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

Fawziyah Sholihah Bayliz[1,*], Rizqy Nur Sholihat[2], Meyliana Wulandari[3]

[1,2] Department of Chemistry Education, Faculty of Educational Sciences, Universitas Islam Negeri (UIN) Syarif Hidayatullah Jakarta, Jl. Ir. H. Djuanda No. 95, Ciputat, Kota Tangerang Selatan, Banten
[3]Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta, Jl. R. Mangun Muka Raya No.11, East Jakarta City, Jakarta 13220, Indonesia

Email: fzyhsbylz@gmail.com*

Abstract

Scientific process skills (SPS) are essential competencies that enable individuals to solve real-world problems through systematic inquiry. This study aims to analyze the profile of students' scientific process skills during the implementation of the discovery learning model on the topic of colligative properties of solutions. The research involved 34 students from class XII-6 at SMA Negeri 14 Bekasi, selected using purposive sampling. A descriptive quantitative design with a one-shot case study approach was employed. Data were collected through observation sheets (15 items, rated by six observers) and questionnaires (21 statements), both using a Likert scale (1–4). Validity and reliability of instruments were verified prior to data collection. Data were analyzed using descriptive statistics to determine percentage scores and categories. The observation results yielded an average score of 74.16% (Good category), while the questionnaire results yielded 76.54% (Good category). The highest-scoring aspect in both instruments was Using Tools and Materials (91.91% and 83.82%, respectively), while Predicting obtained the lowest score from observations (55.14%, Sufficient). These findings suggest that the discovery learning model effectively supports the development of students' scientific process skills, particularly in practical laboratory contexts, though further attention is needed for higher-order predictive and hypothesizing skills. These results have implications for the design of inquiry-based chemistry instruction, particularly in the selection of learning models and the structuring of laboratory activities that systematically target all dimensions of scientific process skills at the senior high school level.

Keywords: scientific process skills; discovery learning model; colligative properties of solutions; descriptive quantitative; senior high school

Introduction

Chemistry is a natural science that studies the structure, properties, and transformations of matter (Priliyanti et al., 2021). In chemistry education, three interrelated components are expected to be achieved: scientific process, scientific attitude, and scientific products

(Amaliyah et al., 2024). Therefore, chemistry learning should not be limited to conceptual knowledge (product), but must also emphasize the process by which scientific knowledge is constructed. The skills required for this purpose are referred to as scientific process skills (Ramlawati & Rampean, 2024).

Scientific process skills (SPS) are defined as the skills needed to acquire, develop, and apply scientific concepts, laws, and theories through physical, mental, and social activities (Rustaman, 2005). These skills encompass four main dimensions: (1) process or method, which emphasizes scientific inquiry including observation, hypothesis formulation, experimentation, measurement, analysis, and communication; (2) content or product, which reflects the substantive knowledge students must acquire; (3) technology, which highlights the interconnection between scientific discoveries and their applications in daily life; and (4) scientific attitude, including curiosity, intellectual honesty, critical thinking, creativity, open-mindedness, and environmental sensitivity (Vázquez-Villegas et al., 2023; Spires et al., 2022; Zamiri & Esmaeili, 2024; Fatonah et al., 2023).

However, studies have indicated that students' scientific process skills in various regions in Indonesia remain relatively low (Dani et al., 2022). This condition is attributed to the prevalence of teacher-centered instruction, which limits students' active participation in the learning process (Eman Nataliano Busa, 2023), reduces motivation, and creates academic disengagement (Risanatul & Junaidi, 2022). Furthermore, although laboratory facilities are available in many schools, their utilization is often suboptimal, thereby restricting opportunities for students to develop practical scientific skills (Maulana & Mutmainah, 2025).

To address these challenges, student-centered learning models that actively engage learners in inquiry-based activities are required (Jannah & Shofiyah, 2023). One such model is discovery learning, which invites students to construct scientific understanding through guided exploration and experimentation (Nurain et al., 2023). Through discovery learning, students engage in direct observational activities such as laboratory work, fostering deep conceptual understanding rather than passive reception of information (Niman et al., 2024). This model has also been shown to improve problem-solving abilities, enhance intrinsic motivation, and create a more dynamic and engaging learning environment (Muthalib et al., 2024). Discovery learning is particularly relevant for complex topics such as colligative properties of solutions, which require students to integrate conceptual understanding with laboratory skills involving concentration, ionization, and formula application (Manurung & Pappachan, 2025).

