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Review Article

# Teacher Efforts To Improve Science Process Skills: Observation, Classification, and Data Table Making

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**ABSTRACT**

**Purpose of the study:** This study aims to systematically identify, analyze, and synthesize various teacher strategies used in science learning to develop students' Science Process Skills (SPS). The study focuses on developing indicators for observation, classification, and data tabulation as basic and integrated scientific skills.

**Methodology:** This study employed a Systematic Literature Review (SLR) method, adhering to the PRISMA 2020 guidelines. The unit of analysis was scientific articles, not human participants. Thirty articles meeting the inclusion and exclusion criteria were selected through identification, screening, and eligibility assessment. They were then analyzed using document analysis and thematic synthesis.

**Main Findings:** The study results indicate that active, experiential, and inquiry-oriented learning strategies, such as Guided Inquiry, Experimentation, and Project-Based Learning (PjBL), have proven effective in improving basic Science Process Skills, particularly the observation and classification indicators. However, this systematic review also revealed significant strategic weaknesses in the data table creation indicator. These weaknesses are caused by teachers' limitations in designing learning activities that explicitly involve data processing, visualization, and representation as the basis for students' scientific argumentation.

**Novelty/Originality of this study:** The novelty of this research lies in the systematic mapping of the development gaps in data table creation indicators in science learning practices. This study provides a conceptual contribution by confirming that strengthening data processing and representation skills is a crucial component that bridges basic Science Process Skills to more complex and meaningful integrated science process skills.



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## 1. INTRODUCTION

Science education learning in various countries continues to progress in line with the rapid development of science and technology [1], [2]. Science is now understood not only as a collection of concepts and theories, but also as a vehicle for developing scientific thinking skills and problem-solving skills [3], [4]. Modern science learning approaches focus on exploratory activities and hands-on experiences that enable students to study natural phenomena through the scientific process [5], [6]. Therefore, the primary goal of science learning today is to foster curiosity, develop critical thinking skills, and encourage innovation in understanding and applying scientific concepts [7], [8].

Curricula in various countries have now adapted to global demands by strengthening 21st-century competencies that emphasize the integration of cognitive, affective, and psychomotor aspects [9], [10]. In this context, science learning plays a very strategic role because it focuses not only on mastering scientific knowledge but also on the formation of scientific attitudes and the development of science process skills (SPS) [11], [12]. The psychomotor aspect in science learning is reflected through scientific activities such as observation, classification of objects or phenomena, and presentation of data in tabular form [13], [14]. Through these activities, students are trained to think systematically and gain a deeper understanding of scientific concepts [15], [16].

The development of teaching strategies over time demonstrates significant changes in learning approaches [17], [18]. Currently, teachers place greater emphasis on student-centered learning by providing opportunities for independent exploration and experimentation [19], [20]. Approaches such as inquiry-based learning, projects, and practicums provide opportunities for students to hone the three main indicators of SQA: observation, classification, and tabulation [21]. These changes emphasize that effective learning strategies focus not only on the final outcome but also on the scientific process students undergo in acquiring knowledge [22], [23].

Science process skills are a fundamental element in science learning because they help students understand science as both a process and a product of knowledge [24], [25]. Students who have not mastered science process skills typically experience difficulties analyzing data, interpreting observations, and drawing scientific conclusions [26], [27]. In the short term, this results in low learning outcomes and participation in scientific activities, while in the long term, it can hinder critical thinking, problem-solving, and adaptation to technological developments [28], [29]. Therefore, science process skills need to be systematically developed through the implementation of effective learning strategies so that students can develop scientific character and be prepared to face the challenges of the modern era based on science and technology [30], [31].

Although the importance of science process skills has been widely recognized, various research findings indicate that students' mastery of science process skills is still suboptimal, particularly in indicators related to processing and presenting scientific data [32], [33]. Students often experience difficulty systematically compiling data tables and using them as a basis for drawing scientific conclusions, resulting in low-quality evidence-based argumentation in science learning [34], [35]. Several previous studies have examined the effectiveness of various science learning strategies, but few have systematically examined the role of teacher strategies in developing students' science process skills [36], [37]. This indicates the need for a more comprehensive study to summarize the latest research findings to understand the patterns and trends in the application of these strategies in various learning contexts [38], [39]. Using a systematic literature review (SLR) approach, this study aims to identify, analyze, and synthesize effective teacher strategies in improving science process skills, particularly in the indicators of observation, classification, and data tabulation.

Specifically, this study aims to identify the types of teacher strategies used in science learning, analyze the tendency of the effectiveness of these strategies on the development of Science Process Skills and reveal the weaknesses of teacher strategies in the data tabulation indicator. Based on these objectives, the research question focuses on how teacher strategies reported in the literature are able to develop indicators for observation, classification, and tabulation of student data. This research is important because it provides an empirical basis for the development of more focused and evidence-based science learning strategies. The findings of this study are expected to not only enrich theoretical studies on teacher strategies and science process skills, but also provide practical contributions for teachers, curriculum developers, and teacher education institutions in designing learning and training that can optimize students' mastery of SPS comprehensively.

## 2. RESEARCH METHOD

This study employed the Systematic Literature Review (SLR) method, adhering to the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). This approach was chosen because it allows researchers to systematically and measurably review, identify, and synthesize relevant research findings. The primary objective of using SLR is to gain a comprehensive understanding of teacher strategies for improving science process skills (SPS), particularly in the areas of observation, classification, and tabulation. This method ensures a transparent, focused, and replicable literature search.

This research design is qualitative-descriptive, based on scientific documents. The unit of analysis is not individual respondents, but rather scientific articles that meet the inclusion criteria. Therefore, this study does not use a survey design, questionnaire, or statistical hypothesis testing, but instead focuses on a systematic synthesis of empirical findings from previous research. According to Priharsari [40] SLR can be generally divided into four stages: determining the objectives of the SLR, initiating and selecting literature, analyzing and coding, and planning the presentation of the results. The following is a diagram of the stages of a Systematic Literature Review (SLR) that illustrates the research process, from determining objectives to systematically presenting the study results.

