FOSTERING SCIENCE PROCESS SKILLS: STRATEGIES AND ISSUES

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ABSTRACT: *The present study investigates effective instructional strategies for promoting science process skills (SPS) and the assessment measures used to evaluate these skills. Science teachers have expressed the ease of integrating certain science process skills, leading to their more frequent use in the classroom. Several instructional approaches have been identified as effective in developing various science process skills, including observing, classifying, measuring and using numbers, inferring, predicting, communicating, using space-time relations, interpreting data, controlling variables, defining operationally, hypothesizing, and experimenting. The successful development of these skills is closely tied to teachers' knowledge, skills, and attitudes toward curriculum integration. Teaching methodologies such as problem-based learning and inquiry-based learning have demonstrated effectiveness, provided that the learning journey is thoughtfully designed and time management is implemented. Emphasizing student-centered learning, relevance to socio-economic issues, interest, time-bound activities, and engagement are key considerations for effective instruction. Furthermore, the integration of technology in the teaching of science process skills is highly encouraged as a valuable tool in the learning process.*

Keywords: science process skills, student achievement, assessment of SPS, promotion of SPS, curriculum integration

1. INTRODUCTION

1.1. Background of the Study

Science process skills are fundamental abilities that enable students to think critically, engage in scientific inquiry, and develop a deeper understanding of scientific concepts. Science teachers play a crucial role in fostering these skills as they provide students with the necessary tools and guidance to become effective scientific thinkers. There are several reasons why science teachers should prioritize the development of science process skills in their students. This includes promoting scientific inquiry, enhancing critical thinking, developing problem-solving skills, fostering scientific literacy, nurturing a growth mindset, and cultivating a scientifically literate society. Students who have low process skills will tend to have low critical thinking skills. Low science process skills and students' thinking abilities lead to low student learning outcomes [1].

Promoting Scientific Inquiry

Science process skills, such as observation, questioning, predicting, and experimenting, are essential for engaging in scientific inquiry. By fostering these skills, teachers empower students to ask meaningful questions, design investigations, collect and analyze data, and draw evidence-based conclusions. These abilities are at the heart of scientific discovery and are transferable to various real-world situations.

Enhancing Critical Thinking

Science process skills encourage students to think critically and logically. Through activities such as formulating hypotheses, designing experiments, and evaluating evidence, students learn to analyze information objectively, make informed judgments, and draw valid conclusions. These critical thinking abilities are valuable not only in science but also in other academic disciplines and everyday life as there is a relationship between the science process skills and the students' critical thinking skills [2]. A pedagogical approach coupled with a well-designed learning environment promoted the use of system thinking and science process skills resulting in increased systems understanding. Thinking skills and science process skills characteristic of scientifically literate individuals to solve a challenge [3]. Since science process skills and thinking skills are interrelated, it is hoped that through active learning in science, students are able to acquire both the process skills as well as develop their thinking skills [4].

Developing Problem-Solving Skills

Problem-solving is defined to be composed of observation and critical thinking skills. Observation skill refers to collecting data, understanding and interpreting the meaning of the information using all the senses. Critical thinking involves the individual's ability to do the following: conceptualizing, logical reasoning, applying strategy, analytical thinking, decision-making, and synthesizing to solve any problem [5]. Meanwhile, science process skills involve identifying problems, generating possible solutions, and implementing strategies to solve them. By nurturing these skills, teachers enable students to become effective problem solvers. They learn to approach challenges systematically, apply logical reasoning, and adapt their methods when faced with obstacles. These problem-solving abilities extend beyond the science classroom and are applicable to a wide range of situations in both academic and professional settings. Analytical thinking is related to science process skills which are used by students to solve complex and unstructured problems [6]. Problem-solving is often challenging for students because they do not understand the problem-solving process (PSP). Students' understanding of the steps and function of the PSP through context-based learning experience will help them to solve problems correctly when encountering complex, difficult, and badly structured problems in the future [7].

