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Analysis of Students' Scientific Process Skills Using the Discovery Learning Model on the Colligative Properties of Solutions

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Abstract

Scientific process skills (SPS) are essential competencies that enable students to investigate phenomena, solve problems, and construct scientific understanding. Despite their importance, the development of SPS in chemistry learning remains challenging, particularly in topics that require conceptual understanding and practical investigation, such as colligative properties of solutions. This descriptive quantitative study assessed students' scientific process skills during Discovery Learning-based instruction on colligative properties of solutions. The participants were 34 twelfth-grade students from SMA Negeri 14 Bekasi selected through purposive sampling. Data were collected using observation sheets completed by six observers and a 21-item student questionnaire. The data were analyzed using descriptive statistics to determine the level of SPS achievement across eleven skill indicators. The findings revealed that the average SPS score was 74.16% based on observations and 76.54% based on questionnaires, both categorized as good. Students demonstrated the strongest performance in using laboratory tools and materials, while predicting and hypothesis formulation showed comparatively lower achievement. These results suggest that Discovery Learning effectively supports the development of practical and inquiry-based scientific skills by actively engaging students in experimentation and concept discovery. However, higher-order SPS components, particularly prediction and hypothesis formulation, require additional instructional support. This study contributes empirical evidence on students' SPS profiles in chemistry learning and highlights specific skill areas that should be strengthened to optimize Discovery Learning implementation in secondary education.

Keywords: scientific process skills; discovery learning model; colligative properties of solutions

Introduction

Chemistry is a branch of science that examines the composition, properties, structure, and transformation of matter (Priliyanti et al., 2021). Effective chemistry learning involves not only the acquisition of scientific knowledge but also the development of scientific attitudes and scientific processes (Amaliyah et al., 2024). Consequently, chemistry education should emphasize how scientific knowledge is generated through inquiry and investigation rather than focusing solely on conceptual outcomes. This perspective highlights the importance of scientific process skills (SPS), which enable students to engage in scientific reasoning and construct knowledge through direct experience.

Scientific process skills encompass a set of cognitive, practical, and social competencies used to acquire, develop, and apply scientific concepts, principles, and theories (Nur et al., 2026). These skills include observing, questioning, formulating hypotheses, predicting, designing and conducting experiments, interpreting data, applying concepts, and communicating findings. SPS are fundamental to scientific literacy because they allow students to think critically, solve problems systematically, and understand the nature of scientific inquiry (Vázquez-Villegas et al., 2023). Previous studies have consistently emphasized that students who actively engage in scientific processes demonstrate better conceptual understanding and stronger problem-solving abilities than those who learn through passive knowledge transmission.

Despite their recognized importance, the development of SPS among Indonesian students remains a challenge. Several studies have reported that students often exhibit low proficiency in key scientific skills, particularly those requiring higher-order thinking, such as hypothesis formulation, prediction, and data interpretation (Teig, 2024). This condition has been linked to learning environments that remain predominantly teacher-centered, limiting opportunities for students to actively investigate scientific phenomena and construct their own understanding (Julius & Audrey, 2025). Furthermore, although laboratory facilities are available in many schools, their utilization is often insufficient to support meaningful scientific inquiry and practical skill development. Collectively, these findings suggest that instructional approaches that promote active learning and inquiry are needed to strengthen students' SPS.

Among the various student-centered approaches, Discovery Learning has been widely recognized as a promising model for fostering scientific inquiry. The model encourages students to explore problems, gather evidence, conduct investigations, and derive conclusions independently (Nurain et al., 2023). Previous studies have shown that Discovery Learning can improve students' conceptual understanding, learning outcomes, critical thinking, and scientific process skills by increasing their engagement in learning activities (Niman et al., 2024, Muthalib et al., 2024). Through exploration and experimentation, students become active participants in the learning process rather than passive recipients of information. These characteristics make Discovery Learning particularly relevant to chemistry education, where conceptual understanding is often strengthened through observation, experimentation, and data analysis.

