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ORIGINAL ARTICLE

Improving Science Process Skills of Students: A Review of Literature

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ABSTRACT

This paper aims to review and assess the strategies available in literature to improve the practices of science process skills (SPS) among students. SPS encompasses the mental and physical activities of students in collecting and organizing information and then using the information to make predictions, explain phenomena, solve problems, understand the scientific endeavor, and learn science. Students were required to develop and use these skills in the teaching and learning process. The commonly identified and described SPS are observation, measuring, classifying, communicating, predicting, inferring, using numbers, using space/time relationship, questioning, identifying and controlling variables, hypothesizing, defining operationally, designing experiments, interpreting data, and modeling. These skills are important for students as tools for exploration and investigation of the natural world, improving academic achievements and attitudes towards science, learning science with understanding, and promoting development of mental and intellectual processes. From the literature reviewed the following strategies were recognized for the development of SPS in students: integration of SPS in curriculum materials, classroom lessons and assessments, use of instructional strategies or methods, and providing explicit instruction or training on SPS. The instructional strategies identified for enhancing SPS were student-centered teaching methods and multiple representation approaches. Student-centered teaching approaches promote the development of SPS in students by engaging them in mind-on and hand-on activities. Multiple representation approaches involve presenting lessons by using a combination of various teaching methods or various media in the same lesson and are found important for SPS development in students. Therefore, it was recommended to use these strategies for developing SPS to attain science education goals.

KEY WORDS: Science education; science process skill development; science process skills; scientific literacy

INTRODUCTION

The present era is the age of science and technology. Science is a systematic process of seeking knowledge about nature through disciplined observation and experimentation (Johnson and Lawson, 1998). This scientifically accumulated knowledge about nature is disseminated back into society by science education. Science education is the scholarly and practical discipline concerned with the teaching, learning and assessment of science content, science process skills (SPS), and the nature of science (McComas, 2014). According to the American Association for Advancement of Science Education (AAAS) (1993), a prominent goal of science education is the production of scientifically literate society. A scientifically literate society is a society which has informed understanding about the nature of science and is well equipped with SPS (Lederman, 2009). Scientifically literate citizens by drawing upon their rich scientific knowledge, such as an understanding of the concepts, principles, theories, and SPS have the capability of making informed decisions regarding science-related issues and using science productively in their lives (Abd-El-Khalick and Lederman, 2000). The achievement of scientific literacy for individuals is viewed by many science educators as the educational solution to the many economic, social, and environmental challenges of the 21st century (Eisenhart et al., 1996).

Zeidan and Jayosi (2015) contended achieving scientific literacy requires more than simply understanding major concepts in the contents, the acquisition of SPS. SPS development took the attention from science education scholars after the launching of the curriculum project called Science-A Process Approach (AAAS, 1967). Science-A Process Approach was designed to develop SPS in students to support their scientific investigation and to guide teachers on SPS practices students would learn at different grade levels. Starting from the launching of this project the idea that students should learn and engage in the processes of science becomes an element of science instruction.

In contrast to Science-A Process Approach project teaching process in science subjects primarily focus on delivery of the content information or knowledge to the students. SPS is usually overlooked and assumed to be obtained somewhere in the learning process by students (Coil et al., 2010). However, existing literatures confirm these assumptions and beliefs are wrong. For instance, Abd Rauf et al. (2013) implied that without planning of lesson and guidance, students might not develop the SPS. Moreover, Ango (2002) argued teachers should master the SPS and teaching strategies to help students to develop SPS. Therefore, attention should be given on strategies for the development of SPS in students.

Reports from the study made by trends in international mathematics and science studies indicated the SPS proficiency of students in many countries is not satisfactory (Mullis et al., 2020). Therefore, it is reasonable to search for strategies to enhance students' SPS. Several studies were executed on the strategies for the development of SPS, factors affecting the development of SPS, and the importance of SPS in the teaching and learning of science contents. This study focuses on reviewing strategies that exist in literature which are relevant for the development of SPS among students.