Fostering Scientific Literacy

In an increasingly complex and technology-driven world, scientific literacy is crucial. Science process skills equip students with the ability to understand and critically evaluate scientific information presented in various forms, such as articles, media, and online sources. By developing these skills, science teachers empower students to make informed decisions, participate in public discourse, and contribute to the advancement of science and society. There are many teaching strategies that teachers may employ to develop scientific literacy. Problem-based learning was proven to develop critical thinking and scientific literacy among students [8]. Socio-Scientific Inquiry-Based Learning (SSIBL) pedagogywas also verified to help cultivate students' scientific literacy for responsible citizenship [9].

Nurturing a Growth Mindset

A growth mindset is defined as the belief that human capacities are not fixed but can be developed over time [10]. It is claimed that students with a growth mindset are more likely to seek out opportunities to learn, extend beyond assigned requirements, pursue learning opportunities both in and out of class, embrace and persist in the face of challenges, and utilize both feedback and study strategies to improve, among others [11]. Science process skills involve experimentation, making mistakes, and learning from them. By emphasizing the process of science rather than solely focusing on correct answers, teachers can foster a growth mindset in students. Students learn that setbacks and failures are part of the scientific journey and opportunities for growth. This mindset encourages persistence, resilience, and a willingness to embrace challenges, all of which are essential for lifelong learning and success.

Cultivating a Scientifically Literate Society

By nurturing science process skills, teachers contribute to cultivating a scientifically literate society. Students who develop these skills are more likely to pursue further education and careers in science, technology, engineering, and mathematics (STEM) fields. Furthermore, they become informed citizens capable of making evidence-based decisions on societal issues with scientific dimensions, such as climate change, public health, and technological advancements. Thus, there is a need for a curriculum for scientific literacy that empowers and supports students to engage in critical deliberation on science-based social issues so that they can critically develop virtues needed in shaping their personal and political lives [12].

In conclusion, science teachers should prioritize fostering science process skills in students to promote scientific inquiry, enhance critical thinking, develop problem-solving abilities, nurture scientific literacy, cultivate a growth mindset, and contribute to a scientifically literate society. By equipping students with these skills, science teachers prepare them for success in various academic and professional pursuits while fostering a deeper appreciation and understanding of the natural world.

However, a number of studies have determined that science process skills are not well-developed among students. One study found that 120 students from the lower secondary school have high physics factual and conceptual knowledge but when it comes to the three science process skills of planning experiments, interpreting results, and making conclusions, the lowest is on planning experiments. Thus, science process skills can be related to problem-solving and analytical skills [13].

2. THEORETICAL FRAMEWORK

The study is anchored on the Constructivist Learning Theory. The constructivist learning theory provides a suitable framework for investigating the strategies and issues related to fostering science process skills in students. This theory posits that learners actively construct knowledge and understanding through their experiences, interactions, and reflections. It emphasizes the importance of hands-on, inquiry-based learning and the role of the teacher as a facilitator of learning. Within this theoretical framework, the study can include social constructivism, inquiry-based learning, authentic contexts, metacognition and reflection and assessment and feedback.

Social constructivism emphasizes the collaborative nature of learning, where students actively engage in shared experiences and interactions with their peers and teachers. This component highlights the significance of creating a supportive classroom environment that promotes dialogue, collaboration, and the exchange of ideas. Investigating how social interactions and collaborative activities enhance the development of science process skills would be an essential aspect of the study.

Inquiry-based Learning

Inquiry-based learning is a key strategy for fostering science process skills. It involves posing questions, designing investigations, conducting experiments, and drawing conclusions based on evidence. This component focuses on exploring different inquiry-based approaches, such as problem-based learning, project-based learning, and open-ended investigations, and examining their effectiveness in promoting science process skills.

Authentic contexts refer to real-world situations or problems that provide relevance and meaning to students' learning experiences. This component emphasizes the importance of connecting science process skills to authentic contexts, such as environmental issues, health-related topics, or technological advancements. Investigating how the use of authentic contexts influences students' motivation, engagement, and application of science process skills would be a valuable aspect to explore.

Metacognition and Reflection

Metacognition refers to students' awareness and control over their thinking processes. This component emphasizes the significance of metacognitive strategies, such as goal-setting, self-monitoring, and reflection, in fostering science process skills. Examining how metacognitive practices can be incorporated into science teaching and how they influence students' self-regulation and improvement of science process skills would be an important focus of the study.