Although the positive effects of Discovery Learning on SPS have been reported in various science subjects, empirical evidence regarding students' SPS profiles during Discovery Learning-based chemistry instruction remains limited, particularly in the context of colligative properties of solutions. This topic presents unique learning challenges because it requires students to integrate abstract concepts, quantitative reasoning, and laboratory observations. Students must understand relationships among concentration, particle number, and measurable physical properties while simultaneously applying scientific reasoning during practical activities. Therefore, investigating SPS within this context can provide valuable insights into how students engage in scientific inquiry when learning complex chemistry concepts.

Based on these considerations, there remains a need to examine the extent to which students demonstrate scientific process skills during Discovery Learning-based instruction on colligative properties of solutions. Understanding students' strengths and weaknesses across different SPS indicators can help educators design more effective learning experiences and provide targeted support for skill development. Therefore, this study aims to assess the scientific process skills of Grade XII students at SMA Negeri 14 Bekasi during the implementation of Discovery Learning on the topic of colligative properties of solutions.

Method

Research Design

This study employed a descriptive quantitative approach to assess students' scientific process skills (SPS) during Discovery Learning-based instruction on the topic of colligative properties of solutions. The study used a one-shot case study design, in which data were collected after the implementation of the learning activities. Because the primary objective was to describe and evaluate students' SPS profiles rather than to determine the effectiveness of Discovery Learning compared with another instructional approach, no control or comparison group was included. This design was considered appropriate for obtaining an in-depth description of students' performance across various SPS indicators within an authentic classroom setting.

The participants were 34 students from class XII-6 at SMA Negeri 14 Bekasi during the 2024/2025 academic year. The sample was selected using purposive sampling, which is categorized as a non-probability sampling technique (Tajik et al., 2024). The class was chosen based on several considerations, including students' learning readiness, consistent attendance records, active classroom participation, and recommendations from the chemistry teacher. While purposive sampling enabled the selection of participants who could fully engage in the learning activities and practical sessions, it may introduce selection bias and limit the generalizability of the findings to other student populations. Therefore, the results should be interpreted as representative of the participants studied rather than all secondary school students.

Research Procedure and Data Analysis

Data were collected through classroom observations and student questionnaires. The observation instrument consisted of 15 items assessing students' scientific process skills during learning and laboratory activities, while the questionnaire contained 21 statements designed to capture students' perceptions of their own SPS. Observations were conducted by six trained observers, with each observer assigned to one student group during the implementation of Discovery Learning activities. The learning process included pre-laboratory, laboratory, and post-laboratory sessions. Following the completion of the instructional activities, students completed the questionnaire.

Both instruments employed a four-point Likert scale ranging from 1 to 4. The collected data were analyzed using descriptive statistics to determine the percentage achievement and category of each SPS indicator. The percentage score was calculated using Equation (1) (Firdaus & Yukamana, 2024):

$$NP = \frac{R}{SM} x100\% \quad (1)$$

Where:
NP = the percentage value sought

R = the raw score obtained by the student
SM = the ideal maximum score from the test in question

Then the scores obtained are categorized into five groups, namely excellent, good, sufficient, less and significantly less to facilitate reading and concluding. The score intervals (Table 1) were used to categorize the overall percentage and percentage of each aspect of students' science process skills based on the research data that had been processed and analyzed.

Table 1. Score Interval

Score Interval	Category
81-100%	Very good
61-80%	Good
41-60%	Sufficient
21-40%	Less
0-20%	Very less

Results and Discussion

This study aimed to assess students' scientific process skills (SPS) during Discovery Learning-based instruction on the topic of colligative properties of solutions. The findings indicate that students demonstrated an overall good level of SPS, with average scores of 74.16% based on observations and 76.54% based on questionnaires (Table 2). These results suggest that Discovery Learning provides a learning environment that enables students to actively engage in scientific inquiry through observation, experimentation, data analysis, and communication of findings.

Table 2. Presentation of Students' Scientific Process Skills Aspects Based on Observation Sheets

No.	Science Process Skills Aspect Category	Percentage (%)	Category
1	Observing	78.43	Good
2	Asking Questions	65.44	Good
3	Formulating Hypotheses	60.29	Sufficient
4	Predicting	55.14	Sufficient
5	Planning Experiments	79.41	Good
6	Conducting Experiments	88.23	Very good
7	Using Tools and Materials	91.91	Very good
8	Grouping	70.58	Good
9	Communicating	67.64	Good
10	Applying Concepts	71.69	Good
11	Summarizing	75.73	Good
	Average	74.16	Good

The results support the theoretical foundation of discovery learning, which emphasizes active knowledge construction through exploration and direct experience. According to constructivist learning theory, students develop deeper understanding when they actively investigate phenomena rather than passively receive information. In the present study, students participated in pre-laboratory, laboratory, and post-laboratory activities that required them to observe, collect evidence, discuss findings, and formulate conclusions. Such learning

experiences are consistent with the principles of Discovery Learning and likely contributed to the generally positive SPS outcomes.

