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Descriptive Analysis of Science Process Skills (SPS) and Scientific Reasoning (SR) of High School Students and Pre-service Teacher in Science Learning

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Abstract

This study aimed to analyze science process skills (SPS) and scientific reasoning (SR) among high school students and prospective teachers. This study used a quantitative descriptive approach with a survey method involving a self-report perception questionnaire to collect data from eleventh and twelfth grade science students and 187 prospective teachers majoring in Physics Education. The results showed that Science learning in high school and pre-service teachers has begun to integrate science process skills (SPS) and scientific reasoning (SR), but its implementation is inconsistent and practicums are still less intensive, so that SPS strengthening is not optimal. Obstacles that arise include limited practicums and facilities, the dominance of theoretical learning, difficulty understanding abstract concepts, and low systematic thinking habits and confidence in scientific argumentation. On the other hand, students and pre-service teachers hope that science learning is more based on interesting and contextual practicums, relevant to everyday life, utilizing technology, and designed collaboratively and adaptively so that SPS and SR can develop simultaneously and be ready to face the challenges of the 21st century.

INTRODUCTION

21st-century learning prioritizes critical and creative thinking skills, as well as the ability to collaborate and communicate effectively [1]. This is crucial for preparing students to face future global challenges. Achieving these 21st-century learning indicators can be achieved through the implementation of innovative and adaptive learning patterns [2]. In the 4.0 and 5.0 eras, learning must be integrated with technology and social skills that can help students develop their knowledge and skills. One such skill is science process skills, which are necessary for understanding and applying scientific concepts effectively [3]. These skills include the ability to observe, formulate hypotheses, and conduct experiments.

Good science process skills will improve students' critical thinking and problem-solving abilities, which are essential in this modern era [4], [5]. Science process skills are essential for every student to adapt to raSRd changes in science and technology [6]. These skills will help them develop the scientific attitudes necessary for everyday life and future careers. However, science process skills have not always been a priority in learning objectives. The learning process focuses solely on the delivery of material by teachers or lecturers without actively involving students. This fact impacts students' ability to master scientific concepts comprehensively. Scientific activities such as observation, experimentation, measurement, hypothesis testing, and communication are still unfamiliar to students, resulting in their scientific thinking skills being suboptimal [7].

The low scientific process skills possessed by students or university students impacts their weak scientific reasoning in applying the theories they have learned [8]. As student teachers, this situation cannot be ignored, because it can trigger the same problems to occur continuously in the next generation through the process of knowledge and skills transfer in the classroom [9], [10]. Furthermore, prospective students have a more crucial position in developing scientific process skills and scientific reasoning, because students are not enough to master the material but must also have the pedagogical ability to explore students' understanding through learning experiences that are challenging and stimulate students' curiosity.

The conceptual structure of Natural Science learning, with a focus on two main components: Science Process Skills (SPS) and Scientific Reasoning (SR)[11]. SPS, located on the left side, covers essential skills in the scientific process, such as observing, formulating hypotheses, and conducting experiments. On the right side, scientific reasoning (SR) focuses on scientific thinking skills, such as analyzing data, drawing conclusions, and understanding scientific theories [12]. These two components are explained in the context of learning that is contextual [13], meaning relevant to real life, collaborative, which encourages cooperation between students, and adaptive, meaning able to adapt to developments in science and technology [14]. This approach emphasizes the importance of integrating these two skills in science learning to prepare students to face future global challenges.

Science process skills and scientific reasoning are considered core 21st-century competencies that must be taught explicitly through inquiry and practical activities, not just through lectures [15]. Science process skills, such as observing, classifying, interpreting data, predicting, and designing experiments, have been shown to contribute directly to student conceptual mastery, critical thinking, and learning outcomes [16]. Numerous correlational studies demonstrate a strong relationship between science process skills and conceptual mastery and other 21st-century skills, particularly when learning utilizes structured practicals and systematic laboratory activities. Scientific reasoning is described as an evidence-based thinking process that includes argument construction, logical inference, and claim evaluation, and can be enhanced through tiered inquiry learning, data literacy, and multiple representation-based worksheets [17]. A literature review confirms that authentic assessments based on inquiry tasks and performance assessments are more capable of capturing the full spectrum of science process skills and scientific reasoning than memorization tests. In general, international literature recommends consistent integration of meaningful practicums, guided inquiry, simulation technology, and authentic assessment so that science process skills and scientific reasoning develop simultaneously in science learning [18].