Objectives

This review searched the literature for strategies helpful to develop SPS among students and the factors which affect their development. Based on these objectives the study addressed the following research questions:

RQ1. What strategies enhance SPS development in students?

RQ2. What are the factors which affect the development of SPS in the students?

REVIEW OF LITERATURE

SPS

SPS is also known as procedural skills, experimental and investigating science habits of mind, scientific inquiry abilities, and inquiry process skills (Harlen, 1999; Chakraborty and Gillian, 2021). Ozgelen (2012) defined SPS as encompassing the mental and physical activities for collecting and organizing information and then using it to make predictions, explain phenomena, solve problems, understand the scientific endeavor, and learn science. Major features of SPS according to Finley (1983) are:

- SPS are hierarchically organized with ability to use each upper-level process dependent on the ability to use the simpler underlying process
- Each SPS is a specific intellectual skill used by all scientists and applicable to understanding any phenomena
- Each SPS is an identifiable behavior of scientists that can be learned by students
- SPS are generalizable or transferable across content domains and contribute to rational thinking in everyday affairs.

Types of SPS

In the beginning, AAAS (1967) identified twelve skills as SPS in the projects Science-A Process Approach. Later in 1993, the association has been ordered the SPS into 15 activities, such as: observing, measuring, classifying, communicating, predicting, inferring, using numbers, using space/time relationship, questioning, controlling variables, hypothesizing, defining operationally, formulating models, designing experiments, and interpreting data. SPS differ in their level of complexity hierarchically. AAAS (1967) classified SPS in two categories based on their level of complexity; Basic and integrated SPS. Basic SPS are skills at a lower level and contain the SPS: observation, classifying, measuring, prediction, inferring, and communication. Integrated SPS are skills at a higher level of complexity and usually result from the combination of two or more basic skills. Integrated SPS includes identifying and controlling variables, defining variables operationally, formulating hypotheses, experimenting, formulating models, and interpreting data. The descriptions of the SPS are presented in Table 1 below.

Importance of SPS

Science explores the natural world to discover factual information called scientific knowledge. Seeking and accumulating of factual information about the natural world is an active process which is driven by curiosity of individuals. SPS serves as tools to learn more about our natural world through scientific investigation and exploration (Shahali and Halim, 2010; Kruea-In and Thongperm, 2014; Alatas and Fachrunisa, 2018). The events in scientific methods like observation, questioning, formulating hypothesis, experimenting, data analysis and interpretations, and drawing conclusions are SPS. As elements of scientific method, SPS enhances students' capability of doing science; that is, how they know what they want to know. Ergul et al. (2011) claimed mastery of SPS is fundamental for both effective teaching and learning of science. Supporting this claim, (Gagne, 1965) and Choirunnisa et al. (2018) argued students need SPS to better obtain science concepts and principles. Other scholars (Livermore, 1964; Harlen, 1999; Ongowo and Indoshi, 2013) also stated content knowledge is obtained more efficiently and understood deeply when obtained through practice or investigation using SPS reported from several studies. Furthermore, the importance of SPS at all age levels for building conceptual understanding of science is established by Keil et al. (2009).

The acquisition of SPS has a profound impact on the academic achievement of students. This is indicated by several research studies which established the existence of positive relationship between SPS and academic achievement (Aktamis and Ergin, 2008; Aktamis and Yenice, 2010; Raj and Devi, 2014; Zeidan and Jayosi, 2015; Suman, 2020). SPS enhances a student's attitude towards science. Zeidan and Jayosi (2015) stated that SPS serves as a driving force for the growth and development of positive attitudes and values of science in students. They added SPS raises interests and motivation in students to learn science. Anderson (2002) stated that SPS is foundation of inquiry teaching, arguing they are an integral part of scientific inquiry and required to accomplish scientific inquiries. The vital role of SPS for promotion of the development of mental and intellectual skills was reported by Karamustafaoglu (2011). Moreover, SPS inspires reflective thinking and innovativeness towards problem-solving processes and makes students personally creative, critical thinkers, and competitive in the global competition in society (Turiman et al., 2012).

