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Science Process Skills Profile of First Semester Students in Basic Chemistry Course

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ABSTRACT

A study was conducted to describe the profile of science process skills (SPS) of first-semester students through basic chemistry courses. This information is useful for preparing students early as a foundation that will influence their learning success in the following semester. This is because students must adapt to the campus academic environment that demands high-level skills. The research method used is a mixed method where qualitative data describes the profile of students' SPS and quantitative data is used to process the value data obtained by students through the SPS pretest and posttest. The tools and instruments used to collect data have been validated by experts and received good to very good ratings so they are suitable for use in data collection. The results obtained that student development in SPS based on the N-Gain score at the low, medium and high levels were 5.97%, 70.15% and 23.88%, respectively. The SPS indicators that obtained the lowest to highest scores based on the posttest results, respectively, were creating operational definitions, analyzing, predicting, formulating hypotheses, formulating problem formulations, observing, formulating variables, designing experiments and creating data tables. The results of this study are expected to be the basis for development to prepare students to become competent scientists or practitioners in the future.

INTRODUCTION

Based on PP 57 of 2021 concerning National Education Standards Article 6 paragraph 4, Permendikbud no. 3 of 2020 concerning National Standards for Higher Education and Permendikbud 53 of 2023 concerning Quality Assurance of Higher Education Article 9 that undergraduate programs at least master the theoretical concepts of certain fields of knowledge and skills in general and specifically to solve problems procedurally according to the scope of their work. The skills that students must master are known as hands-on (hand skills or physical skills) and minds-on (thinking skills). The thinking skills expected are high-order thinking skills. Higher-order thinking skills (HOTS) function as a driver for conveying innovation in all fields, building knowledge and information to improve achievement (Zebua, 2024).

One type of higher-order thinking skill is science process skills. Science process skills (SPS) are related to cognitive development. Developing SPS can support students' thinking, reasoning, investigation, evaluation, and problem-solving skills, as well as creativity (Ozgelen, 2012). Science process skills and reasoning have a positive effect resulting in increased problem-solving abilities (Markawi, 2013). So problem-solving abilities can be improved by training and developing SPS. Science process skills have a strong relationship with critical thinking skills (Nugraha, et.al. 2017). Improving argumentation skills is in line with improving science process skills (Ping, et.al. 2020). In previous research, it was found that students' SPS in the fourth semester was still in the poor to good category (Rusmini, et.al., 2021) even in semester 7 students only obtained a fairly good average score of 69.27 (Rusmini, 2024). The assessment carried out in semester 4, especially in semester 7, was too far behind so it was necessary to detect it early when becoming a student. Introducing SPS from the beginning is a good provision for students and can be practiced sequentially in semesters and next course.

Research on the science process skills of first-semester students is important because the early stages of lectures lay the foundation that will influence learning success in subsequent semesters. During this time, students begin to adapt to the academic environment of higher education, which demands independence, critical thinking, and advanced scientific skills. By conducting research, lecturers or researchers can determine the extent of students' initial abilities in observing, classifying, measuring, interpreting data, and formulating hypotheses (Darmaji, et.al., 2019; Gizaw & Sota, 2023; Darmaji, et.al. 2020). The results of this study can provide a clear picture of students' starting point in mastering science process skills. This data can then serve as a basis for designing appropriate learning strategies, so that students can develop optimally in practical and research activities.

Research to determine the profile of first-semester students' science process skills is also useful for evaluating the effectiveness of existing curricula in higher education. If weaknesses are found in certain skills, such as the ability to analyze data or communicate results, the study program can immediately improve learning methods. This is in line with the demands of 21st-century education, which emphasizes the importance of scientific literacy, critical thinking, and problem-solving (Ozgelen, 2012; Markawi, 2013; Nugraha, et.al., 2017). Science Process Skills (SPS) are the foundation of science learning, which will form the basis and encourage the process of inquiry and scientific investigation (Panjaitan & Siagian, 2020; Ekici & Erdem, 2020). Commonly identified and described SPS are observation, measurement, classification, communication, prediction, inference, use of numbers, use of space/time relationships, asking questions, identifying and controlling variables, hypothesizing, defining operationally, designing experiments, interpreting data, and modeling (Gizaw & Sota, 2023).

By knowing the ability of scientific process skills from an early age, institutions can ensure that students not only master theory, but are also able to apply it scientifically in real life. SPS is the key to students developing their science abilities. Thus, these research has a strategic role in improving the quality of science education in higher education and preparing students to become competent scientists or practitioners in the future.