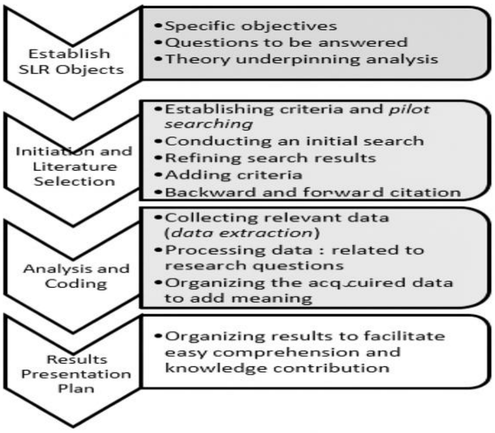


Figure 1. SLR steps

Article Search Sources and Strategies, The data sources for this study were scientific articles published in reputable international journals. The literature search was conducted through several online databases, including Taylor & Francis, SpringerLink, and ERIC. Keywords used in the search included: “teacher strategies,” “science process skills,” “science education,” “observing,” “classifying,” and “data table creation”. The publication period was limited to 2015 and 2025 to ensure the relevance of the research findings to the current curriculum context and science learning approaches. Database and keyword selection was conducted purposively to capture articles that specifically address teacher strategies and science process skill indicators. This process serves as a sampling technique in the context of SLR, where the selected articles are considered representative of the research population relevant to the study’s focus.

Inclusion and Exclusion Criteria, To ensure the accuracy of the literature selection, this study applied the following inclusion and exclusion criteria: 1). The article discusses teacher strategies in science learning; 2). The article addresses or examines indicators of science process skills (SPS), namely observation, classification, and data tabulation; 3). The article is empirical research and available in full text; 4). The article was published in English between 2015 and 2025. Exclusion criteria: 1). The article is a theoretical review, conceptual opinion, or has not undergone a peer-reviewed process; 2). The article is not relevant to the context of science learning; 3). The article does not include a complete list of research methods or results. In the context of this study, articles that meet the inclusion criteria are treated as the main data source, so that the number of articles that passed the selection (n = 30) represents the entire unit of analysis that was analyzed in depth in this study.

Article Selection Procedure, The article selection process in this study followed the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. A PRISMA flowchart was used to illustrate the stages of article identification, screening, eligibility, and inclusion used in the systematic review. Identification, In the initial stage, researchers searched for articles from three major databases: Taylor & Francis, SpringerLink, and ERIC. The initial search, using a combination of predetermined keywords, yielded 350 potentially relevant scientific articles. Screening, Duplicate articles were then removed, leaving 280 articles. Next, a title and abstract screening was conducted to assess their relevance to the research focus. From this stage, 61 articles were eliminated for being irrelevant to the topic of teacher strategies or science process skills, leaving 219 articles. Eligibility, A total of 219 articles were then thoroughly analyzed to assess their suitability for inclusion criteria. At this stage, 189 articles were excluded because they did not specifically examine the science process skills indicators in question (observation, classification, and data tabulation) or the strategies teachers use to improve science process skills. In other words, they did not present the empirical data required by the researchers. Inclusion, Ultimately, 30 articles met all criteria and were included in the systematic analysis phase. These articles were then analyzed in depth to identify the strategies teachers used, the context in which they were implemented, and their impact on the development of students' science process skills.

The number of articles at each selection stage describes the systematic and multi-layered data filtering process, thus ensuring that only articles that are relevant, of high quality, and in accordance with the research objectives are analyzed further. The article selection process is visualized in a PRISMA flowchart, which depicts the number of articles at each stage, from identification to final inclusion. This diagram ensures transparency in the selection process and demonstrates that each article analyzed has undergone a rigorous and verified selection process.

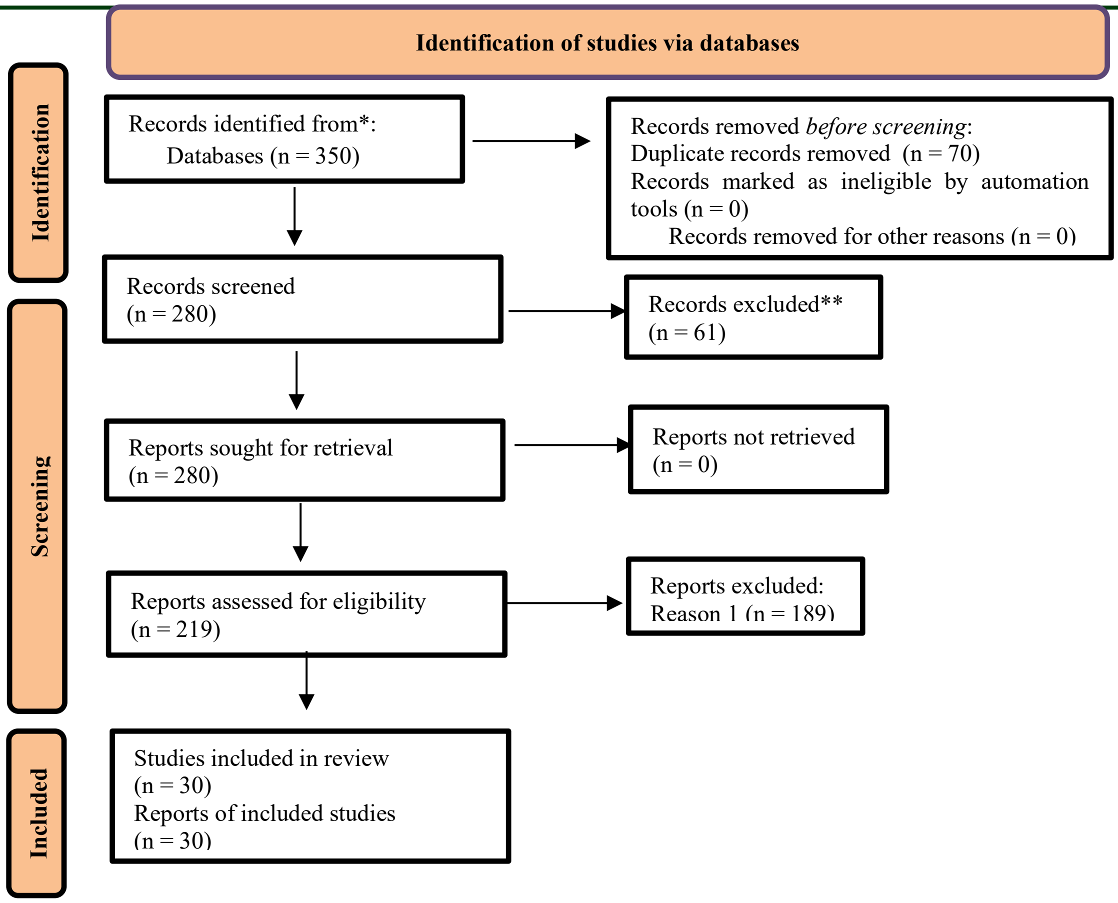


Figure 2. Review process flowchart (PRISMA)

Data analysis was conducted using a qualitative approach based on document analysis. The data analysis technique used is content analysis, with stages including organizing articles that passed the inclusion stage, coding data based on predetermined categories, grouping themes, and drawing conclusions. Each article that passed the inclusion stage was analyzed based on the research identity (author and year of research), research methods and design, teacher strategies used, SPS indicators developed, and the main results and implications of the research. The analysis results were compiled in the form of synthesis tables and narrative explanations to reveal patterns, trends, and the effectiveness of teacher strategies in developing students' science process skills. Through this approach, researchers were able to draw more comprehensive conclusions and comprehensively map the relationship between learning strategies and the improvement of science process skills (SPS). Because this research is a literature review based on document analysis, data analysis does not involve respondents, questionnaires, or statistical hypothesis testing.