Table 1: Description on types of SPS

Basic SPS	Description
Observation	Observation is the process of gathering information about objects and events using senses (eye, ear, skin, nose, tongue) or instruments aid the senses such as telescope, microscope, and medical instruments. Critical observation is a fundamental process in science (Kurniawati, 2021).
Measuring	Measuring is qualitative presentation or assigning values for variables. Measurements are carried out by using instruments with defined units. Effectiveness of measurements depends on the skills and knowledge of using the measuring instruments effectively and performing important calculations accurately (Suman, 2017).
Classifying	Classifying is grouping or categorizing or ordering of objects or events into groups or classes based on similarities, differences, and relationships in characteristics or defined criteria among the objects or events (Suman, 2017).
Inferring	Inferring refers to the process of formulating assumptions or making possible explanations or drawing conclusions about observations using prior information. Individuals attempt to identify the causes of observed events through inferring skill. Predicting why a specific event happened (Kurniawati, 2021).
Use of numbers	Use of numbers includes sorting, counting, adding, subtracting, multiplying, and dividing (Kurniawati, 2021).
Predicting	Predicting is the skill of projecting events based on existing information or making a specific statement about what will likely happen in the future based on evidence. Making effective prediction requires critical observations, accurate measurements, and past experiences (Baxter and Kurtz, 2001).
Communication	Communication is the process of using words, symbols, graphics, diagrams, graphs, tables and figures, and other written or oral representations to describe and exchange information, such as an action, object, or event, from one person or system to another. It requires students to put information that they have gathered from observations so that it can be shared with others. With good communication skills, students will be able to describe natural phenomena in science class (Bilgin, 2006).
Questioning	Questioning is asking to enquire the bases or causes for object and events happening. It originates from hypotheses and observation, and answered through investigation (Khan and Vanaja, 2019).
Integrated SPS	
Identifying and controlling variables	Variables are changing quantities or conditions in experiments. Variables in the experiments include independent (the one being manipulated by the experimenter), dependent (the one which values changes and determined when independent variable manipulated), and controlled variable (the one which affects the value of dependent variable but is kept constant to overcome their effects) (Suman, 2017).
Defining variables operationally	Defining variables operationally is made in certain boundaries to simplify communications regarding the events being studied. It gives information to differentiate the definitions given from other related phenomena. It usually bases on the observable characteristics of events and operations expected to be performed (Kurniawati, 2021).
Formulating hypotheses	Formulating hypotheses is making a statement based on accurate observations or inferences about a possible relationship in the natural world. It involves suggesting explanations or potential solutions for the problems identified or events observed. It is making predictions and generalizations about an event or situation based on experiences, thinking about why something will happen (Baxter and Kurtz, 2001).
Experimenting	Experimenting is a process involved in the systematic evaluation of hypotheses. Its purpose is to judge the degree in which the hypothesis is true and set the standards for judgment (Baxter and Kurtz, 2001).
Interpreting data	Interpreting data is an intrinsic capability to identify patterns, relationships, and associations within data. It requires previous experiences, observations, making predictions, inferences, and hypotheses.
Modeling	Modeling is organizing data collected through experiment and symbolizing the data in mental, visual, or physical terms (Ostlund, 1992). It is the process of creating a mental, pictorial, written, or physical representation to explain an idea, object, or event.

Research on SPS

Many researchers have conducted studies related to SPS in science education. The most common areas of the researches have been analysis of the SPS level of students and teachers (Downing and Gifford, 1996; Beaumont-Walters and Soyibo, 2001; Aydogdu et al., 2014), relationships between SPS and academic achievement of students (Koray et al., 2007; Aktamis and Ergin, 2008; Aktamis and Yenice, 2010; Raj and Devi, 2014; Zeidan and Jayosi, 2015; Suman, 2020), development of SPS among students by using various teaching methods (Lazarowitz and Huppert, 1993; Huppert et al., 2002; Harrell and Bailer, 2004; Saat, 2004; Wilke and Straits, 2005; Bilgin, 2006; Colley, 2006; Metin and Bilisci, 2009), analysis of representation of SPS in curricular materials like text books and laboratory manuals (Zeitoun and Hajo, 2015; Karadan and Hameed, 2016; Yumusak, 2016; Antrakusuma et al., 2017) and integration of science SPS in the assessment items (Ongowo and Indoshi, 2013; Elmas et al., 2018). Most of these studies were conducted in developed countries rather than developing countries (Mushani, 2021).