Despite the growing body of research on discovery learning and scientific process skills, a significant research gap remains. Existing studies have largely focused on the effect of discovery learning on student learning outcomes or academic achievement, with limited attention given to the detailed profiling of individual SPS dimensions during its implementation in chemistry, particularly at the senior high school level (Nurain et al., 2023; Muthalib et al., 2024). Furthermore, most studies on SPS in Indonesia have been conducted in the context of biology or general science education, while chemistry-specific investigations especially on topics requiring both conceptual depth and laboratory competence such as colligative properties of solutions remain underrepresented in the literature (Dani et al., 2022; Ramlawati & Rampean, 2024). The absence of such empirical evidence makes it difficult for chemistry educators to identify which specific SPS dimensions require targeted instructional intervention in discovery learning environments.

Addressing this gap is urgently needed in the current educational context. The implementation of the Merdeka Belajar curriculum in Indonesia increasingly emphasizes students' active participation in inquiry-based learning and the development of higher-order thinking skills, both of which are closely aligned with the goals of scientific process skill development (Kemendikbudristek, 2022). Without a clear empirical profile of students' SPS under discovery learning conditions, curriculum design and pedagogical decision-making in chemistry education risk remaining theoretically driven rather than evidence-based. Generating context-specific data on the strengths and limitations of students' SPS during discovery learning implementation is therefore essential to inform teacher professional development, instructional design, and assessment practices in Indonesian secondary chemistry education.

This study therefore aims to determine the percentage mastery of scientific process skills among class XII-6 students at SMA Negeri 14 Bekasi during the implementation of the discovery learning model on colligative properties of solutions. The findings are expected to provide empirical evidence to support the integration of discovery learning in senior high school chemistry instruction.

Method

Research Design

This study employed a descriptive quantitative research design with a one-shot case study approach. Descriptive quantitative research was selected as the methodology because this study aimed to portray the actual condition of students' scientific process skills without manipulating variables or comparing groups (Sugiyono, 2020). The one-shot case study design was appropriate given that data were collected at a single time point following the implementation of the discovery learning model. The sampling technique used was purposive sampling, which belongs to the category of non-probability sampling (Kurniawan, 2018). Sample selection was guided by specific considerations, including students' level of classroom activity, consistency of attendance, and demonstrated adequate cognitive performance. The study was conducted at SMA Negeri 14 Bekasi, involving 34 students from class XII-6 during the odd semester of the 2024/2025 academic year.

Research Procedure

The discovery learning model was implemented across three structured learning phases: pre-practical, practical, and post-practical activities. In the pre-practical phase, students engaged in literacy activities by reading materials related to colligative properties of solutions, followed by hypothesis formulation and experimental planning using structured student worksheets (LKPD). During the practical phase, students were divided into six groups and conducted laboratory experiments covering four colligative phenomena: boiling point elevation, vapor pressure depression, osmotic pressure, and freezing point depression. Each group was accompanied by a designated observer. In the post-practical phase, students completed their worksheets, analyzed data, formulated conclusions, and presented their findings in cross-group discussions. Throughout all phases, the LKPD was specifically designed to scaffold both discovery learning processes and the systematic development of scientific process skills. Class selection was based on the recommendation of the subject teacher, who considered the class's readiness and alignment with the learning schedule.

Instrument

Data were collected through two instruments: (1) an observation sheet and (2) a questionnaire. The observation sheet consisted of 15 items measuring students' SPS during the learning and laboratory activities, rated by six designated observers using a four-point Likert scale (1 = poor to 4 = excellent). The questionnaire consisted of 21 statements assessing students' self-perceived SPS and was distributed upon completion of all learning activities. Both instruments were developed based on the eleven SPS dimensions identified by Rustaman (2005): observing, asking questions, formulating hypotheses, predicting, planning experiments, conducting experiments, using tools and materials, grouping/classifying, communicating, applying concepts, and concluding. The content validity of both instruments was assessed through expert judgment, and construct validity was verified using Pearson product-moment correlation. Reliability was established using Cronbach's alpha coefficient, with a minimum acceptable threshold of 0.70, prior to deployment in data collection.