Research on science process skills and scientific reasoning has generally separated the two, leaving their relationship unclear, particularly in the context of Pre-service Teacher. Existing studies have largely focused on improving science process skills or scientific reasoning alone, and tySRcally on only one group (students or student teachers). Consequently, there has been no comparative mapSRng that places students and student teachers within a single analytical framework. Therefore, the title "analysis of science process skills and scientific reasoning in students and student teachers" fills an important gap, it comprehensively examines the levels of science process skills and scientific reasoning, compares the profiles of both in students and Pre-service Teacher, and examines the extent to which Pre-service Teacher are truly prepared to serve as role models and facilitators of scientific practice and reasoning in the classroom.

Therefore, it is important to identify and develop science process skills and scientific reasoning among high school students and pre-service teachers. This study aims to explore the level of mastery of these skills and identify factors that influence their development. With a better understanding, it is hoped that more effective learning strategies can be found that can improve science process skills and scientific reasoning, so that students and pre-service teachers can be better prepared to face the increasingly complex challenges of education and the real world.

METHOD

This research is a descriptive quantitative study, which aims to provide a systematic and structured overview or description of a particular phenomenon or variable. In this context, the primary objective is to identify and describe science process skills and scientific reasoning in learning at school and university. The method used was a survey, distributing a questionnaire to respondents. The population in this study was all high school students in grades 11 and 12 studying science and prospective teacher education. The research sample was determined using a purposive sampling technique, taking into account majors and subjects. The sample consisted of high school students in grades 11 and 12 studying physics and prospective teacher education majors majoring in physics. The research instrument used was a questionnaire containing questions related to science process skills and scientific reasoning currently taught in schools and universities. This questionnaire was structured using a Likert scale. The questionnaire outline can be seen in Table 1 below.

Table 1. Grid of the science process skills and scientific reasoning questionnaire

Indicator	
Science Process Skills	**Scientific Reasoning**
Application of science process skills in learning	Application of scientific reasoning in learning
Experiences and constraints in developing science process skills	Experiences and constraints in developing scientific reasoning
Hopes for science learning	Hopes for science learning

The research procedure consisted of determining the research sample as respondents, administering a questionnaire regarding students' perceptions of scientific process skills and reasoning, analyzing the survey results from the questionnaire, and providing conclusions. This is shown in Figure 1.

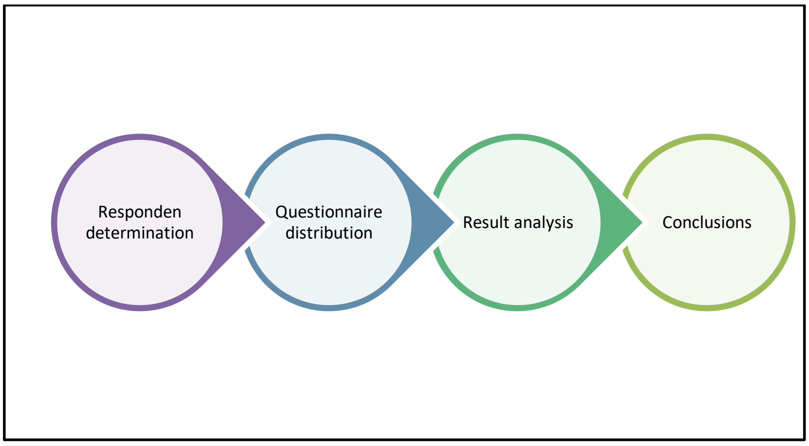

Figure 1. Research procedure

The data analysis technique uses a rating scale of 1-4, calculating the average score of each indicator of science process skills and scientific reasoning and converting it into a percentage.

RESULTS AND DISCUSSION

Application of Science Process Skills and Scientific Reasoning in Learning

fter being given a questionnaire regarding the application of science process skills and scientific reasoning in science learning, the responses of students were then calculated in Table 2 below.

Table 2. Student and university student responses to the implementation of SPS and SR

Science Process Skills (SPS)		Scientific Reasoning (SR)	
Statement	**Response (%)**	**Statement**	**Response (%)**
Level of understanding of SPS	Very Understanding (9,5%) Understanding (39,7%) Lack of understanding (50,8%) Don't Understand (0%)	Level of understanding of SR	Very Understanding (4,2%) Understanding (83,3%) Lack of understanding (12,5%) Don't Understand (0%)
Teachers/lecturers involve students in practicals to improve SPS	Very often (17,2%) Quite often (42,2%) Rarely (40,6%) Never (0%)	Teachers/lecturers involve students in practicals to improve SR	Very often (13,9%) Quite often (50%) Rarely (34,7%) Never (1,4%)
SPS can help understanding	Very helpful (46.9%) Helpful (53.1%) Not very helpful (0%) Not helpful (0%)	SR helps Understanding	Very helpful (29.2%) Helpful (68%) Not very helpful (2.8%) Not helpful (0%)
Difficulty in understanding SPS	Very easy (9.4%) Fairly easy (62.5%) Fairly difficult (25%) Very difficult (3.1%)	Difficulty in understanding SR	Very easy (0%) Fairly easy (61.1%) Fairly difficult (37.5%) Very difficult (1.4%)