Among the eleven SPS indicators assessed (Table 3), the highest achievement was observed in the use of laboratory tools and materials (91.91% from observations; 83.82% from questionnaires). This finding suggests that Discovery Learning is particularly effective in supporting procedural and practical scientific skills. Students were required to independently identify, assemble, and operate laboratory equipment during investigations of colligative properties, which provided repeated opportunities to practice these competencies. Similar findings have been reported by Nurain et al. (2023) and Muthalib et al. (2024), who found that Discovery Learning promotes active engagement in experimental activities and strengthens students' practical scientific abilities.

Likewise, students demonstrated strong performance in conducting experiments, planning investigations, observing phenomena, applying concepts, and drawing conclusions. These findings indicate that Discovery Learning successfully facilitates inquiry-based learning processes by encouraging students to collect and analyze evidence before constructing scientific explanations. The results are consistent with previous studies showing that Discovery Learning enhances students' participation and promotes the development of scientific reasoning through direct interaction with scientific phenomena (Manurung & Pappachan, 2025).

Table 3. Presentation of Students' Science Process Skills Aspects Based on Observation Sheets

No.	Scientific Process Skills Aspect	Percentage (%)	Category
1	Observing	79.41	Good
2	Asking Questions	75	Good
3	Formulating Hypotheses	76.47	Good
4	Predicting	75.24	Good
5	Planning Experiments	76.10	Good
6	Conducting Experiments	80.88	Very good
7	Using Tools and Materials	83.82	Very good
8	Grouping	76.47	Good
9	Communicating	78.30	Good
10	Applying Concepts	73.16	Good
11	Concluding	72.05	Good
	Average	76.54	Good

However, not all SPS indicators achieved equally high scores. The skills of predicting (55.14%) and formulating hypotheses (60.29%) were among the lowest-performing aspects. These findings suggest that while Discovery Learning effectively supports practical and observational skills, students may still experience difficulties with higher-order cognitive processes that require abstract reasoning and scientific inference. Prediction and hypothesis formulation require students to connect prior knowledge with unfamiliar situations and generate evidence-based expectations, competencies that often develop gradually through repeated inquiry experiences. Similar challenges have been reported in previous SPS studies, which found that students generally perform better on procedural skills than on reasoning-based scientific skills (Inayah et al., 2020).

The discrepancy between observation and questionnaire results also provides useful insight. Questionnaire scores were generally higher than observation scores, indicating that students tended to perceive their SPS more positively than was observed during classroom

activities. This difference may reflect students' increased confidence after completing the learning activities or their subjective evaluation of their own abilities. Therefore, combining observational and self-reported data provides a more comprehensive understanding of students' SPS development than relying on a single assessment method.

A notable contribution of this study is its focus on SPS within the context of learning colligative properties of solutions, a chemistry topic that integrates conceptual understanding, quantitative reasoning, and laboratory investigation. While previous studies have demonstrated the benefits of Discovery Learning in science education generally, fewer studies have specifically examined how SPS are manifested across multiple skill indicators in chemistry learning involving complex and abstract concepts. The findings suggest that Discovery Learning is particularly effective in fostering hands-on scientific inquiry but may require additional scaffolding strategies to strengthen students' abilities in prediction and hypothesis development. Therefore, teachers implementing Discovery Learning should provide explicit guidance and repeated opportunities for students to practice higher-order scientific reasoning alongside laboratory activities (Morris, 2025).

Observation

Three aspects of observation skills were measured: observing images and texts provided in the worksheet, formulating problems based on the texts provided, and conducting observations during lab experiments. Based on the analysis of observation sheet data, the average percentage of observation skills among grades XII-6 students was 78.43%, which is considered good. Students achieved 78.67% in the first criterion, 71.32% in the second, and 85.29% in the third. It was further supported by the questionnaire results, which showed that students' observation skills were in the good category, with an overall percentage of 79.41%.