Data Analysis

The collected data were analyzed using descriptive statistics. The percentage score for each SPS aspect was calculated using Equation 1 (Purwanto, 2020):

$$NP = \frac{R}{SM} x 100\% \quad (1)$$

Where:
NP = the percentage value sought
R = the raw score obtained by the student
SM = the ideal maximum score from the test in question

The resulting percentage scores were categorized using the five-tier classification adapted from Riduwan (2009), as presented in Table 1. This categorization was applied to both the overall SPS score and each individual aspect score to allow for a detailed and comparative interpretation of students' proficiency levels across all eleven SPS dimensions.

Table 1. Score Interval and Category Classification

Score Interval	**Category**
81–100%	Excellent
61–80%	Good
41–60%	Sufficient
21–40%	Poor
0–20%	Very Poor

Results and Discussion

The study was conducted at SMAN 14 Bekasi involving 34 students of class XII-6 during the odd semester of the 2024/2025 academic year. Students' scientific process skills were assessed through observation sheets and questionnaires. Eleven aspects of SPS were measured: observing, asking questions, formulating hypotheses, predicting, planning experiments, conducting experiments, using tools and materials, grouping/classifying data, communicating results, applying concepts, and concluding. The overall results from both instruments are summarized in Tables 2 and 3.

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

Science Process Skills Aspect	Percentage (%)	Category
Observing	78.43	Good
Asking Questions	65.44	Good
Formulating Hypotheses	60.29	Sufficient
Predicting	55.14	Sufficient
Planning Experiments	79.41	Good

Conducting Experiments	88.23	Very Good
Using Tools and Materials	91.91	Very Good
Grouping/Classifying	70.58	Good
Communicating	67.64	Good
Applying Concepts	71.69	Good
Concluding	75.73	Good
Average	74.16	Good

Table 3. Students' Scientific Process Skills Based on Questionnaire

Scientific Process Skills Aspect	Percentage (%)	Category
Observing	79.41	Good
Asking Questions	75.00	Good
Formulating Hypotheses	76.47	Good
Predicting	75.24	Good
Planning Experiments	76.10	Good
Conducting Experiments	80.88	Very Good
Using Tools and Materials	83.82	Very Good
Grouping/Classifying	76.47	Good
Communicating	78.30	Good
Applying Concepts	73.16	Good
Concluding	72.05	Good
Average	76.54	Good

Overall, the results demonstrate that students' scientific process skills during the implementation of the discovery learning model on colligative properties of solutions fall into the Good category, with an average observation score of 74.16% and a questionnaire score of 76.54%. These findings are consistent with and strengthen prior research by Nurain et al. (2023), who reported a mean SPS score of 71.12% (Good) following discovery learning implementation on biodiversity material. Similarly, Muthalib et al. (2024) found that discovery learning-based worksheets yielded Good-category SPS scores among junior high school students, affirming that the structured inquiry nature of discovery learning is conducive to SPS development across educational levels and subject domains. The convergence of these findings across different research contexts underscores the robustness of discovery learning as a pedagogical approach for fostering scientific inquiry competencies. The present study extends this evidence base to the senior high school chemistry context, specifically within the challenging topic of colligative properties, providing contextually specific empirical support for discovery learning's role in SPS development.

Laboratory-related SPS dimensions namely Using Tools and Materials (91.91%), Conducting Experiments (88.23%), and Planning Experiments (79.41%) consistently achieved the highest scores in this study. This pattern is corroborated by Inayah et al. (2020), who found that practical and procedural skills are typically better developed among high school students compared to higher-order inquiry skills. The high score for Using Tools and Materials is further supported by Salosso et al. (2018), who reported similar outcomes in studies involving Learning Cycle 5E, attributing this proficiency to students' thorough pre-laboratory preparation and their understanding of the functional role of each instrument. Adilla & Utami (2022) similarly noted that direct laboratory experience enhances students' scientific self-efficacy and procedural accuracy. These findings collectively suggest that students in the present study benefited significantly from the pre-practical phase of discovery learning, during which they planned their experiments and identified the tools required, thereby entering the practical phase with a clear procedural understanding. These results have practical implications for instructional design: chemistry teachers are encouraged to consistently implement structured pre-practical activities including tool identification, procedural planning, and relevant reading tasks as these preparatory phases appear to be key drivers of high laboratory-related SPS performance.

