Chemistry teachers’ understanding of science process skills in relation of science process skills assessment in chemistry learning

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Abstract. A Science process skill (SPS) is a fundamental scientific method to achieve good knowledge. SPS can be categorized into two levels: basic and integrated. Learning SPS helps children to grow as individuals who can access knowledge and know how to acquire it. The primary outcomes of the scientific process in learning are the application of scientific processes, scientific reasoning, accurate knowledge, problem-solving, and understanding of the relationship between science, technology, society, and everyday life's events. Teachers' understanding of SPS is central to the application of SPS in a learning process. Following this point, this study aims to investigate the high school chemistry teachers' understanding of SPS pertains to their assessment of SPS in chemistry learning. The understanding of SPS is measured from the conceptual and operational aspects of SPS. This research uses qualitative analysis method, and the sample consists of eight chemistry teachers selected by random sampling. A semi-structured interview procedure is used to collect the data. The result of the analysis shows that teachers' conceptual and operational understanding of SPS is weak. It affects the accuracy and appropriateness of the teacher's selection of SPS assessment in chemistry learning.

Key words: Science process skills, science process skills assessment, chemistry teacher

1. Introduction
The purpose of science education is to help students to understand scientific knowledge and build students' abilities using scientific approach [1]. SPS is an important aspect of teaching to achieve good knowledge. SPS skill in the learning process is not only served as the basis of scientific methods but also learning about the characteristics of knowledge. SPS can be categorized into two levels, which are basic and integrated levels. Basic science process skills consist of observing, classifying, measuring, using numbers, using space and time relationship, inferring, predicting, and communicating. Integrated science process skills consist of identifying variables, formulating hypotheses, defining variables operationally, experimenting, and interpreting data and drawing conclusions[2]. Changing hypotheses, building and interpreting data and images will help children to grow as individuals who are capable not only to access knowledge but also determine it [3]. Individuals with higher mental development can describe, portray and solve both individual and social problems. Also, SPS has a great influence in
developing ones higher mental processes including critical and creative thinking and they can transfer this ability to other disciplines [4]. Teachers are expected to have a good understanding of SPS so they can transfer it to their students [5] and they are expected to be able to measure SPS from students so that students' achievement in mastering SPS can be appropriately evaluated. From the results of this evaluation, teachers are expected to develop SPS learning method to their students.

2. Methodology
The methodology of this research is qualitative analysis. The sample in this study consists of 8 chemistry teachers, with the detail of four chemistry teachers with 1-5 years of teaching experience and four chemistry teachers with teaching experience of more than five years. Data is collected by semi-structured interviews with six questions present. From the interview, data is classified based on the suitability of the answers. Data is presented in a table form for each question. Data analysis is conducted by connecting the interview results.

3. Findings
The Results from semi-structured interviews are shown in the following tables 1-6.

Question 1: What do you know about SPS? Explain your answer.

Table 1. Chemistry Teachers’ Opinion about SPS

| Category                  | Frequencies | Chemistry teachers’ ideas                                                                 |
|---------------------------|-------------|------------------------------------------------------------------------------------------|
| Scientific Method         | 4           | SPS is a skill in using scientific methods                                                 |
| Theoretical understanding | 2           | SPS is student’s ability to understand science                                             |
| learning approaches       | 2           | SPS is a learning approach which is designed for students to discover facts and concepts   |

Question 2: How do you teach SPS to students in chemistry learning?