Table 2 above shows that respondents' understanding of Science Process Skills (SPS) still needs improvement. Most respondents (50.8%) admitted to having little understanding of SPS, while only a small proportion (9.5%) felt they understood it very well. This contrasts with Scientific Reasoning (SR), where most respondents (83.3%) felt they understood it, indicating that scientific thinking skills are more developed than scientific process skills. Practical activities, which should be the primary means of training students in the field of mathematics and natural sciences, have not been optimally implemented. Although most teachers and lecturers frequently involve students in practical activities, the frequency is still low (only 17.2% and 13.9% said they do so very often). This can contribute to poor mastery of the field of natural sciences, as they require direct experience and repeated practice in observing, measuring, classifying, and summarizing data.

Although understanding of SPS is not optimal, the majority of respondents considered that SPS and SR were very helpful or helpful in understanding the material, in line with previous research which stated that students recognized the benefits of SPS on scientific literacy even though indicators such as data interpretation were still low [19]. This means that respondents are aware of the importance of science process skills and scientific reasoning in learning. This finding is reinforced by the findings of previous research which revealed that science process skills and scientific reasoning are very much needed in improving understanding of material, even though there are several shortcomings in several aspects such as data interpretation, communication, hypotheses, and variable control [20].

In general, these findings illustrate that SPS and SR learning needs to be maintained and its application improved, especially through more frequent and focused practical activities, because practical activities can provide authentic experiences rather than methods that tend to be passive [21], [22], [23]. In this way, students not only understand the concept theoretically (through SR), but are also able to master the scientific steps practically (SPS) as emphasized in the real science approach.

Obstacles to Developing SPS and SR in Science Learning

The distributed questionnaire also explored the obstacles faced by students in developing science process skills (SPS) and scientific reasoning (SR). These obstacles are summarized into several important aspects, as shown in Table 3 below.

Table 3. Constraints or problems in developing SPS and SR

Science Process Skills (SPS)	Scientific Reasonng (SR)
Lack of hands-on practice and experiments	Difficult language and explanation methods
Lack of engaging teaching methods	Difficulty understanding basic and abstract concepts
Focusing solely on theory, lacking practical skills	Lack of practice and rarely applying SR
Limited facilities and lab equipment	Difficulty analyzing data and drawing conclusions
Low basic understanding of SPS	Lack of confidence in asking questions and arguing
Lack of space for asking questions, observing, and drawing conclusions	Limited understanding of experimental activities
Lack of time allocated for SPS labs and exercises	Lack of systematic thinking

Table 3 shows that the obstacles to the development of Science Process Skills (SPS) and Scientific Reasoning (SR) faced by students are systemic, encompassing pedagogical, structural, and cognitive aspects. In the SPS domain, the dominant obstacles are a lack of direct practice and experiments, less engaging teaching methods, a focus on theory, limited laboratory facilities, and minimal time allocated for practical work.

This pattern indicates that students have not yet received an adequate learning environment to fully experience the scientific process, from observing, measuring, classifying, to interpreting and communicating results. This pattern indicates that students have not yet received an adequate learning environment to fully experience the scientific process, from observing, measuring, classifying, to interpreting and communicating results. This finding aligns with previous research that indicates that inadequate learning environments, such as facilities and learning models, can hinder the scientific process and communication, and encourage practical learning [24], [25]. SPS, which actually requires active physical and mental involvement, ultimately develops only partially because students' learning experiences mostly stop at the level of verbal explanations from teachers and conceptual exercises on paper [26].

In the realm of SR, prominent obstacles relate to the ability to understand and process scientific information. Students reported difficulty grasSRng basic and abstract concepts, teachers' language and explanations deemed difficult to understand, infrequent practice and application of SR in learning, and a lack of systematic thinking habits [27]. These conditions indicate that scientific thinking processes such as interpreting data, connecting theories to phenomena, and drawing evidence-based conclusions have not yet become common cognitive practices in the classroom. Limited understanding of the purpose and meaning of experiments, coupled with a lack of confidence in asking questions and presenting arguments, reinforces the indication that students' SR is not developing optimally desSRte their involvement in practical activities.

Integratively, it appears that the Science and Science Process (SPS) and scientific reasoning (SR) not only equally constrained, but also interconnected. Limited practice, facilities, and time mean that students lack rich emSRrical data and experiences to base their reasoning on. On the other hand, weak conceptual reasoning means that practicums are easily reduced to procedural activities without in-depth reflection. This means that the main problem is not simply a lack of practicums or difficulty understanding concepts, but rather the lack of a learning design that intentionally integrates experiences of the science process with the development of scientific thinking. This finding is important for the development of science learning theory, as it reinforces the view that SPS and SR should be positioned as two dimensions of competence that are developed coherently, rather than as separate skills taught sporadically.