METHODOLOGY

Review of literature on the subject development of SPS among students was conducted based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2015). Literature relevant for the review was accessed between October, 2020, and November, 2020, from search engines (Google Scholar, Scopus, ERIC, Science Direct, Justor, and Researchgate) using search terms; SPS and science education and SPS skill development in students. The search was limited to journal articles written in English. The search resulted in 512 articles.

From the total 512 article results that came out of the initial search, 56 articles were selected for review use. In line with the research questions and objectives, the inclusion criteria used were articles that dealt with the development of SPS among students, peer reviewed, and whose completed papers were accessible on the databases. Moreover, articles published starting from 1967 were considered for the analysis since emphasis was given for studies on the development of SPS after the launching of the Science-A Process Approach project (AAAS, 1967). Articles focus on other aspects such as analysis of SPS level of students, development, and validation of instruments for measuring SPS, and relationships between SPS and academic achievement of students were excluded from the study. Finally, on the 56 papers, selected content analysis was carried out.

RESULTS AND DISCUSSIONS

RQ1. What strategies enhance SPS development in students?

The following strategies were identified from the literature reviewed for SPS inculcation in students:

Integration of SPS in curricular materials

Curriculum materials were textbooks, modules, syllabus, and manuals used for instruction purposes. Curriculum materials can help teachers in the selection of teaching methods, usage of instructional aids, provision of activities for students, and preparing lesson plans with the potential for inculcation of SPS in students. There was strong evidence which indicated increasing objectives, activities, and methods with roles in the development of certain SPS in the student curricular materials and monitoring their implementation in the instruction process had significant contribution for the development of required SPS in students. For instance, Overman et al. (2013) argued curriculum materials which prioritize activity and students' direct involvement in learning create opportunities for the development of SPS than material focus on memorizing issues and teacher explanations.

Textbooks were among the frequently used teaching resources by teachers in schools. Banilower et al. (2018) reported that, for six out of ten science teachers, school textbooks served as the exclusive teaching material for the classroom. Studies also indicated 90% of the science teachers who use the school textbooks not only to carry out their lesson but also to assign tasks (questions and activities) to the students (Chiappetta et al., 2006, as cited in Sideri and Skoumios, 2012). Ma et al. (2019) indicated inclusion of SPS in textbooks successfully promoted SPS development in students. Moreover, a study made by Yang et al. (2019) on Chinese Biology school textbooks showed some SPS activities included in the textbook provided for students satisfactory opportunities to engage sufficiently in inquiry processes and develop certain SPS. These studies recognized the importance of the inclusion of SPS in textbooks for the development of SPS. Textbooks that failed to sufficiently include the essential features of SPS for students (Dunne et al., 2013; Kahveci, 2010; Aldahmash et al., 2016) would not bring inculcation of these skills in the students. Cruz (2015) studied the development of an experimental science module to improve middle school students' integrated SPS. The module was prepared with the aim to support students' understanding of sciences by providing them with opportunities to investigate independently through research and experimentation. Emphasis was given in the module on the use of the scientific method in performing an investigation by experimentation and inquiry-based learning and designing and executing experiments in a strategic and unified manner to develop critical thinking and SPS. It was found that this module significantly improved integrated SPS of students. Increase in the students' SPS was also reported by Martiningsih et al. (2019) using scientific context modules.