Table 2. Chemistry Teachers’ Ideas About Teaching SPS to Students in Chemistry Learning.

| Frequencies | Chemistry Teachers’ Ideas                  |
|-------------|-------------------------------------------|
| 7           | Practical work/ Laboratory performance    |
| 1           | Science project                           |
| 2           | Problem-based learning                     |
| 1           | Discussion                                |
| 1           | Visiting industry                          |
| 1           | Lecture                                   |

Question 3: What SPS indicators that are trained to students?
### Table 3. Chemistry Teachers' Ideas About SPS Indicators That are Trained to Students

| Category                     | Frequencies | Chemistry Teachers’ Ideas                                                                 |
|------------------------------|-------------|------------------------------------------------------------------------------------------|
| Scientific Method            | 5           | Skills in practical work in laboratory such as observing, formulating problems, hypothesizing, designing experiments, analyzing data, drawing conclusions, and communicating |
| Skills using equipment       | 1           | Skill in utilizing laboratory equipment                                                   |
| Concept                      | 1           | Understanding of scientific concepts in chemistry                                         |
| Learning activities          | 1           | Students’ active performance in learning process                                          |

Question 4: In chemistry, how do you assess student's SPS?

### Table 4. Chemistry Teachers' Ideas About How to Assess Student's SPS

| Category                     | Frequencies | Chemistry Teachers’ Ideas                                   |
|------------------------------|-------------|------------------------------------------------------------|
| Observation of practicum     | 4           | Observations from laboratory performance                  |
| Paper and Pencil Test        | 2           | Written test about conceptual understanding                |
| Observation class            | 2           | Observations during learning in the classroom              |

Question 5: What SPS indicators are assessed in chemistry?

### Table 5. Chemistry Teachers’ Ideas About Indicators are Assessed in Chemistry

| Category                     | Frequencies | Chemistry Teachers’ Ideas                                                                 |
|------------------------------|-------------|------------------------------------------------------------------------------------------|
| Scientific Method            | 5           | Skills in laboratory performance such as observing, formulating problems, hypothesizing, designing experiments, analyzing data, drawing conclusions, and communicating |
| Skills using laboratory equipment | 1       | Skill in utilizing laboratory equipment                                                   |
| Concept                      | 2           | Understanding of scientific concepts in chemistry                                         |

Question 6: What is the difficulty in assessing SPS?

### Table 6. Chemistry Teachers' Ideas About The Difficulty in Assessing SPS

| Category                     | Frequencies | Chemistry Teachers’ Ideas                                                                 |
|------------------------------|-------------|------------------------------------------------------------------------------------------|
| Instrument of assessment     | 5           | There is no special assessment instrument to assess all SPS indicators, so the assessment is subjective |
| Students ability             | 2           | Students are not accustomed to doing problem-solving, so SPS is difficult to perform      |
| Assessment method            | 1           | Teachers can’t assess students’ SPS one by one accurately because of the weakness of the observation method |
4. Discussion and Conclusion

In table 1. It shows that four chemistry teachers have an understanding that SPS is a skill in using scientific methods. Meanwhile, two chemistry teachers understand SPS as a concept, and the rest two chemistry teachers understand SPS as a learning approach. This fact shows that chemistry teachers still have a weak understanding of SPS.

In table 2. It shows that the majority of chemistry teachers believe that SPS can be trained to students through practice in laboratory, science projects and problem-based learning. However, chemistry teachers who argue that discussions, industry visits, and lecture methods can be used as SPS learning methods. This argument doesn't follow the definition of SPS. SPS cannot be trained through discussions, industry visits, and lecture method.

In table 3. It shows that most of the chemistry teachers train SPS to students as a scientific skill that included in laboratory practice. However, some teachers who instruct SPS less appropriately. They train SPS by enhancing student's ability in using equipment in the laboratory, while in fact, SPS is not only about the skills of using equipment, they also teach SPS as mere conceptual understanding and consider that student's actual performance during learning process as a part of SPS.

In Table 4. It shows that four chemistry teachers assess SPS through observations during practical work in the laboratory, two chemistry teachers using written test, and two teachers assess SPS through observations in the classroom. Those form of assessments is in line with their understanding of SPS. Observation during practical work in the laboratory is appropriate to assess SPS, but the written test of concept comprehension is not. The written test cannot be used to assess SPS if the question indicators do not refer to SPS. Meanwhile, classroom observation is not suitable to assess SPS.