RESEARCH METHOD

The research method used is a mixed method (Creswell & Creswell, 2017). Qualitative methods were used to describe the profile of students' KPS and quantitative methods were used to process the data obtained by students through the SPS pretest and posttest. The tools and instruments used to collect data have been validated by experts and received good to very good ratings so they are suitable for use for data collection. The research sample selection used a purposive sampling method, meaning the sample was selected from within the population according to the researcher's wishes. The number of samples in this study was 67 first-semester students consisting of students from Chemistry Education and Biology Education. The development of SPS abilities used the N-gain score (Hake, 1998). The profile of students' SPS abilities was also analyzed from each SPS indicator. The material used to study this SPS is stoichiometry. Before the measurement, students were given a SPS-based student worksheet used to practice SPS. The worksheet used for practice has been validated by experts and declared suitable for use as a means of practicing SPS.

RESULTS AND DISCUSSION

In this section, the results and discussions obtained during the research will be explained.

Determining the SPS Indicator

The material used to measure the SPS is the introduction and stoichiometry. A general explanation of the SPS is provided in the introduction. The questions then use stoichiometry material. Stoichiometry is conceptual and quantitative in nature. It discusses quantitative relationships in chemical reactions based on the law of conservation of mass and the law of definite proportions. This material also requires students to understand the basic concepts of moles, molar mass, molar volume of gases, the ratio of reaction coefficients in reaction equations, and limiting reagents. Stoichiometry forms the basis for many other chemistry topics such as solutions, thermochemistry, acids and bases, electrochemistry, and organic chemistry. Therefore, stoichiometry is considered an important prerequisite for further understanding. The quantitative nature of stoichiometry problems, such as calculating the mass, number of moles, volume of gas, or concentration of substances in a reaction, requires logic, numeracy skills, and precision in using units. These things are very necessary in training sequential thinking, problem solving and training analytical thinking skills (Brown, et.al., 2018; Petrucci, et.al., 2017; Gabel, 1999).

The SPS measured uses several SPS indicators ranging from basic SPS to integrated SPS. SPS indicators include observing, using units, formulating problems, formulating hypotheses, formulating variables, creating operational definitions, designing experiments, creating data tables, analyzing, and predicting. Before the SPS assessment, students were given an explanation and practice questions first. SPS practice was provided using worksheet media. The worksheet used for practice has been validated by experts and declared suitable for use as a means of practicing SPS. In this worksheet, each SPS indicator is described in the form of questions based on the given phenomenon. Table 1 presents the implementation of each indicator written in the worksheet.

Table 1. Table 1 SPS question indicators in the worksheet

No	SPS indicator	SPS question indicators in the worksheet
1	Observing	Given a phenomenon, students could read the phenomenon to formulate subsequent questions.
2	Determining units	Given a phenomenon, students could write down the units involved in the phenomenon.

No	SPS indicator	SPS question indicators in the worksheet
3	Formulate the problem	Students could write a problem formulation based on the given phenomenon.
4	Formulating a hypothesis	Based on the problem formulation, students can formulate a hypothesis.
5	Formulating variables	Based on the phenomenon, students could formulate experimental variables, namely independent variables, response variables, and control variables.
6	Creating operational definitions	Based on the variables that have been compiled, students could create operational definitions for each element involved in the experimental variables.
7	Designing experiments	Based on the problem formulation and hypothesis, students could design experimental activities.
8	Creating a data table	Based on the video presented, students can create an observation data table.
9	Analyzing	Based on the data in the observation data table, students can analyze the results of the experiment.
10	Predicting	Based on changes in the conditioning of a reaction, students can predict the outcome of the reaction.

In the student worksheet, students were provided with example questions and practice questions for all of these indicators. Providing examples could reduce cognitive load by requiring students to simply observe patterns and help beginners grasp procedures quickly. Practice questions can provide students with opportunities to actively practice applying knowledge and strengthen long-term memory through retrieval practice (Van & Rummel, 2020; Roelle & Berthold, 2022; Ngu et al., 2025).

Student SPS Profile

The student SPS profile was measured using a SPS post-test. This question contained several predetermined SPS indicators. The data in Figure 1 shows that the highest average score was for creating a data table, while the lowest average score was for creating operational definitions.

