotse.1388

Istiqomah, I. (2022). Implementation of the Discovery Learning Model with Small-Scale Chemistry Media to Improve Student Activity and Learning Outcomes in Grade XI Science at State Senior High School 1 Talun. *Jurnal Pendidikan Sosiologi Dan Humaniora*, 13(2), 652.

Juwita, R. (2022). Best Practices for Developing Science Process Skills through the Project-Based Learning Model with a STEAM Approach in Grade XI Science Acid-Base Materials at State Senior High School 1 Bontang. *LEARNING: Jurnal Inovasi Penelitian Pendidikan Dan Pembelajaran*, 2(3), 268-277.

Khairunnisa, K., et al. (2022). The Use of Effect Size as a Mediator in Correcting Research Effects. *Jurnal Pendidikan Matematika (Judika Education)*, 5(2), 138-51.

Listyorini, R. V., et al. (2019). The Integration of Green Chemistry Principles into Small Scale Chemistry Practicum for Senior High School Students. *Jurnal Pendidikan IPA Indonesia*, 8(3), 371-78.

Matsna, F. U., Rokhimawan, M. A., & Rahmawan, S. (2023). Analysis of Students' Science Process Skills through Practicum-Based Learning on Acid-Base Titration Materials for Grade XI SMA/MA. Dalton: *Jurnal Pendidikan Kimia Dan Ilmu Kimia*, 6(1), 21.

Mendikbudristek. (2022). Decree of the Minister of Education, Culture, Research, and Technology Number 56 of 2022 regarding Guidelines for Curriculum Implementation in the Framework of Learning Recovery. Jakarta.

Montessori, V. E., Murwaningsih, T., & Susilowati. (2023). Implementation of 21st-Century Skills (6C) in Online Learning for Business Simulation Courses. *Jurnal Informasi dan Komunikasi Administrasi Perkantoran*, 7(1), 65-72. https://dx.doi.org/10.20961/jikap.v7i1.61415

Mutawally, A. F. (2021). Development of Project-Based Learning Models in History Learning. Universitas Pendidikan Indonesia. https://osf.io/xyhve/

OECD. (2023). PISA 2022 Results (Volume I): The State of Learning and Equity in Education. Paris: OECD Publishing. https://doi.org/10.1787/53f23881-en

Piaget, J. (1954). The Construction of Reality in the Child. New York: Basic Books.

Rahma, Y. T., Putri, D. H., & Syarkowi, A. (2023). Analysis of the Need for Simple Visual Aids to Train Students' Science Process Skills in Physics Learning. *Jurnal Penelitian Pembelajaran Fisika*, 14(1), 57-66.

Safrina, R., Riswandi, & Sugiman. (2018). The Effect of the Problem-Based Learning Model on Critical Thinking Skills in Grade IV. Jurnal FKIP Unila, 4(3), 2685-2692. https://www.jptam.org/index.php/jptam/article/view/760

Santiawati, S., Yasir, M., Hidayati, Y., & Hadi, W. P. (2022). Analysis of Science Process Skills of Students at State Junior High School 2 Burneh. Natural Science Education Research, 4(3), 222-30.

Suhanda, & Suryanto, S. (2018). Implementation of Project-Based Chemistry Learning to Improve Science Process Skills of Grade 10 Students at State Senior High School 2 Purworejo. Jurnal Inovasi Pendidikan Kimia, 12(2), 2137-48.

Sukmawijaya, Y., Suhendar, S., & Juhanda, A. (2019). The Influence of the STEM-PjBL Learning Model on Students' Creative Thinking Skills regarding Environmental Pollution. Jurnal Program Studi Pendidikan Biologi, 9(2), 28-43.

Sumarni, W., Wijayati, N., & Supanti, S. (2019). Students' Cognitive Ability and Creative Thinking through Project-Based Learning with a STEM Approach. J-PEK (Jurnal Pembelajaran Kimia), 4(1), 18-30.

Tsaniyyah, D., Marianti, A., & Isnaeni, W. (2019). Students' Science Process Skills in Learning Cell Materials using the Problem-Based Learning Model Assisted by Peer Tutors. Phenomenon: Jurnal Pendidikan MIPA, 9(1), 21-35.

Wismaningati, P., Nuswowati, M., Sulistyaningsih, T., & Eisdiantoro, S. (2019). Analysis of Science Process Skills in Colloid Materials through SETS-Oriented Project-Based Learning. Jurnal Inovasi Pendidikan Kimia, 13(1), 2287-2294.

Wulandari, Y., Mutmainnah, P. A., & Agustina, S. (2022). The Use of the Predict-Observe-Explain (POE) Learning Model to Analyze Science Process Skills in Grade 11 Acid-Base Materials at State Senior High School 1 Kilo. Jurnal Pendidikan Kimia dan Ilmu Kimia, 5(2), 61-73.