In table 5. It shows that chemistry teachers assess SPS based on the learning activities that are employed in training SPS. Majority of chemistry teachers assess SPS indicators as integrated skills in the laboratory. One chemistry teacher assesses SPS only through skills in using laboratory equipment, and two chemistry teachers are inappropriately assessing SPS by assessing students' conceptual understanding and attitudes during the learning process.

In table 6; It shows that chemistry teachers assess SPS based on subjective observation because there is no particular instrument is available to be used. The observation instrument can't be used to assess SPS accurately, so it is not the best and suitable one to assess SPS. Meanwhile, there is teacher's misconception in understanding SPS, so their assessment of the students' SPS is not legit.

From the results of the chemistry teacher's answers to the question of SPS and its assessment, the majority of the teachers do not fully understand SPS. They can adequately define SPS but cannot mention skill indicators in the SPS. Some chemistry teachers already understand the concept of SPS, but they lack in SPS operational practices. Most of the chemistry teachers train SPS to students through practical work in the laboratory. SPS is considered taking place in a science laboratory and the practical work only about using apparatus and following instructions [6], and many of the skills associated with experimental investigations are rarely taught explicitly [7]. This happens because teachers assume that students can obtain SPS only through experience doing practical work in the laboratory. The assumption facilitates the acquisition of the operational aspects of the SPS but does not promote a conceptual understanding of the accuracy of the scientific inquiry process involved in the investigation. Students may be able to observe procedurally, but they do not have a clear understanding of the purpose of observation in scientific investigation. Thus, creativity and originality, which are the characteristics of scientific inquiry, will also be difficult to develop with the limited acquisition of conceptual understanding required in SPS [8]. Chemistry teachers’ should have a strong understanding of SPS and demonstrate competency in SPS both operational and conceptual so SPS can be effectively and meaningfully taught to students[9].

Chemistry teachers understand that observation can be used as an SPS method of assessment, but in practice, teachers observe without using appropriate assessment instruments, so the science process skills are not measured accurately and adequately. Besides, the teachers who assess SPS through the written test but only measure the concepts and theories instead of SPS. There are also teachers who measure SPS only from students' accuracy in using tools or instruments. Teachers' difficulty in
assessing SPS by observation method lies in large classes with 30 students. Teachers will find it difficult to accurately assess the SPS of each student. These conditions prompted the efficient and objective SPS measurement. One of the possible solutions is using written test [10]. The test subject may take written test even though a tool is often required to complete the test subject. The process of science is inseparable in practice from the conceptual understanding involved in learning and the application of science [11].

One of the role the chemistry teacher as a science teacher is to facilitate and help students to understand the content of science knowledge. One of the contents of science knowledge is the skill of science process. Chemical teachers are required to have an in-depth understanding of the science process’s skills as well as how to teach the science process. Content and pedagogical knowledge should be integrated to create new knowledge [12]. It can be defined as pedagogical content knowledge (PCK). PCK is a special knowledge that teachers have about how to teach certain content to learners through a strategy that leads to understanding. PCK is the ability of teachers to understand and apply how to help a group of students understand the specific subject by using some instructional, representational, and assessment strategies by working within the contextual, cultural, and social constraints in environmental learning [13].

PCK is described as the knowledge that used to transform the content of subject into a form that easier understood by students [14][15][16][17][18]. In this case, PCK development involves a shift in the teachers’ understanding of the ability to understand the subject matter for themselves, and can explain the subject matter in new ways, rearrange every part of the material in activity and emotion, in metaphors and exercises, and in the example and demonstrations, so that it can be understood by students [17].

Seven categories of knowledge according to PCK that teachers should have to manage to learn effectively. The seven categories are [19]:

| Components                        | Elements                                                                 |
|-----------------------------------|--------------------------------------------------------------------------|
| Knowledge of science              | Science content, scientific practice, the nature of science, scientific process |
| Knowledge of goals                | Scientific literacy, real-life application, integrated understanding     |
| Knowledge of students             | Different levels, needs, interests, prior knowledge, ability, learning difficulties, misconceptions |
| Knowledge of curriculum organization | State and local standards, state and local standardized tests, making connections between lessons and units, organizing lessons in specific order, making decisions about what to teach, flexible design |
| Knowledge of teaching             | Various teaching methods, use of motivating activities, ability to select effective activities. |
| Knowledge of assessment           | Formal and informal ways of assessment, skills for students' discussion and questioning, immediate feedback |
| Knowledge of resources            | Materials, activities, multimedia, local facilities, laboratory technology, science magazines |

Based on PCK exposure, the following are the PCK chemistry teacher description based on seven components according to pedagogic competence and professional competence.