Students were able to identify and formulate problems based on the texts provided in the worksheet. Students in grades XII-6 were also able to measure temperature using a thermometer, observe vapor points on beaker lids, and weigh samples during lab experiments on colligative properties of solutions. On average, students in the class were able to systematically collect data, record observations in tables, and perform necessary calculations. Discovery learning requires students to be actively involved in classroom learning, starting from gathering information, formulating problems, to conducting investigations. In learning with the discovery model, the teacher's role is only as a facilitator so that the focus of learning is more inclined towards students.

Asking a Question

Based on the results of the observation sheet data analysis, the average questioning skill score of grade XII-6 students obtained was 2.61 with a percentage of 65.44% which is included in the good category and strengthened by the results of the questionnaire which showed that students' observation skills were included in the good category with an overall percentage of 75%. It shows that students are quite active in asking questions related to things they do not understand. The application of the discovery learning model can improve students' thinking skills through discussion activities with teachers and group members (Mustikaningrum & Mediatati, 2021). Students are also given the freedom to ask questions about anything they do not understand, also assisted by the stimulus given before the learning begins.

Formulating Hypotheses

A hypothesis can be defined as a tentative assumption proposed to answer the research problem. In formulating hypotheses, students must use accurate sources. Based on the analysis of observation sheets, the hypothesis-formulating skills of grades XII-6 students fell into the sufficient category with a percentage of 60.29%. Meanwhile, the questionnaire results showed

a percentage of 76.74%. Formulating hypotheses is a challenging process because it requires a basic understanding of the topic being researched. This results in students' hypothetical skills remaining in the sufficient category. The percentages in this study were strengthened by pre-learning literacy activities, where students read related material. This helped students develop a basic understanding of the colligative properties of solutions. Before formulating hypotheses, students were given the freedom to seek information from various sources. This activity can help students formulate hypotheses that align with the discourse provided in the student worksheet.

Predicting

This section covers the skill of estimating something that has not yet occurred based on pre-existing patterns or events. Analysis of observation sheets indicates that the prediction ability of grades XII-6 students is in the sufficient category, with a percentage of 55%. Meanwhile, questionnaire results indicate that the percentage of students' prediction skills is 75.24%. This result is obtained because students are not trained or accustomed to predicting something, either in practical activities or previous classroom learning (Inayah et al., 2020). Prediction skills involve connecting facts, concepts, or principles of knowledge to anticipate or predict things that will happen in the future (Anyiendah et al., 2020).

Planning an Experiment

This skill is measured through two sub-aspects: determining the tools and materials used and developing detailed and systematic work steps. The first sub-aspect, planning an experiment, was categorized as good, with a score of 78.67%. This indicates that students were able to determine the tools and materials for the experiment effectively. The second sub-aspect received a score of 80%, falling into the outstanding category, thus concluding that students successfully developed the work steps. In the discovery learning model, students are allowed to design their own experiments by seeking relevant information and engaging in discussions. This allows students to hone their experimental planning skills, as they can freely seek resources and exchange ideas with others, thereby enhancing their engagement in the learning process.

Conducting Experiments

The experiments conducted involved a practical work on the colligative properties of solutions, including boiling point elevation, vapor pressure depression, osmotic pressure, and freezing point depression. The skill of conducting the experiments achieved a score of 88.23%. The questionnaire results also indicated that this skill was in the very good category, with a score of 80.88%. The systematic nature of the experiments resulted in a good score. This was because the students had planned the experiments and developed the work steps before the experiments began. Through these experiments, students gained lasting, hands-on experience, fostering enthusiasm and enriching their scientific knowledge. Practical activities can foster students' scientific development and help them recognize their potential.

Using Tools and Materials

The observation sheet assessment instrument noted that students were generally quite skilled at assembling tools, using tools and materials according to procedures, and understanding the function of each experimental component. This was evident during laboratory experiments, where students were more independent and precise in following the procedures outlined in the work steps they had prepared. They were also able to describe the tool functions well and in a variety of ways. Based on the analysis of the observation sheet instrument, the percentage of students in grades XII-6 who were skilled at using tools and

materials was 91.9%, which is in the good category. The questionnaire results also showed a very good category with a percentage of 83.82%. This result was achieved because the students understood the function of each tool they would use (Contrino et al., 2024). This was driven by the students' high enthusiasm for learning, which led them to study in advance what they would do in the practicum (Tong et al., 2022).