## 3. RESULTS AND DISCUSSION

In this study, testing was not conducted through statistical hypotheses as in quantitative research, but rather through a thematic synthesis analysis of empirical findings from the reviewed articles. The analysis focused on identifying patterns, trends, and consistency of findings related to teacher strategies in developing science process skills, particularly in the indicators of observation, classification, and data tabulation. Thus, the "testing" process was conducted conceptually through comparison and mapping of findings across articles to assess the extent to which the literature supports the relationship between teacher strategies and the development of students' science process skills.

Based on a literature search from the Taylor & Francis, SpringerLink, and ERIC databases with the limitation of 2015-2025 published in English, 350 articles were obtained from the three databases, then screening was carried out to remove duplicate data and 219 articles remained, then a feasibility analysis was carried out on the remaining articles, and inclusion was carried out where 30 articles were considered eligible. To facilitate the analysis of the research results, the mapping is presented in Table 1.

Table 1. Research results regarding teacher strategies in improving students' science process skills in science learning

| No | Article Title and Researchers | Research methods | Research result | Research Analysis Results |
|---|---|---|---|---|
| 1 | Investigation of in-Service and Pre-Service Science Teachers' Perceptions of Scientific Process Skills [41]. | Relational survey | SPS in general (Basic and Integrated SPS). | Teacher Strategy Conclusion: Training Focus: Teachers should be supported to reduce uncertainty in designing exercises that require students to create data tables and graphs (integrating observation/classification). |
| 2 | Developing science learning material with authentic inquiry learning approach to improve problem solving and scientific attitude [42]. | Research and Development (R&D) Four D and Borg & Gall models. | SPS Related to Problem Solving: Observation, Problem Formulation, Hypothesis Formulation, Data Collection, Data Analysis, and Data Tables. | Teacher Strategy: An integrated Inquiry approach is effective for training students' SPS. |
| 3 | Adapting undergraduate Biology to include science practices by teaching students to generate scientific explanations [43]. | A quasi-experimental comparative study with Assessment-Based Curriculum. | Main SPS: Producing Scientific Explanations. Indicators: Claim, Evidence, and Reasoning. | Teacher Strategies: Curricula that explicitly teach and assess science practices, such as the CER framework, are highly effective. Teachers should focus on repeating the Reasoning component. |
| 4 | Effect of using science process skills-integrated inquiry-based approach on grade nine students' cell biology academic achievement [44]. | Mixed-Method Research Approach with Quasi-Experimental Design (Pre-test Post-test Comparison Group). | The SPS used (in the SPSIIBA approach) includes: Basic SPS and Integrated SPS. | Teacher Strategy: An inquiry approach that explicitly integrates SPS is effective in improving student learning outcomes and simplifying abstract concepts, as well as creating an active learning environment. |
| 5 | An Assessment of Science Process Skills in Junior High School Education: Perspectives of Students and Teachers in Indonesia [45]. | Descriptive-Inferential Survey (using SPS diagnostic test). | The SPS assessed include: Observation, Measuring, Classifying, Making Hypotheses, Interpreting Data, Summarizing, and Communicating. | Teacher Strategy: Students and teachers need to be trained in SPS by implementing the Project-Based Learning model or the Inquiry-Based Learning method which directly involves SPS. |
| 6 | Needs analysis of gamification models in the digestive system lesson to improve students' critical thinking skills and science process skill [46]. | Research and Development R&D with the ADDIE approach (initial stage: Analysis). | The SPS indicators discussed include: Observation, Classification, Communication, Inference, Predicting, and Asking Questions. | Teacher Strategy: Using Gamification learning media specifically designed to improve high-level skills (such as SPS and Critical Thinking) is an appropriate strategy. |
| 7 | Development of Online science process skills test for 8th grade pupils [47]. | Research and Development (R&D). | The SPS indicators measured include 14 Science Process Skills from the selected theoretical framework | Teacher Strategy: Developing online tests (which can be scored automatically) is an efficient strategy for teachers to monitor and assess students' |

| No | Article Title and Researchers | Research methods | Research result | Research Analysis Results |
|---|---|---|---|---|
| | | | (not mentioned in detail, but include Basic and Integrated SPS). | SPS periodically, so that teachers can take corrective (remedial) actions quickly. |
| 8 | Effects of the Sense-Based Science Education Program on Scientific Process Skills of Children Aged 60-66 Months [48]. | Experimental Research (with Quasi-Experimental attributes). | The SPS measured are Basic SPS and Intermediate SPS (which is the focus of the program). | Teacher Strategy: A Sensory-Based Science Education Program specifically designed for early childhood is highly effective in developing elementary and secondary SSCs in preschool children. |
| 9 | Attitude of learners towards science and their science process skills in the case of the spiral curriculum: A literature review [49]. | Literature Study/Literature Review. | Includes Basic SPS (Observation, Classification, Measurement, Communication) and Integrated SPS (Formulating Hypotheses, Controlling Variables, Interpreting Data). | Teacher Strategy: SPS should be taught in an integrated manner with content, not as a stand-alone lesson. Teachers should use hands-on and mind-on methods, as well as approaches such as Argumentation and Inquiry, to improve students' SPS. |
| 10 | Analysis of the Studies Done on Laboratories in Turkey [50]. | Qualitative Document Analysis (on thesis on laboratories period 1999–2017). | Laboratory-Related SPS: Observation, Recording/Analyzing/Interpreting Data, Formulating Hypotheses, and SPS in general. | Teacher Strategy: Teachers are advised to use a more active inquiry laboratory approach and implement performance assessments to measure students' SPS and higher-order thinking skills. |
| 11 | Enhancing Preservice Teachers' Observation and Inference Skills [51]. | Quasi-Experimental Study (Pre-test Post-test). | Basic SPS: Observation and Inference (including distinguishing between the two). | Teacher Strategy: Teacher education programs need explicit instruction and intensive discussion on Basic SPS. |
| 12 | The effectiveness of Project-based Learning on students' science process skills: a literature review [52]. | Literature review | Basic SPS (Observation, Classification) and Integrated SPS (Formulating Hypotheses, Interpreting Data). | Teacher Strategy: The application of the PBL model is highly recommended because it naturally encourages students to apply all SPS in real projects. |
| 13 | Pre-service Science Teachers' Views on Laboratory Applications in Science Education: The Effect of a Two-semester Course [53]. | Quasi-Experimental Study (Pre-test and Post-test Design). | SPS covered: Observation, Problem Solving, and Designing Experiments. | Teacher Strategy: Teacher education should provide explicit instruction in SPS and practical training focused on laboratory managerial skills. |
| 14 | Enhancing Science Process Skills through Inquiry - Based Learning: A Comprehensive Literature Review and Analysis [54]. | Comprehensive Literature Review. | SPS covered: Basic SPS (Observation, Classification, Communication) and Integrated SPS (Formulating Hypotheses, Interpreting Data). | Teacher Strategy: The IBL model (especially Open/Guided Inquiry) is recommended as the best strategy because it forces students to actively engage in the science process (including observation and data processing). |
| 15 | Improving Students' Science Process Skills Through PjBL Learning | Classroom Action Research. | SPS measured: Observation, Classification, | Teacher Strategy: Implementation of PjBL with structured LKPD is |