Assessment and Feedback

Effective assessment practices play a vital role in fostering science process skills. This component highlights the importance of formative assessment, providing timely and constructive feedback, and using authentic assessment tasks to evaluate students' proficiency in science process skills. Investigating how different assessment approaches impact students' learning and the identification of potential issues and challenges related to assessment in fostering science process skills would be a valuable contribution to the study.

By adopting the constructivist learning theory as the theoretical framework, the study can explore the strategies and issues surrounding the fostering of science process skills in students. It can investigate the effectiveness of various instructional approaches, the influence of social interactions, the role of authentic contexts, the impact of metacognitive practices, and the significance of assessment and feedback in promoting science process skills. This framework provides a comprehensive lens to understand and improve the teaching and learning of science process skills.

2. THE OBJECTIVE OF THE STUDY

The study aims to determine what teaching strategies were found to be effective in fostering science process skills amonghigh school students and the issues and challenges related to the teaching and learning of science process skills as communicated by the researchers through a simple literature review. Assessment of measurement of science process skills was also included to identify which science process skills were developed and not developed and the probable reasons for the underdevelopment.

3. MATERIAL AND METHODS

The study made use of the findings of Roa and Fajardo in 2022 [14] entitled, "Science Process Skills Survey as Input to Instructional Materials Development" as a starting point. The study was able to determine the science process skills that the teachers integrated into their lessons and the ease of integration. The teacher claimed that for ease of integration, the sequence is as follows: observe, classify, infer, measure, communicate, and predict. However, when asked what science processes were frequently integrated or promoted, the teachers named observe and communicate as the most often promoted while the rest of the science process skills are just often.

Then a simple review of the literature was conducted to determine the practices/strategies in promoting the development of science process skills and the issues and challenges encountered by the teachers. The published articles considered in the study are published for the last 10 years, with high school students as the level of education for the subject of the study or participants, and must be about the measurement of science process skills or instructional strategies used to promote the development of science process skills.

4. RESULTS AND DISCUSSION

The table 1 below shows the studies with pedagogical approaches and assessments to promote and measure science process skills development

Table 1. Studies with Instructional Approaches to Promote and Assess Science Process Skills

Title of Study	Authors	Strategies/Assessment	Results	Issues
E-Module Based Problem Solving in Basic Physics Practicum for Science Process Skills	Darmaji, Astalini, Dwi Agus Kurniawan , Hanaiyah Parasdila, Iridianti and Kuswanto, Muhammad Ikhlas	Use of e-module to promote science process skills	the use of e-modules can train students' science process skills [15]	Printed modules tend to be informative and less attractive which cannot display sound, video, animation, and images that can provide a clear explanation of the concepts conveyed.
Science Process Skills and Attitudes Toward Science among Palestinian Secondary School Students	Afif Hafez Zeidan1,* & Majdi Rashed Jayosi	18 - question science process skills test and a 25-item attitudes toward science questionnaire	Observation skills, prediction skills, and measuring skills are well-developed among students. They found the skill of observation and predicting easier than the other science process skills [16]	The traditional methods cannot develop integrated science process skills.
Science Process Skills Characteristics of Junior High School Students in Lampung	Sunyono Sunyono	Grade 9 students were made to answer a survey questionnaire on Science Process Skills	Low SPS with observing and classifying as moderate for students living near the capital and low for all SPS for students living from the capital [17]	Students cannot relate concepts to real-world phenomena and the teachers do not have sufficient knowledge of the conceptual change process, thus delivery of lessons is limited to the curriculum
The Effectiveness of Inquiry-Based Learning Model to Improve Science Process Skills and Scientific Creativity of Junior High School Students	Muktar B. Panjaitan and Asister Siagian	The instrument used to measure science process skills was in the form of a 6-point essay. The test showed indicators of science process skills in the form of formulating hypotheses, naming variables, controlling variables, making operational definitions, conducting experiments, interpreting, designing investigations, application of concepts	Students who are able to do tasks related to science process skills will also be able to do scientific creativity tasks. [18]	Teachers lacked the knowledge and skills to foster students' ability to generate new ideas for technology.
The teaching of science process skills in Thai contexts: Status, supports and obstacles.	Kruea-In, N., & Thongperm, O.	Case study of 5 teachers being observed in their classes to see science process skills promotion	Selective science courses were more responsible to promote student understanding and performance of science process skills. [19]	Time constraints and Insufficiency of laboratory equipment