Grouping

The classifying/grouping aspect is defined as the process skill of forming groups/categories of similar observation results by selecting and placing them based on their specific characteristics (Inayah et al., 2020) . Classification is used to identify similarities, differences, and patterns or relationships in data or results. Based on the results of the observation sheet analysis, the percentage of students in grades XII-6 who had grouping skills was 70.58%, which is considered good. The questionnaire results also showed that this skill was considered good, with a percentage of 76.47%. During the practicum, students were able to record all observations correctly in a table, making it easier for them to present their results through written reports and cross-group discussions. However, some students experienced difficulty grouping samples, some of which were due to inaccurate measurements of the solution temperature using a thermometer, resulting in temperatures that did not match the theory. Their alternatives were to repeat the practicum or seek references from other sources that could explain why this occurred.

Communicating

Communication skills refer to students' abilities to organize data and lab reports systematically and objectively, and to present discussion results effectively (Khairunnissa et al., 2024). Communication can take the form of writing, speaking, drawing, or graphics (Pratiwi et al., 2020). These communication skills were measured and observed after the lab was completed. Based on the analysis, the percentage of students in grades XII-6 who demonstrated good communication skills was 67.64%, which is considered good. The questionnaire results also showed that these skills were in the good category, with a percentage of 78.30%.

Applying Concepts

Applying concepts is a skill students possess in applying previously learned knowledge and the ability to explain new events using existing concepts. In accordance with cognitive development, humans must be able to adapt their knowledge to various situations, including those that are new to them. Cognitive skills are defined as students' ability to think more complexly, as well as their ability to reason and solve problems (Nopriana et al., 2021). Based on the analysis, the percentage of students in grades XII-6 who demonstrated the ability to apply concepts was 71.69%, which is considered good. This is supported by the questionnaire results, which obtained a percentage of 73.16%, also considered good.

Summarizing

This skill encompasses students' ability to summarize the results of experiments conducted and combine observations and information obtained (Tong et al., 2022). Based on the analysis, the average summarizing skill score for students in grades XII-6 was 3.02, with a percentage of 75.73%, which is considered good. Their conclusions align with the concept of colligative properties of solutions, which states that "Colligative properties of solutions depend only on the number of solute particles, not their type. The greater the concentration of solute in a solution, the greater the change in colligative properties." This conclusion indicates that students can understand the concept of colligative properties of solutions well. This is

supported by the results of a student questionnaire, which obtained a percentage of 72.05%, also considered good. This indicates that students themselves feel capable of interpreting the concept of colligative properties of solutions based on the practicums they have conducted and are assisted by extensive information searches using the internet and books provided by the school. Discovery learning encourages students to actively engage in deepening their insights to understand better and remember the lesson material they have learned (Firdaus & Yukamana, 2024). Learning activities that involve students directly can help students understand concepts better (Mcdonald et al., 2024).

Conclusion

This study demonstrates that students' scientific process skills (SPS) during Discovery Learning-based instruction on colligative properties of solutions were generally at a good level, with average scores of 74.16% from observations and 76.54% from questionnaires. The highest achievement was found in the use of laboratory tools and materials (91.91% and 83.82%, respectively), indicating that Discovery Learning effectively supports the development of practical and procedural scientific skills through active experimentation and hands-on investigation. In contrast, predicting (55.14%) and hypothesis formulation (60.29%) showed the lowest performance, suggesting that higher-order scientific reasoning skills remain challenging for students. These findings address the research objective by showing that Discovery Learning can facilitate the development of students' SPS, particularly skills directly associated with inquiry-based laboratory activities. The stronger performance in practical skills may be attributed to the model's emphasis on exploration, observation, and experimentation, which aligns with constructivist learning theory that views knowledge as actively constructed through direct experience. However, the relatively lower achievement in prediction and hypothesis formulation indicates that students require additional scaffolding and opportunities to engage in abstract reasoning and evidence-based thinking.

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