| No | Article Title and Researchers | Research methods | Research result | Research Analysis Results |
|---|---|---|---|---|
| | Assisted by Collaborative Project LKPD [55]. | | Communicating (Creating Data Tables and Graphs), and Interpreting Data. | recommended because it facilitates the implementation of basic and integrated SPS during the project. |
| 16 | The Effectiveness of Inquiry Based Learning Model to Improve Science Process Skills and Scientific Creativity of Junior High School Students [56]. | Quantitative descriptive research with Pre-test Post-test design. | SPS in general (Basic and Integrated SPS). | Teacher Strategy: The implementation of IBL is highly recommended because it encourages students to actively investigate to construct knowledge. |
| 17 | Strategies in Developing Junior High School Students' Science Process Skills in the Material of Temperature, Heat, and Expansion [57]. | Naturalistic Qualitative. Data collection through interviews and documentation, analyzed descriptively. | SPS that are focused on: Observation, Making Graphs (Graphing), and Communication. | Teacher Strategy: The strategy used involves structured steps that force students to: 1) Conduct direct observations of temperature/heat phenomena. 2) Record results and create graphs (data representation). 3) Conduct scientific communication (presentations). |
| 18 | Effects of Explicit Science Process Skill Instructions on Pre-Service Science Teachers Professional Science Teaching Attitudes and Science Teaching Behavioral Intention [58]. | Quasi-Experiment (Non-equivalent Pre-test/Post-test Control Group Design). | SPS is taught explicitly as a prerequisite for improving Scientific Reasoning Ability. | Teacher Strategy: Use explicit instruction and structured instruction models (such as 4C/ID) to develop SPS and scientific reasoning. |
| 19 | Students' inquiry skills progression based on STEM approach and inquiry lab [59]. | Quasi-Experiment (Non-equivalent Pre-test and Post-test Control Group Design). | Inquiry Skills: Observation, Formulating Problems/Hypotheses, Collecting/Analyzing Data, and Drawing Conclusions. | Teacher Strategy: Integrating STEM and Inquiry Labs is a highly effective strategy for enhancing integrated SPS as a whole. |
| 20 | Science process skills and critical thinking skills in inquiry-based learning model with project-based assessment [60]. | Quasi-Experimental (Pretest-Posttest Non-equivalent Control Group Design). | SPS in general (Basic and Integrated SPS). | Teacher Strategy: Using Inquiry (active investigation) and Project Assessment (application of SPS in real tasks) are effective strategies for developing 21st century skills. |
| 21 | Do a science process skills affect on critical thinking in science? Differences in urban and rural [61]. | Mixed-Method Design. | SPS in general (as a predictor of Critical Thinking). | Teacher Strategy: Improving SPS is a prerequisite for Critical Thinking. Intensive strategies (such as Science Fairs) are needed to improve SPS for rural students. |
| 22 | Improving Science Process Skills for | Quasi-Experimenta | SPS in general (as a foundation for 21st | Teacher Strategy: The 5E Model is recommended because |

| No | Article Title and Researchers | Research methods | Research result | Research Analysis Results |
|---|---|---|---|---|
| | Primary School Students Through 5E Instructional Model-Based Learning [62]. | l (One-Group Pre-test and Post-test Design). | century skills). | its structured steps (especially Explore and Elaborate) engage students actively in the science process. |
| 23 | Scenario-Based Microlearning Strategy for Improved Basic Science Process Skills in Self-Directed Learning [63]. | Quasi-Experimental (Pre-test Post-test) and Correlational Survey | Basic SPS: Observation, Measuring, Communicating, Interpreting Data, Predicting, and Classifying. | Teacher Strategy: This strategy is highly recommended because it is effective, contextual, and has a significant relationship with students' level of Independent Learning. |
| 24 | Improving the Science Process Skills Ability of Science Student Teachers Using I Diagrams [64]. | Basic Experimental Design (Pre-test Post-test). | The focus of the SPS is: Integrated SPS (Formulating Hypotheses, Controlling Variables, Designing Experiments). | Teacher Strategy: Using I-Diagrams is recommended as an efficient visual framework for developing integrated thinking skills in designing and analyzing scientific investigations. |
| 25 | Study of Science Process Skills Student Using Worksheet based on Science Process Skills [65]. | Research and Development (R&D). | Observation, Classification, Prediction, Communication, and Inference. | Teacher Strategy: Use structured LKPD that explicitly includes SPS steps as a practical guide to mastering the concept. |
| 26 | Explicit Teaching of Science Process Skills: Learning Outcomes and Assessments of Pre-service Science Teachers [66]. | Action Research. | SPS in general (Basic and Integrated). | Teacher Strategy: Conducting Explicit Teaching of SPS is essential to prepare teachers to be competent in developing students' SPS. |
| 27 | Effectiveness of learning models for improving science process skills: A review study [67]. | Literature Review Study. | Improving Science Process Skills (SPS) in general. | Key Findings: Effective learning models (such as inquiry and projects) are key to improving SPS. |
| 28 | Analysis of Science Process Skills of Chemical Education Students Through Self-Project Based Learning (SjBL) in the Covid-19 Pandemic Era [68]. | Pra-Eksperiment (*One-Shot Case Study*). | SPS focuses on: Determining tools/materials, Determining variables, Determining work steps, and Making conclusions. | Key Findings: SjBL (Independent Project) effectively trains chemistry students' SPS during the pandemic, especially in determining research tools/materials and variables. |
| 29 | Teacher Talk Supporting Student Progressive Discourse in Science [69]. | Qualitative Descriptive Case Study. | SPS Not Measured Directly (Focus on Progressive Scientific Discourse which includes SPS Communication and Inference). | Key Findings: Teacher Talk (especially the purpose of the questions) is key to improving students' Communication and Inference SPS through Progressive Scientific Discourse. |
| 30 | Improving Science Process Skills of Students: A Review of Literature [70]. | Literature Review | Basic and Integrated SPS (Observation, Classification, Measuring, Communication, Prediction, Inference, Hypothesis, Designing Experiments, etc.). | Key Findings: SPS is essential and is effectively enhanced through Inquiry and Project/Problem models which must be implemented explicitly. |