Thus, the constraints of SPS and SR not only serve as a descriptive overview of classroom-level problems, but also as an emSRrical basis for developing a more comprehensive science learning design framework to provide conceptual and practical contributions. Conceptually, by reaffirming the close relationship between scientific practice and scientific reasoning, and practically, by offering a learning model capable of bridging the gap between scientific practice and scientific thinking in the classroom.

Students' and College Students' Expectations for Science Learning

The distributed questionnaire also examined students' expectations for future science learning, ensuring they possess both practical and theoretical skills. Table 4 summarizes these expectations across several aspects.

Table 4. Students' and College Students' Expectations for the Development of SPS and SR

Science Process Skills (SPS)		**Scientific Reasoning (SR)**	
Statement	**Response (%)**	**Statement**	**Response (%)**
Do you want science learning to involve more SPS?	Really want (48.4%) Want (46.9%) Don't want (0%) Don't know (4.7%)	Do you want science learning to involve more SR?	Really want (34.7%) Want (55.6%) Don't want (5.6%) Don't know (4.2%)
What are your hopes regarding the implementation of SPS in future learning?	More applied in learning (29.7%) More fun and engaging (51.6%) Focused on practical experience (7.8%) More relevant to everyday life (10.9%)	What are your hopes regarding the implementation of SE in future learning?	More applied in learning (31%) More emphasis on experimental activities and data analysis (29.6%) More use of technology in experiments and data collection (35.2%) No expectations (10.9%)

Based on Table 4 above, the majority of students want science learning to involve more Science Process Skills (SPS) and Scientific Reasoning (SR). For SPS, 48.4% stated they "really want" and 46.9% "want," while for SR, 34.7% said they "really want" and 55.6% "want." The proportion of students who didn't want or didn't know was very small (0% didn't want SPS, 5.6% didn't want SR, and around 4-5% didn't know). This demonstrates students' positive attitudes toward science learning that emphasizes processes and reasoning, rather than simply memorizing concepts.

Students' greatest hope was for SPS to be implemented more extensively in their learning (29.7%), meaning they want activities that truly practice observing, measuring, classifying, and inferring. Approximately 51.6% hoped for learning to be more fun and engaging, thus viewing SPS as a means to make lessons more lively and less boring. Some students wanted learning to focus more on practical experiences (7.8%) and be more connected to everyday life (10.9%), indicating a need for real-world contexts and applications.

Regarding the SR, 31% of students hoped for more application of SR in learning, aligning with their expectations for the Scientific Reasoning (SR) aspect. 29.6% wanted learning to emphasize more experimental activities and data analysis, which are core to scientific reasoning. Furthermore, 35.2% hoped for greater use of technology in experiments and data collection, indicating that students are ready to utilize digital technology to support scientific understanding. Only 10.9% stated they had no specific expectations, indicating that most students already had an ideal vision of what they wanted science learning to be like.

These data indicate that teachers need to design science lessons that center on scientific activities such as experiments, direct observation, and data analysis. Learning should be presented in an engaging manner, integrating SPS and SR, and linking the material to everyday contexts to enhance its meaning. The use of technology is also crucial to meeting students' expectations for modern and interactive learning. By fulfilling these expectations, it is hoped that students' learning motivation and understanding of science concepts will increase.

CONCLUSIONS

Science learning in high school students and prospective teacher students has begun to integrate science process skills (SPS) and scientific reasoning (SR), but its application is still inconsistent and has not become the main focus of learning activities, so that practical activities that can practice observation, measurement, classification, experiments, and data analysis are not intensive enough to really strengthen SPS even though students feel their scientific reasoning is relatively better. The main obstacles that arise include limited direct practical work, minimal integration of real experiences in learning, limited laboratory facilities and time, and teaching methods that are still predominantly theoretical, plus difficulties in understanding basic and abstract concepts, teachers' explanatory language that is considered difficult, systematic thinking habits that have not yet been formed, and low self-confidence in asking questions or arguing scientifically, so that SPS and SR develop partially and are not integrated. On the other hand, the majority of students and prospective teachers have a strong hope that science learning will involve more SPS and SR through interesting, fun, relevant to daily life practicums, emphasizing data analysis and experiments, and utilizing technology for experiments and data collection, with contextual, collaborative, and adaptive learning designs so that SPS and SR can develop simultaneously and prepare them to face the challenges of 21st-century science and education.

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