Activities in laboratory manuals play a central role in shaping students' learning and defining their goals and procedures (Hofstein and Lunetta, 2003). Yakar and Baykara, 2014) indicated that laboratory manuals with open-ended investigation questions make laboratory experiments engaging and demanding for students and create opportunities for students to practice SPS and improve SPS. However, results from several studies made on the analysis of laboratory manuals for their inclusion of SPS demonstrated that the involvement of SPS in the manuals examined does not follow a balanced distribution (Tamir and Lunetta, 1978; Germann and Aram, 1996; Basey et al., 2000; Tweedy and Hoese, 2005; Getachew, 2016). Certain SPS was presented relatively more frequently and to a greater extent than others, which may lead to unequal promotion of the development of SPS among students.

Integration of SPS in classroom lessons

Science educators believe both science content and SPS are mutually valuable, complementary and should be taught together (Scharmann, 1989; Rillero, 1998). Teachers have responsibilities of organizing the teaching environment, designing teaching methods and activities, facilitating the teaching–learning process in the classroom, developing and enabling students to develop SPS, and following the level of development of SPS in the students (Harlen, 1999; Arslan and Tertemiz, 2004). Therefore, while teaching different contents teachers are required to incorporate or integrate different SPS purposefully. For instance, teachers may deliberately make students undergo observations, predictions, inferences, and hypotheses on the area of the content they teach. Abungu et al. (2014) indicated teachers' intentional integration of SPS in teaching science content helps students to develop SPS since it creates opportunities for students to practice and exercise the skills in the classroom. Teachers are required to own a strong conceptual understanding and perform well on the SPS for the effective conveyance of SPS to their students in classrooms integrating with the contents.

Integration of SPS in assessment

Assessment is collection of information or data for use for various purposes. Assessing the SPS of students through questions in the examinations and delivering lessons in the classrooms increase the student's exposure to the skills.

When students attempt to give answers for the question, they engage in mental processes and physical activities which could stimulate and lead to the development of SPS. Effective use of questioning strategies can promote thinking among students and force them to undertake experiments to get the answers (Nikam, 2014). Engagement of students in the experiments enables students to develop experimenting skills and other related SPS. Etkina et al. (2006) ascertained the importance of assessment for the development of SPS stating "to help students to develop SPS; one needs to engage students in appropriate activities, find ways to assess the students' performance on these activities and provide timely feedback" (p. 2).

Use of instructional strategies or methods

The increase in the importance of the occurrence of SPS in the students posed the question of finding ways to improve their development in the students through instructional approaches. Literature indicates the presence of a variety of instructional strategies developed and implemented to improve students' SPS in classrooms. These strategies range from highly structured, manual-directed exercises to completely open student-directed inquiries. Studies made on the development of SPS by using various teaching approaches are presented in Table 2 below.

The instructional approaches with significance for the development of SPS among students presented in the table above can be categorized into two groups. The first group is student-centered teaching approach. Student-centered approaches are teaching approaches in which students actively participate through mind-on and hand-on activities, have high responsibility in their learning process, and construct knowledge by themselves with the facilitation role of teacher. The extent that students took responsibility in their learning process is in continuum, from one end where students took limited or very few activities to the other end where students engage in multiple self-managed activities and largely relied on their own in their learning process (Luke, 2004). The hand-on and mind-on activities on which students engage during the construction of knowledge enable them to develop different SPS. Balanay and Roa (2013) stated the use of student student-centered approach which contains hand-on activities and inquiry in science instruction significantly improves the students' SPS.

The second instructional group was multiple representation approaches. These involves undertaking the lesson using a combination of various teaching methods or various media in the same lesson. Therefore, multiple representation approaches

Table 2: Studies made on improving students SPS by using different teaching approach