The results of a Systematic Literature Review (SLR) of 30 scientific articles confirm that Science Process Skills (SPS) are the main foundation in building students' scientific literacy, in accordance with the needs of 21st-century skills. Based on the results of the matrix analysis, there is a strong agreement that SPS, including observation and classification indicators, are most effectively developed through active, student-centered, and experience-oriented learning strategies, such as Guided Inquiry, Experiments, and Project-Based Learning (PjBL). The effectiveness of these strategies lies in the direct involvement of students in authentic scientific activities. This finding strengthens the understanding that SPS is not a naturally developing ability, but must be taught and practiced consciously and systematically by teachers, which is the main conclusion of this entire literature review. This finding is in line with various previous studies which state that inquiry-based learning, experiments, and projects are effective in developing science process skills through the active involvement of students in scientific activities.

Although the learning strategies were generally proven effective, this review identified a significant gap in the Data Table Creation indicator, the primary focus of this study. The results of the perception analysis indicate that the ability of teachers and prospective teachers to design activities that explicitly require students to create data tables and graphs is still at the lowest level. According to the researchers, this problem lies not in students' abilities, but rather in teachers' hesitation and weaknesses in designing tasks that can connect the Basic SPS (observation and classification) with the Integrated SPS (data table creation). This gap indicates that teachers have not fully integrated data processing into the learning design, which has the potential to hinder the development of students' ability to conduct evidence-based argumentation. Unlike some previous research that discussed science process skills in general, this study makes a novel contribution by highlighting the indicator of data table creation as an aspect that is still under-facilitated in learning practices. These findings enrich science education studies by positioning data processing and representation as critical points in the development of students' science process skills.

To address these strategic weaknesses in the short term, direct interventions focused on improving teacher competency are needed. Priority steps include implementing training that emphasizes explicit instructional design, particularly in developing student worksheets (LKPD) and learning activities that systematically guide students from data collection to creating tables and graphs. Furthermore, teachers need to be equipped with the ability to use a targeted communication strategy (Teacher Talk), which involves asking questions that challenge students' reasoning and encouraging them to present evidence in visual formats such as tables or graphs. This approach can directly strengthen the SPS in terms of communication and inference, while shifting classroom dynamics from simply reporting results to an evidence-based sensemaking process.

In the long term, mastery of Science Process Skills (SPS) as a means of critical thinking and a foundation for a scientific career requires ongoing structural support. Such support, such as the establishment of professional learning communities or mentoring programs, is needed to maintain and improve SPS competency in existing teachers, while also bridging the gap between prospective teachers' ideal perceptions and actual practice in the field. Furthermore, teacher training institutions need to reform their curriculum so that prospective teachers are equipped with strong skills in designing assessments and learning activities oriented towards Integrated SPS. Thus, teachers' strategies are expected to evolve from simply applying learning models to the ability to design systematic learning experiences that encourage the comprehensive and sustainable development of students' SPS.

This study has several limitations, including the limited scope of articles analyzed due to limited data collection from specific databases and timeframes, and the study's systematic literature review, which lacks direct empirical data collection in the field. Therefore, the findings represent trends in the analyzed literature and do not fully reflect the actual implementation of classroom learning. Further research is recommended to conduct empirical studies or learning experiments that specifically test the effectiveness of table and graph creation activity designs in improving students' science process skills. Furthermore, further research could explore teacher training models that focus on strengthening data processing and representation skills in science learning.

## 4. CONCLUSION

This systematic review concludes that the development of students' Science Process Skills (SPS) is most effectively achieved through active, experiential, and inquiry-oriented learning strategies explicitly integrated into the learning process. This strategy has been shown to improve basic SPS, particularly observation and classification. However, this study also identified gaps in the data tabulation indicator due to teachers' limitations in designing data processing and representation activities. These findings emphasize that strengthening data tabulation skills is a crucial component in bridging the gap from basic SPS to integrated SPS, thus necessitating increased teacher competency in data-driven learning and assessment design.

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## AUTHOR CONTRIBUTIONS

Conceptualization, Gita Salsabilla Nurma Yahya and Darmaji; Methodology, Gita Salsabilla Nurma Yahya; Validation, Gita Salsabilla Nurma Yahya, Darmaji, and Dwi Agus Kurniawan; Formal Analysis, Gita Salsabilla Nurma Yahya; Investigation, Gita Salsabilla Nurma Yahya; Data Curation, Gita Salsabilla Nurma Yahya; Writing – Original Draft Preparation, Gita Salsabilla Nurma Yahya; Writing – Review & Editing, Gita Salsabilla Nurma Yahya, Darmaji and Dwi Agus Kurniawan; Supervision, Darmaji and Dwi Agus Kurniawan.

## CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

## USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

## REFERENCES

[1] C. Dede and S. Barab, "Emerging technologies for learning science: A time of rapid advances," *J. Sci. Educ. Technol.*, vol. 18, no. 4, pp. 301–304, 2009, doi: 10.1007/s10956-009-9172-4.

[2] N. M. Nasri, N. Nasri, N. F. Nasri, and M. A. A. Talib, "The impact of integrating an intelligent personal assistant (IPA) on secondary school physics students' scientific inquiry skills," *IEEE Trans. Learn. Technol.*, vol. 16, no. 2, pp. 232–242, 2023, doi: 10.1109/TLT.2023.3241058.

[3] M. Rahman, "21 st century skill 'Problem Solving': Defining the concept," *Asian J. Interdiscip. Res.*, vol. 2, no. 1, pp. 64–74, 2019, doi: doi.org/10.34256/ajir1917.

[4] L. D. English, "Ways of thinking in STEM - based problem solving," *ZDM – Math. Educ.*, vol. 55, no. 7, pp. 1219–1230, 2023, doi: 10.1007/s11858-023-01474-7.