Conversely, the lowest-performing aspects were Predicting (55.14%, Sufficient) and Formulating Hypotheses (60.29%, Sufficient) as assessed through observations. These results are consistent with findings by Inayah et al. (2020), who reported that predictive and hypothetical thinking are among the most underdeveloped SPS dimensions in senior high school students, and with Anyiendah et al. (2020), who argued that prediction skills require deliberate, repeated practice integrated into regular learning routines rather than incidental exposure. The disconnect between observation scores and questionnaire scores for these two aspects where Predicting rose to 75.24% and Formulating Hypotheses to 76.47% in self-report may reflect social desirability bias, as students tend to rate their perceived competence higher than what is directly observable (Podsakoff et al., 2003). The relatively lower performance on hypothesis formulation may also be attributed to students' limited experience with constructing scientifically rigorous hypotheses, a skill that requires not only content knowledge but also metacognitive awareness of scientific reasoning processes. These findings have important implications for pedagogy: teachers should intentionally integrate prediction and hypothesis-formulation exercises such as think-aloud activities, structured prediction templates, and guided pre-experiment discussions into the discovery learning sequence, particularly before practical activities begin, to elevate these higher-order inquiry skills to Good or Excellent levels.

The remaining SPS dimensions Observing (78.43%), Asking Questions (65.44%), Grouping/Classifying (70.58%), Communicating (67.64%), Applying Concepts (71.69%), and Concluding (75.73%) all fell within the Good category based on observation data, and were consistently supported by questionnaire results. These outcomes align with Rizal (2019), who demonstrated that discovery learning effectively promotes fundamental inquiry skills such as observation, questioning, and data organization in secondary science students. Wahyudi & Lazulfa (2021) similarly reported Good-category classifying skills in project-based learning, noting that systematic worksheet activities support students' data recording and grouping capabilities. Khairunnissa et al. (2024) and Pratiwi et al. (2020) further noted that communication skills tend to score moderately lower in observational assessments compared to self-report, a discrepancy that this study also observed, reflecting the inherent challenge of real-time oral scientific communication. The overall Good-category performance across most SPS dimensions indicates that the structured three-phase implementation of discovery learning in this study incorporating pre-practical literacy, hands-on laboratory work, and post-practical discussion provided an effective and balanced scaffolding framework for SPS development. These findings suggest that well-structured discovery learning sequences, particularly when supported by carefully designed student worksheets (LKPD), can serve as an effective institutional model for fostering broad-based SPS in senior high school chemistry, and that this approach merits wider adoption and adaptation in Indonesian secondary education.

A noteworthy discrepancy was consistently observed between observation scores and questionnaire scores across multiple SPS dimensions, with questionnaire scores generally 5–16 percentage points higher than observation scores. This pattern is consistent with Podsakoff et al. (2003), who identified self-report inflation as a common measurement artifact in educational research, particularly when students assess their own competencies immediately following a novel learning experience. Additionally, Fitriyani et al. (2017) noted that following guided inquiry activities, students often report a heightened sense of scientific self-efficacy that may not yet be fully reflected in directly observable behavioral outcomes. This disparity underscores the methodological strength of using multiple data sources both observational and self-report instruments as employed in the present study, as each instrument captures complementary dimensions of students' SPS. From an implications standpoint, this finding highlights the importance of triangulating SPS assessment through both direct observation and student self-reflection instruments, and suggests that future studies should incorporate performance-based assessment tasks or think-aloud protocols to obtain a more complete and valid picture of students' actual SPS competencies in chemistry learning.

Conclusion

This study analyzed the profile of students' scientific process skills during the implementation of the discovery learning model on the topic of colligative properties of solutions at SMA Negeri 14 Bekasi. Based on observation sheets, the average percentage score was 74.16% (Good). The highest-scoring aspect was Using Tools and Materials (91.91%, Very Good), while the lowest was Predicting (55.14%, Sufficient). Questionnaire data yielded an average score of 76.54% (Good), with Using Tools and Materials again achieving the highest score (83.82%, Very Good) and Concluding the lowest (72.05%, Good). Overall, the discovery learning model demonstrated effectiveness in fostering students' scientific process skills in a laboratory-based chemistry context, particularly for aspects directly related to practical experimentation. However, higher-order inquiry skills specifically predicting and hypothesis formulation require targeted pedagogical interventions to reach higher proficiency levels. Future studies are recommended to examine the effect of discovery learning on SPS using quasi-experimental or mixed-methods research designs, and to investigate the effectiveness of specific scaffolding strategies for improving students' predictive and hypothesis-formulating competencies in senior high school chemistry education.

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