Guided Inquiry Model Through Virtual Laboratory to Enhance Students' Science Process Skills on Heat Concept	Gunawan, Harjono, Hermansyah, & Herayanti,	The guided inquiry model through the virtual laboratory was applied to the experimental group and the conventional model for the control group.	The guided inquiry models through virtual laboratory have a significant effect on science process skills, especially on skills: hypothesizing, practicing, and communicating.[20]	The duration of laboratory and practicum activities is often lengthy, which poses challenges in terms of time management.
The Effects of Computer Simulations on Students' Science Process Skills? Literature Review	Behçet Çelik	reviewed the research about computer simulations whether or not they have an effect on students' SPSs in science education	Computer simulations have been shown to be more effective in science teaching compared to traditional methods. However, it has been observed that solely relying on simulations to present science concepts is insufficient for developing science process skills (SPSs). While simulations can enhance students' understanding of scientific concepts, they need to be complemented with other teaching methods to fully cultivate SPSs. [21]	virtual laboratories in online learning still have some problems
Practicum Activity: Analysis of Science Process Skills and Students' Critical Thinking Skills	Endah Febri Setiya Rini, and Febri Tia Aldila	Interview science teachers and students on implemented practicum activities, and assessment of science process skills in practicum activities	The schools included in the study were found to have implemented practicum activities as part of their science curriculum. However, the assessment of science process skills to support science learning was found to be infrequent and lacking in consistency. [22]	SPS is not being measured often

4. CONCLUSION

In conclusion, this study highlights the importance of effective instructional strategies for promoting science process skills (SPS) in the classroom. The findings emphasize that science teachers play a crucial role in integrating and developing these skills through their knowledge, skills, and attitudes toward curriculum integration. The study identifies various instructional approaches, such as problem-based learning and inquiry-based learning, that have proven effective in fostering specific science process skills. Additionally, the integration of technology in science instruction is recognized as a valuable tool for enhancing the learning experience. It is evident that student-centered learning, relevance to socio-economic issues, interest, time-bound activities, and engagement are critical factors in effective instruction.

This research underscores the significance of continuous professional development for teachers, enabling them to acquire the necessary knowledge and skills to effectively promote science process skills among students. Future studies should further explore the best practices for integrating science process skills into the curriculum and provide concrete guidance for teachers in implementing these strategies. By fostering the development of science process skills, we can empower students to become critical thinkers, problem solvers, and lifelong learners in the field of science. Overall, this study contributes to the growing body of knowledge on effective instructional strategies for enhancing science process skills in the classroom, ultimately aiming to improve science education and equip students with thenecessary skills for their future endeavors in the field of science and beyond.

5. RECOMMENDATION

Based on the findings of this study, it is recommended to enhance the promotion of science process skills in the classroom through the following actions: First, provide ongoing professional development opportunities for science teachers, focusing on strategies to integrate and develop science process skills effectively. Second, encourage the use of student-centered instructional approaches, such as problem-based learning and inquiry-based learning, to actively engage students in the process of scientific inquiry and foster the development of science process skills. Third, integrate technology into science instruction to provide additional resources and tools that enhance students' understanding and application of science process skills. Fourth, foster collaboration among science teachers to share best practices, resources, and instructional strategies for promoting science process skills. Fifth, advocate for curriculum frameworks that explicitly address the integration of science process skills and allocate sufficient instructional time for their development. Finally, support research

initiatives that explore the effectiveness of different instructional strategies in promoting science process skills within the local context.

By implementing these recommendations, educators and policymakers can create an environment that supports the development of science process skills among students, enabling them to become critical thinkers, problem solvers, and lifelong learners in the field of science.

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