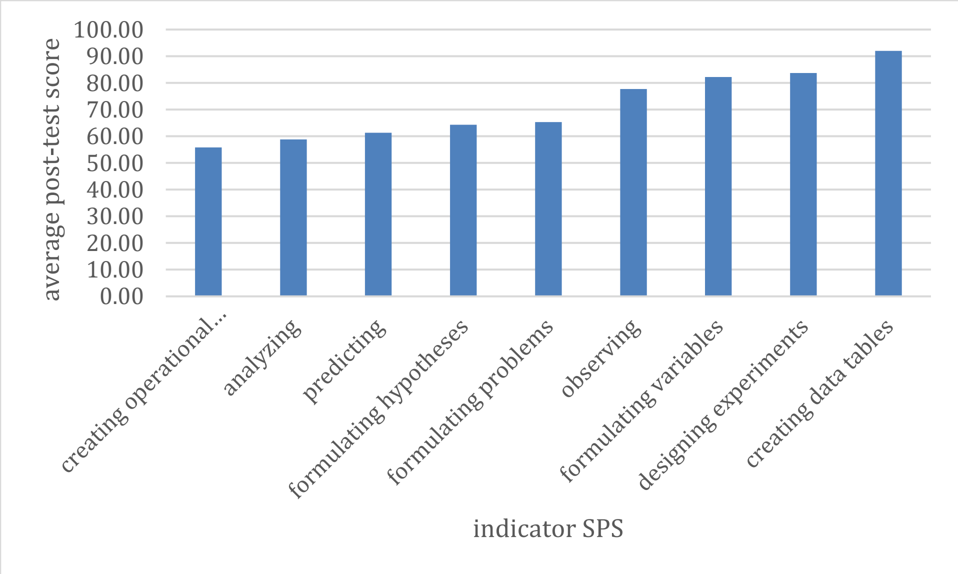

Figure 1. SPS indicator profile based on average SPS post-test scores

Table 2 shows three errors in students' answers to questions on each SPS indicator. In general, it can be said that the error is due to students' lack of understanding of the concepts or aspects of knowledge used to test the SPS. The SPS measurement uses stoichiometry material, the limiting reagent sub-material. In limiting reagents, students must master the chemical reaction equation, the calculation of the reacting moles, the meaning of the limiting reagent, and the application of the limiting reagent. Students must also be able to predict when one reagent is added without limit while the other reagent is limited in amount.

Table 2 The results of identifies student errors in answering the SPS post-test.

No	Indicator SPS	Identify 3 student errors
1	Formulating the problem	1. The problem statement is not in the form of a question. 2. The problem statement focuses on the concept of stoichiometry rather than determining the mass of NaOH in the saponification process. 3. The problem statement focuses on the concentration of NaOH rather than determining the mass of NaOH in the saponification process.
2	Formulating a Hypothesis	1. The hypothesis does not align with the problem statement. 2. The answer to the hypothesis does not lead to the amount of NaOH in the stoichiometric ratio. 3. The answer does not relate the ratio of the amount of triglycerides to the amount of soap produced.
3	Operational Definition	1. The operational definition does not align with the phenomenon.

No	Indicator SPS	Identify 3 student errors
		2. The operational definition provided focuses more on the mass of NaOH, the residual NaOH content, and the coconut oil. 3. The efficiency of the results expressed as a percentage is not explained.
4	Designing an experiment	1. The tools and materials are not suitable for the experiment. 2. The experimental flow is not coherent and complete. 3. The experimental flow does not answer the phenomenon and problem formulation.
5	Analyze	1. The answer does not explain how the actual mass of soap increases closer to the theoretical mass when the amount of NaOH is increased. 2. It does not discuss the remaining NaOH detected after the stoichiometric point is reached. 3. It does not explain each of the experimental results.
6	Predicting	1. Many answered that there was no NaOH residue, whereas there should be. 2. The answer did not align with the reaction yield, increasing from 96.9% to 99.7%. 3. The alkali-free potential and alkali residue were not discussed.
7	Predicting	1. Not specific in explaining the mass of coconut oil. 2. Not explaining the small mass of oil and excess NaOH, resulting in the soap being too basic. 3. Not explaining the large mass of oil and the complete reaction of NaOH, resulting in a safe soap.

If students master the concept of limiting reagents well, they will be able to predict the amount of product formed even though the added reagent does not increase the resulting product. Science process skills will improve the quality of science learning, thereby improving academic abilities and developing students' thinking skills and potential (Winarti, Yuanita & Nur, 2019; Koomson, et al, 2024). There is a moderate and weak positive correlation detected between scientific process skills, science academic achievement, and self-regulation skills (Barut & Yüce (2025). This was also conveyed by Husna (2027) that there is a positive and significant relationship between the level of knowledge and science process skills in learning. These results indicate the need to include learning objectives that require higher levels of cognitive skills that lead to deeper learning and the transfer of knowledge and skills into a wider variety of tasks and contexts.

Student SPS Development Profile

Students' development in understanding SPS was measured using a SPS pretest and posttest. The pretest was administered before students were given the worksheet and discussion of the SPS. The posttest was administered after students completed the practice questions and discussion of the SPS-based worksheet. The results of these tests were analyzed using the N-gain score. N-gain scores are categorized as low, medium, and high (Hake, 1998). The N-gain score results are presented in Figure 2. Figure 2 shows that the majority of students had a medium n-gain. A low n-gain after training does not necessarily mean a low final score, but rather a modest increase. Similarly, a high n-gain does not necessarily mean a high final score. A high n-gain indicates a change from low to high scores of above 71%.