Authors	Description on teaching method	Study design	Instrument used	Findings
O'Brien and Peters (1994)	Cooperative learning techniques with microcomputer-based laboratories	One-group pre-test-post-test	Integrated SPS and logical thinking test.	Greater differences were observed in the achievement of the integrated SPS test after use of cooperative learning and microcomputer based laboratories.
Bilgin (2006)	Hands-on activities incorporating a cooperative learning approach	Pre-test-post- test; control and experimental groups	SPS test and Attitude scale toward science	Students in the experimental group show better performance on post-SPS test scores and post-attitude scale toward science.
Aydogdu et al. (2013)	Laboratory applications with scenarios- based worksheets	Semi-experimental; pre-test-post-test; experimental and control group	SPS test	Laboratory activities conducted with scenario-based worksheets found more effective in developing basic and integrated SPS.
Jeenthong et al. (2014)	Betta-live science laboratory	Experimental; pre-test-post-test; experimental and control group	Experimental skills test, questionnaire, interview and observation	Students experiencing an intervention gained better understanding and experimental skills than in the traditional groups.
Ekici and Erdem (2020)	Mobile Scientific Inquiry	Experimental and control groups; pre-test-post-tests	SPS test, semi-structured interviews and reflective journals	Mobile scientific inquiry affected SPS development significantly and positively.
Panjaitan and Siagian (2020)	Inquiry Based Learning	One-group pre-test-post-test design	SPS and scientific creativity test	Using inquiry-based learning increase SPS and scientific creativity of students.
Colley (2010)	Project-Based Science Instruction	One-group pre-test-post-test design	SPS test	Project-based science instruction enabled to teach science content and SPS in a reasonably short period of time.
Wahyuni et al. (2017)	Outdoor learning	Mixed method with experiments, pre-test- post-test	SPS tests, observation sheets	SPS observations, formulating hypotheses, experimenting, communication, analyzing data, and predictions effectively developed.
Duda and Susilo (2018)	Problem-based learning through an authentic assessment based practicum	Quasi-experimental; non-equivalent control group pre- test-post-test	SPS test	Problem based learning through practical and authentic assessment improved students' SPS
Saat (2004)	Web-based learning	Exploratory qualitative case study	Observations	Acquisition of controlling variables skill involved with its sub-skills in students.

(Contd...)

Table 2: *(Continued)*

Authors	Description on teaching method	Study design	Instrument used	Findings
Guevara (2015)	Multiple representations and collaborative learning approach	Untitled	Science literacy test and rubric	Multiple representations and collaboration brought significantly high scores in SPS.
Athuman (2017)	Inquiry-based approach	Pre-test-post-test; control and experimental groups	Biology SPS test	Experimental group students performed better in SPS after exposed to treatments of inquiry activities.
Cakiroglu et al. (2020)	Flipping experimentation process	Pre-test-post-test; control and experimental groups	Integrated SPS tests, participants' experiment plans and interviews	Flipped experimentation process improved SPS identifying and stating hypotheses and defining operationally
Mulyeni et al. (2019)	Inquiry-Based Approach	Mixed action research method; one group pre- test-post-test	Observation, students worksheets, interviews, SPS test	Basic SPS improved after the intervention of learning.
Abd Rauf et al. (2013)	Uses of various teaching approaches in one lessons	Untitled	Observations, interview, SPS checklist	SPS inculcation and acquisition occurred in students.
Yakar and Baykara (2014)	Inquiry-based laboratory practices	Quantitative research method with one group pre-test-post-test	SPS test, Torrance test of Creative Thinking, Attitude Scale, worksheets	Inquiry-based laboratory practices improved SPS, creative thinking levels and attitudes towards science experiments.
Vebriantoa and Osmanb (2011)	Multiple media instruction	Quasi-experiment with non-equivalent control group; pre-test-post-test	SPS test and Science Achievement Test	SPS and science achievement of students significantly improved in experimental group.
Stephen and Daikwo (2021)	Cooperative instructional strategies	Experimental and control groups; Pre-test-post-test	Test of integrated SPS	Cooperative instructional strategy enhances student's performance in integrated SPS.
Hernawati et al. (2018)	Project Activity	Quasi-experimental, post-test only; group control	SPS test and self-efficacy inventory	Project activity promotes pre-service teachers' SPS and self-efficacy.
Sa-ngiamjit (2016)	Peer-Assisted Technique	Untitled	Achievement and SPS tests	Peer-assisted technique improved academic achievement and SPS.
Elkeey (2017)	Observation of life cycle	Pre-test-post-test; experimental and control group	Scale of SPS	Acquisition and development of SPS occurred in students in experimental group.
Choirunnisa et al. (2018)	5E Instructional Model-Based Learning	Experimental with one group pre-test-post-test	SPS tests	Observation, formulating hypotheses, determining variable, interpreting data and communicating SPS increased.
Karamustafao glu (2011)	Using I Diagrams	Experimental with one group pre-test-post-test	SPS test	Student skills on developing I- diagrams and integrated SPS were increased.