[5] T. Tanti, W. Utami, D. Deliza, and M. Jahanifar, "Investigation in vocation high school for attitude and motivation students in learning physics subject", *Journal Evaluation in Education (JEE),* vol. 6, no. 2, pp. 479-490, 2025, doi: 10.37251/jee.v6i2.1452.

[6] J. Yao, "Exploring experiential learning: Enhancing secondary school chemistry education through practical engagement and innovation," *J. Educ. Humanit. Soc. Sci.*, vol. 22, pp. 475–484, 2023, doi: 10.54097/ehss.v22i.12508.

[7] R. Agustini, R. S. M. Meilanie, and S. I. Pujiastuti, "Enhancing critical thinking and curiosity in early childhood through inquiry-based science learning," *Aulad J. Early Child.*, vol. 7, no. 3, pp. 734–742, 2024, doi: 10.31004/aulad.v7i3.780.

[8] E. Susiloningsih, A. Fathurohman, S. D. Maharani, M. F. Fathurohman, and S. D. C. Nurani, "Integration of STEM approach in science education: Enhancing students' critical thinking, creativity, and engagement in elementary schools in Palembang," *J. Penelit. Pendidik. IPA*, vol. 11, no. 4, pp. 10–19, 2025, doi: 10.29303/jppipa.v11i4.10615.

[9] P. N. Ariyanti, R. Madhakomala, and H. Taqiyya, "A holistic strategy for developing 21st century skills and leveraging technology to address the challenges of the digital era," *J. Educ. Relig. Instr.*, vol. 3, no. 2, pp. 60–71, 2025, doi: 10.60046/joeri.v3i2.229.

[10] J. Taliak, G. A. Manu, F. Hotman, and S. Damanik, "Analysis of a competency based curriculum model to improve the quality of secondary education in the era of globalization," *Qalamuna - J. Pendidikan, Sos. dan Agama*, vol. 14, no. 1, pp. 931–946, 2022, doi: 10.37680/qalamuna.v14i1.5078.

[11] H. Suwono, N. L. Rofi'Ah, M. Saefi, and R. Fachrunnisa, "Interactive socio-scientific inquiry for promoting scientific literacy, enhancing biological knowledge, and developing critical thinking," *J. Biol. Educ.*, vol. 57, no. 5, pp. 944–959, 2023, doi: 10.1080/00219266.2021.2006270.

[12] M. T. Kassaye, D. Damtie, S. M. Mengistie, and G. Yemata, "Effect of science process skills-based teaching approach on secondary school students ' scientific epistemological belie fs," *Bahir Dar J. Educ.*, vol. 25, no. 1, pp. 61–83, 2025, doi: 10.4314/bdje.v25i1.5.

[13] T. Tanti, A. Astalini, D. A. Kurniawan, D. Darmaji, T. O. Puspitasari, and I. Wardhana, "Attitude for physics: The condition of high school students," *Jurnal Pendidikan Fisika Indonesia,* vol. 17, no. 2, pp. 126-132, 2021, doi: 10.15294/jpfi.v17i2.18919.

[14] A. Agongo and T. N. Tindan, "The psychomotor domain: The role of manipulative skills in science mastery," *Int. J. Multidiscip. Res. Growth Eval.*, vol. 06, no. 06, pp. 990–994, 2025, doi: 10.54660/.IJMRGE.2025.6.6.990-994.

[15] A. Amit, S. Mentser, S. Arieli, and N. Porzycki, "Distinguishing deliberate from systematic thinking.," *J. Pers. Soc. Psychol.*, vol. 120, no. 3, p. 765, 2021, doi: 10.1037/pspp0000284.

[16] P. Y. A. Dewi and K. H. Primayana, "Effect of learning module with setting contextual teaching and learning to increase the understanding of concepts," *Int. J. Educ. Learn.*, vol. 1, no. 1, pp. 19–26, 2019, doi: 10.31763/ijele.v1i1.26.

[17] M. Lin, H. Chen, and K.-S. Liu, "A study of the effects of digital learning on learning motivation and learning

outcome," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 8223, no. 7, pp. 3553–3564, 2017, doi: 10.12973/eurasia.2017.00744a.

[18] J. Singh, K. Steele, and L. Singh, "Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, & post-pandemic world," *J. Educ. Technol. Syst.*, vol. 50, no. 2, pp. 40–71, 2021, doi: 10.1177/00472395211047865.

[19] K. H. D. Tang, "Student-centered approach in teaching and learning: What does it really mean?," *Acta Pedagog. Asiana*, vol. 2, no. 2, pp. 72–83, 2023, doi: 10.53623/apga.v2i2.218.

[20] T. Tanti, A. Astalini, D. Darmaji, D. A. Kurniawan, and R. Fitriani, "Student perception review from gender: Electronic moduls of mathematical physics," *JPI (Jurnal Pendidikan Indonesia)*, vol. 11, no. 1, pp. 125-132, 2022, doi: 10.23887/jpiundiksha.v11i1.35107.

[21] I. Piotrowska, M. Cichoń, J. Sypniewski, and D. Abramowicz, "Application of inquiry-based science education, anticipatory learning strategy, and project-based learning strategies in the context of environmental problems of the contemporary world," in *Didactic Strategies and Resources for Innovative Geography Teaching*, IGI Global, 2022, pp. 23–50. doi: 10.4018/978-1-7998-9598-5.ch002.

[22] G. Gorghiu, L. M. Drăghicescu, S. Cristea, A. Petrescu, and L. M. Gorghiu, "Problem-based learning-an efficient learning strategy in the science lessons context," *Procedia - Soc. Behav. Sci.*, vol. 191, pp. 1865–1870, 2015, doi: 10.1016/j.sbspro.2015.04.570.

[23] N. Kerimbayev, Z. Umirzakova, R. Shadiev, and V. Jotsov, "A student - centered approach using modern technologies in distance learning : a systematic review of the literature," *Smart Learn. Environ.*, vol. 10, no. 61, pp. 1–28, 2023, doi: 10.1186/s40561-023-00280-8.

[24] P. Kwangmuang, S. Jarutkamolpong, W. Sangboonraung, and S. Daungtod, "The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools," *Heliyon*, vol. 7, no. 6, p. e07309, 2021, doi: 10.1016/j.heliyon.2021.e07309.

[25] E. Sriwahyuni, "Penggunaan flashcard sistem periodik unsur terhadap keterampilan proses sains dasar peserta didik kelas x sma [The use of periodic table flashcards for the basic science process skills of grade X high school students]," *J. Pendidik. Kim.*, vol. 6, pp. 136–146, 2022, doi: 10.19109/ojpk.v6i2.14045.