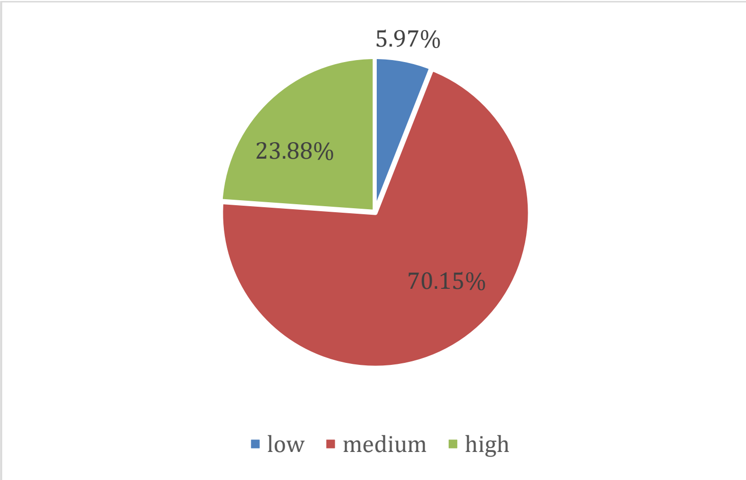

Figure 2. N-gain percentage in SPS

The increase in pretest posttest scores for each indicator is presented in Figure 3. Based on Figure 3, it can be seen that each indicator has increased. Based on the graph in Figure 3, These score increases indicate the development of students' abilities in each indicator. it can be seen that the indicator for creating data tables was the one with the highest score increase. Meanwhile, creating operational definitions experienced the lowest increase. This indicates that students still need SPS training to develop their SPS skills. Practicing students' thinking skills can be done by involving students in learning activities such as analyzing problems, finding relationships between concepts, and making judgments to generate answers or new ideas (Wu, Yen & Lee, 2024).

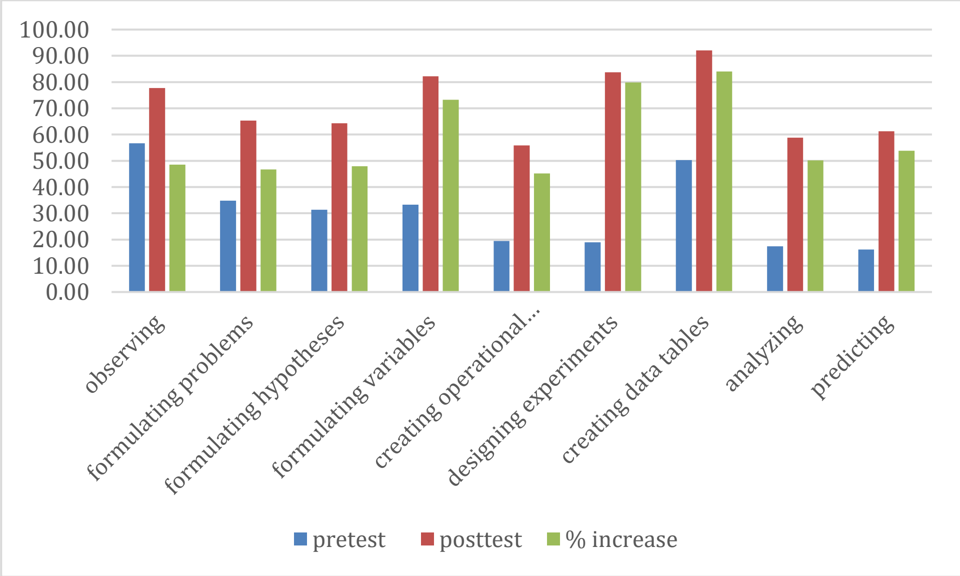

Figure 3. Improvement in pretest/posttest scores for each SPS indicator

SPS includes students' mental and physical activities in collecting and organizing information, then using that information to make predictions, explain phenomena, solve problems, understand scientific activities, and learn science. Students are required to develop and use these skills in the teaching and learning process (Gizaw & Sota, 2023). These skills are important for students as tools for exploring and investigating the natural world, improving academic achievement and attitudes toward science, learning science with understanding, and encouraging the development of mental and intellectual processes.

CONCLUSION

The SPS profile of first-semester students falls into the moderate category. The SPS indicators with the lowest to highest scores based on the post-test results, respectively, are creating operational definitions, analyzing, predicting, formulating hypotheses, formulating problems, observing, formulating variables, designing experiments, and creating data tables. Each SPS indicator increased after the worksheet was given. Student progress in SPS based on the N-Gain score at the low, medium, and high levels was 5.97%, 70.15%, and 23.88%, respectively. The highest progress was in creating data tables and the lowest in creating operational definitions. The results of this study are expected to provide input for lecturers to train SPS in all courses, considering that SPS is an important skill for students to master as a basis for developing their science and knowledge.

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