can be either multiple teaching approaches or multiple media instruction approaches. Multiple teaching approaches are characterized by presentation of concepts and process in redundancy by utilizing various teaching approaches such as descriptive, mathematical, analogical, and kinesthetic in combination. Scholars argue teaching and learning science using several teaching methods at once in the classroom creates more opportunities for inculcation and acquisition of SPS in the classroom (Abd Rauf et al., 2013; Guevara, 2015). Similarly using various teaching media at the same time in the lessons, multiple media instruction is helpful for the development of SPS. Vebriantoa and Osmanb (2011) designated teaching and learning processes using various constructive teaching media (textbooks, television, props, specimens, photos, computer, even the environment itself) significantly improve the SPS and science achievement among students. Therefore, the use of teaching approaches such as student-centered and multiple teaching approach and multiple media instruction approaches are helpful in the inculcation of desired SPS in the students.

Explicit teaching or training of SPS

Teaching or training SPS in explicit manner involves in programmed teaching or training of SPS by developing training materials similarly to content delivery. SPS is taught rarely in the explicit and platform manner for the students. Nevertheless, explicit instructions of SPS help students to acquire a list of SPS and master science disciplines through content acquisition and interdisciplinary way of thinking was reported by Dirks and Cunningham (2006). Moreover, Aktamis and Ergin (2008) indicated that giving SPS training improves SPS and increases the academic achievement of students. Kruit et al. (2018) argued that it could be more effective if SPS explicit teaching or instructions were undertaken at primary education levels.

RQ2. What are the factors which affect the development of SPS in the students?

SPS proficiency of students does not occur uniformly among students at different educational levels, schools or colleges and countries. The variation is due to the existence of several factors that determine their development. Ozgelen's (2012) study shows that SPS are related to cognitive development. Again Ismail and Jusoh (2001) showed these skills are correlated with the skills of logical thinking. There are researchers who implied SPS of children is related to several factors such as grade level or seniority and parents' socioeconomic and educational backgrounds (Dokme and Aydinli, 2009; Aydin et al., 2011). Teachers' proficiency level and understanding of SPS is also another key factor that determines the acquisition of SPS skills by students. High-level teachers' understanding of these skills leads to effective, efficient, and quality implementation of science education at any level. Teachers' attitude towards the science education curriculum and their performance on SPS are helpful for the development of SPS among their students (Downing and Filer, 1999).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

SPS is among the key conditions students need to develop while learning science. They are tools of scientist, thus required for students for self-learning through observation, questioning, experimenting, prediction, and inferring. Studies confirm the importance of the skills for the improvement of students' academic achievement and attitudes toward science, learning of contents with understanding, and promote the development of mental and intellectual process. The articles reviewed ascertained inculcation of these skills can be realized in students through the integration of SPS-related activities in curricular materials, classroom lessons, and assessments or questioning strategies. Teaching strategies particularly student-centered methods and multiple representation approaches are effective for improving students SPS. Pedagogies involve in the use of various teaching aids, practical hand-on activities, and group-based activities to create opportunities to practice and develop SPS. Moreover, conducting explicit training on the SPS for students helps to improve their SPS proficiency.

Recommendations

- Evaluation of curricular material for representation of SPS and inclusion of SPS development strategies in the curriculum materials should be given attention by curriculum developers and textbook writers
- Teachers need to work in the improvement of their own SPS, inclusion of SPS in the assessment of students and in their classroom lessons
- Searching, designing, and implementing of teaching methods with potential for improvement of SPS should be the work of science education scholars.

DECLARATIONS

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