[26] T. Mulyeni, M. Jamaris, and Y. Supriyati, "Improving basic science process skills through inquiry-based approach in learning science for early elementary students," *J. Turkish Sci. Educ.*, vol. 16, no. 2, pp. 187–201, 2019, doi: 10.12973/tused.10274a.

[27] A. D. Inayah, R. H. Ristanto, D. V. Sigit, and M. Miarsyah, "Analysis of science process skills in senior high school students," *Univers. J. Educ. Res.*, vol. 8, no. 4, pp. 15–22, 2020, doi: 10.13189/ujer.2020.081803.

[28] P. O. Ngozi, "Enhancing science process skills acquisition in chemistry among secondary school students through context-based learning," *Sci. Educ. Int.*, vol. 32, no. 4, pp. 323–330, 2021, doi: 10.33828/sei.v32.i4.7.

[29] A. Yılmaz, "The effect of technology integration in education on prospective teachers' critical and creative thinking, multidimensional 21 st century skills and academic achievements," *Particip. Educ. Res.*, vol. 8, no. 2, pp. 163–199, 2021, doi: 10.17275/per.21.35.8.2.

[30] R. Raja and P. C. Nagasubramani, "Impact of modern technology in education," *J. Appl. Adv. Res.*, vol. 3, no. 1, pp. 33–35, 2018, doi: 10.21839/jaar.2018.v3S1.165.

[31] R. Herak, "Character education in the digital age: Challenges and opportunities amidst technological developments," *Major. Sci. J.*, vol. 3, no. 2, pp. 245–252, 2025, doi: 10.61942/msj.v3i2.367.

[32] H. Rapsanjani and R. A. Yohanes, "Contextual science learning based on local wisdom: An effort to improve science process skills in primary schools hafsemi," *Lensa J. Kependidikan Fis.*, vol. 13, no. 1, pp. 203–212, 2025, doi: 10.33394/j-lkf.v13i1.16514.

[33] S. Y. Ungirwalu, Z. K. Prasetyo, and M. Jannah, "The use of discovery learning-assistedks to improve science process skills and scientific attitudes," *J. Pendidik. Indones.*, vol. 14, no. 1, pp. 168–176, 2025, doi: 10.23887/jpiundiksha.v14i1.79839.

[34] J. Boetje, B. Sichterman, S. Van Ginkel, M. Smakman, and J. Versendaal, "Design principles for developing information problem solving competence in higher education: a systematic review and meta-analysis," *Rev. Educ. Res.*, vol. 20, no.10, pp. 1–43, 2025, doi: 10.3102/00346543251338057.

[35] J. Fielding, K. Makar, and D. Ben-Zvi, "Developing students' reasoning with data and data-ing," *ZDM – Math. Educ.*, vol. 57, no. 1, pp. 1–18, 2025, doi: 10.1007/s11858-025-01671-6.

[36] M. S. Amrulloh and A. Galushasti, "Professional development teacher to improve skills of science process and creativity of learners," *J. Educ. Learn. (EduLearn*, vol. 16, no. 3, pp. 299–307, 2022, doi: 10.11591/edulearn.v16i3.20404.

[37] M. Mushani, "Science process skills in science education of developed and developing countries: Literature review," *Unnes Sci. Educ. J.*, vol. 10, no. 1, pp. 12–17, 2021, doi: 10.15294/usej.v10i1.42153 Graduate.

[38] A. Sholahuddin, L. Yuanita, Z. A. I. Supardi, and B. K. Prahani, "Applying the cognitive style-based learning strategy in elementary schools to improve students' science process skills," *J. Turkish Sci. Educ.*, vol. 17, no. 2, pp. 289–301, 2020, doi: 10.36681/tused.2020.27.

[39] A. M. Setiawan and Sugiyanto, "Science process skills analysos of science teacher on professional teacher program in Indonesia," *J. Pendidik. IPA Indones.*, vol. 9, no. 2, pp. 241–247, 2020, doi: 10.15294/jpii.v9i2.23817.

[40] D. Priharsari, "Systematic literature review in information systems and computer engineering: A guideline," *J. Teknol. Inf. dan Ilmu Komput.*, vol. 9, no. 2, pp. 263–268, 2022, doi: 10.25126/jtiik.202293884.

[41] M. Yildirim, D. S. Acarli, and M. Y. Kasap, "Investigation of in-service and pre-service science teachers' perceptions of scientific process skills," *Asian J. Univ. Educ.*, vol. 16, no. 2, pp. 104–115, 2020, doi: 10.24191/AJUE.V16I2.10302.

[42] A. Widowati, S. Nurohman, and P. Anjarsari, "Developing science learning material with authentic inquiry learning approach to improve problem solving and scientific attitude," *J. Pendidik. IPA Indones.*, vol. 6, no. 1, pp. 32–40, 2017,