4.1. Knowledge of Science
All respondents have a chemical education background. However, not all chemistry teachers have an in-depth knowledge of SPS. 4 chemistry teachers are not right in understanding the SPS. They
understand the SPS as the ability of students to use reason and creativity to understand the science and approaches to learning that students can find facts and concepts.

4.2. Knowledge of Goals
The teacher's knowledge of learning objectives is closely related to how the teacher does the learning and evaluates them. Achievement of learning objectives can be known from the evaluation of learning. One of the goals of SPS learning is students can solve problems in daily life. From the eight chemistry teachers, most of them less understand the SPS. This has an impact on SPS learning. Some respondents put incorrect answers regarding SPS learning.

4.3. Knowledge of Students
Knowledge of students includes their interest in chemistry learning. Most of them think chemistry is hard to learn. In this case, the teacher must plan the lesson so that the material can be easily understood by the students. Four chemistry teachers are less precise in planning SPS lessons. This can be seen from the form of learning they are doing: Problem-based learning, Discussion, Visiting industry, and Lesson with the lecture.

4.4. Knowledge of Curriculum Organization
The curriculum includes teacher insight into the high school curriculum in Indonesia. Indonesia uses a scientific approach to science learning. 8 respondents know the curriculum in Indonesia is using the scientific approach. On the other hand, two teachers who argue that the scientific approach is the same thing as the science process skills. This suggests that teachers should better understand the scientific approach and science process skills.

4.5. Knowledge of Teaching
Teachers' understanding of SPS influences how teachers teach SPS to students. The SPS teaching form affects the classroom management conducted by the teacher. Teachers have their form of teaching based on their understanding of the SPS. When teachers think SPS is a skill in using scientific methods, they use the practical work/laboratory performance and science project to teach SPS to students. Teachers who argue that SPS is the ability of students to use reason and creativity to understand science, use Problem-based learning models and discussion methods to teach the KPS.

4.6. Knowledge of Assessment
Assessment has an important role to evaluate the achievement of learning objectives. Four teachers are not appropriate in assessing SPS. They use Paper and Pencil Test and Observation class to rate SPS. and three chemistry teachers evaluated SPS with inappropriate indicators, i.e. Using laboratory equipment and Understanding concepts in chemistry. With improper assessment methods, the achievement of learning objectives can not be evaluated properly.

4.7. Knowledge of Resources
Some chemistry teachers used laboratories and classes to teach SPS. this will support SPS learning. but there are some teachers who only use the class. The using facility is related to how the chemistry teacher understands teaching SPS to the students.

Given the importance of PCK reflection, understanding the relationship between teachers' reflective capacity, PCK, and student learning will give a clearer picture of how student learning relates to the knowledge and thinking brought by the teacher [19]. The teacher's understanding of SPS will affect the learning process that has been planned and its evaluation. The process of science can not be separated in practice from the conceptual understanding involved in learning and the application of science so that appropriate instruments are needed to measure it. Knowledge of assessment is an important component of PCK. This component includes knowledge of specific instruments, approaches, or activities [20]. Also, teachers should know what students know about topics and areas
that may be experiencing difficulties. These components include knowledge of students' conceptions of a particular topic, learning difficulties, motivation, and diversity of abilities, learning styles, interests, developmental levels, and needs [15]. Also, the teachers' knowledge of SPS will affect students' understanding of SPS. Based on PCK analysis, chemistry teachers as respondents in this study still have a weak PCK. Therefore it is expected that teachers can improve their understanding of the SPS by learning independently or attending training.

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