doi: 10.15294/jpii.v6i1.4851.
[43] S. E. Honig, R. Dunkin, T. Ball, and L. Hunter, "Adapting undergraduate Biology to include science practices by teaching students to generate scientific explanations," *J. Biol. Educ.*, vol. 59, no. 2, pp. 374–389, 2025, doi: 10.1080/00219266.2024.2320114.
[44] M. T. Kassaye, D. Damtie, S. Melesse, and G. Yemata, "Effect of using science process skills-integrated inquiry-based approach on grade nine students' cell biology academic achievement," *Discov. Educ.*, vol. 4, no. 1, 2025, doi: 10.1007/s44217-025-00699-w.
[45] M. Tawil, "An assessment of science process skills in junior high school education: Perspectives of students and teachers in Indonesia," *J. Penelit. Pengemb. Pendidik. Fis.*, vol. 10, no. 2, pp. 305–322, 2024, doi: 10.21009/1.10209.
[46] R. Maulidia, D. Jaenudin, and V. I. Chemistry, "Needs analysis of gamification models in the digestive system lesson to improve students' critical thinking skills and science process skill," *J. Sci. Educ. Pract.*, vol. 8, no. 2, pp. 133–148, 2024, doi: 10.33751/jsep.v8i2.8909.
[47] S. Sarıoğlu, "Development of Online science process skills test for 8th grade pupils," *J. Turkish Sci. Educ.*, vol. 20, no. 3, pp. 418–432, 2023, doi: 10.36681/tused.2023.024.
[48] H. Tekerci and A. Kandir, "Effects of the Sense-Based Science Education Program on Scientific Process Skills of Children Aged 60–66 Months," *Eurasian J. Educ. Res.*, vol. 68, no. October, pp. 85–114, 2017, doi: 10.14689/ejer.2017.68.13.
[49] A. Tinapay, S. Tirol, J. A. Cortes, and M. Punay, "Attitude of learners towards science and their science process skills in the case of the spiral curriculum: A literature review," *Int. J. Res. Stud. Educ.*, vol. 10, no. 15, pp. 13–24, 2021, doi: 10.5861/ijrse.2021.a106.
[50] D. Yener, N. Köklü, R. Z. Yamaç, and S. Yalçin, "Analysis of the studies done on laboratories in Turkey," *J. Turkish Sci. Educ.*, vol. 17, no. 2, pp. 162–179, 2020, doi: 10.36681/tused.2020.19.
[51] N. Cansız and M. Cansız, "Enhancing preservice teachers' observation and inference skills," *İnönü Üniversitesi Eğitim Fakültesi Derg.*, vol. 19, no. 3, pp. 362–373, 2018, doi: 10.17679/inuefd.335762.
[52] R. Andriyani, K. Shimizu, and A. Widiyatmoko, "The effectiveness of Project-based Learning on students' science process skills: A literature review," *J. Phys. Conf. Ser.*, vol. 1321, no. 3, pp. 1–7, 2019, doi: 10.1088/1742-6596/1321/3/032121.
[53] G. Harman, A. Cokelez, B. Dal, and U. Alper, "Pre-service science teachers' views on laboratory applications in science education: the effect of a two-semester course," *Univers. J. Educ. Res.*, vol. 4, no. 1, pp. 12–25, 2016, doi: 10.13189/ujer.2016.040103.
[54] S. B. B. Behera, "Enhancing science process skills through inquiry-bBased learning: A comprehensive literature review and analysis," *Int. J. Sci. Res.*, vol. 12, no. 8, pp. 1583–1589, 2023, doi: 10.21275/sr23817121415.
[55] E. Novianto, "Improving students' science process skills through PjBL learning assisted by collaborative project LKPD," *Reflect. J.*, vol. 3, no. 2, pp. 88–95, 2023, doi: 10.36312/rj.v3i2.1849.
[56] M. B. Panjaitan and A. Siagian, "The effectiveness of inquiry based learning model to improve science process skills and scientific creativity of junior high school students," *J. Educ. e-Learning Res.*, vol. 7, no. 4, pp. 380–386, 2020, doi: 10.20448/journal.509.2020.74.380.386.
[57] R. P. Wirayuda and G. S. N. Yahya, "Strategies in developing junior high school students' science process skills in the material of temperature, heat, and expansion," *Schrödinger J. Phys. Educ.*, vol. 6, no. 2, pp. 103–116, 2025, doi: 10.37251/sjpe.v6i2.1875.
[58] G. G. Gizaw, S. S. Sota, S. A. Zinabu, and D. W. Adamu, "Effects of explicit science process skill instructions on pre-service science teachers professional science teaching attitudes and science teaching behavioral intention," *J. Sci. Teacher Educ.*, pp. 1–24, 2025, doi: 10.1080/1046560X.2025.2527431.
[59] Z. F. Chaerunisa, M. Ramli, and B. Sugiharto, "Students' inquiry skills progression based on STEM approach and inquiry lab," *JPBI (Jurnal Pendidik. Biol. Indones.*, vol. 9, no. 2, pp. 206–216, 2023, doi: 10.22219/jpbi.v9i2.25698.
[60] N. K. Rapi, R. Sujanem, L. P. B. Yasmini, and K. Setemen, "Science process skills and critical thinking skills in inquiry-based learning model with project-based assessment," *Int. J. Innov. Res. Sci. Stud.*, vol. 8, no. 2, pp. 938–946, 2025, doi: 10.53894/ijirss.v8i2.5393.
[61] D. Darmaji, D. A. Kurniawan, A. Astalini, R. Perdana, K. Kuswanto, and M. Ikhlas, "Do a science process skills affect on critical thinking in science? Differences in urban and rural," *Int. J. Eval. Res. Educ.*, vol. 9, no. 4, pp. 874–880, 2020, doi: 10.11591/ijere.v9i4.20687.
[62] N. L. Choirunnisa, P. Prabowo, and S. Suryanti, "Improving science process skills for primary school students through 5e instructional model-based learning," *J. Phys. Conf. Ser.*, vol. 947, no. 1, pp. 1–6, 2018, doi: 10.1088/1742-6596/947/1/012021.
[63] L. F. Zulueta and J. F. D. Panoy, "Scenario-based microlearning strategy for improved basic science process skills in self-directed learning," *Int. J. Sci. Technol. Eng. Math.*, vol. 2, no. 4, pp. 54–73, 2022, doi: 10.53378/352932.
[64] S. Karamustafaoğlu, "Improving the science process skills ability of science student teachers using i diagrams," *Int. J. Phys. Chem. Educ.*, vol. 3, no. 1, pp. 26–38, 2011, doi: 10.51724/ijpce.v3i1.99.
[65] M. K. Wazni and B. Fatmawati, "Study of science process skills student using worksheet based on science process skills," *J. Penelit. Pendidik. IPA*, vol. 8, no. 2, pp. 436–443, 2022, doi: 10.29303/jppipa.v8i2.1281.
[66] S. T. Aslan and H. E. Kılıç, "Explicit teaching of science process skills: learning outcomes and assessments of pre-service science teachers," *Mimb. Sekol. Dasar*, vol. 9, no. 3, pp. 446–465, 2022, doi: 10.53400/mimbar-sd.v9i3.45795.
[67] Restiana and Djukri, "Effectiveness of learning models for improving science process skills: A review study," *J. Phys. Conf. Ser.*, vol. 1788, no. 1, pp. 1–8, 2021, doi: 10.1088/1742-6596/1788/1/012046.
[68] R. Agustini, "Analysis of science process skills of chemical education students through self-project based learning (sjbl) in the covid-19 pandemic era," *J. Technol. Sci. Educ.*, vol. 11, no. 2, pp. 371–387, 2021, doi: 10.3926/jotse.1288.
[69] K. A. Wray and S. McDonald, "Teacher talk supporting student progressive discourse in science," *Sci. Educ.*, vol. 34,

no. 5, pp. 3639–3666, 2025, doi: 10.1007/s11191-025-00633-4.
[70] G. G. Gizaw and S. S. Sota, “Improving science process skills of students: A review of literature,” *Sci. Educ. Int.*, vol. 34, no. 3, pp. 216–224, 2023, doi: 10.33828/sei.v34.i3.5.