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Review Paper

Science Process Skills: A Trend Analysis of Research

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ABSTRACT

The trend of science process skills was investigated through systematic analysis. A systematics study involves 23 research articles available on Scopus from 2019 to 2024. The trends in science process skills in school are focused at three levels, such as the primary, secondary, and tertiary levels. These three levels are organized in such a way that the science process involves basic and integrated skills, methodologies of teaching, and learning environments. At the primary level, research reveals that new strategies did not make a significant impact on the scientific process. Guided discovery appeared helpful to most students for improving both basic and integrated science process skills. At the secondary level, the research disclosed that students' attitudes and learning motivations influenced science process skills. At this level, inquiry-based learning, guided inquiry, and digital applications enhance the students' science process skills. Science process skills vary with respect to types of schools and gender. At the tertiary level, the research proved that computer simulations and animations and inquiry-based laboratory activities assist students in learning science process skills. The results showed little difference in science process skills among primary school students, and secondary students showed an increase in science process skills while applying new approaches.

Keywords: *Science Process Skills, Primary, Secondary, Higher Secondary Level*

Science - A Process Approach (SAPA) curriculum Project stated that "Science Process Skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behaviour of Scientists".

According to NCF 2005, "A good science education is true to the child, true to life and true to science. The recommendations of NCF 2005 on teaching of science encourage experimental work. "At the secondary stage the students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced technological modules than at the upper primary stage and in activities and analysis on issues surrounding environment and health. Systematic experimentation as a tool to discover/verify theoretical principles and working on locally significant projects involving science and technology are to be important parts of the curriculum at this stage."

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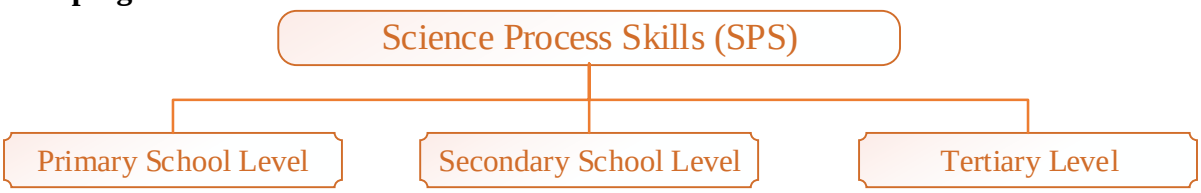
Significance of Science Process Skills

Science process skills are critical to cultivate in science education because they enable students to think critically and generate findings that can be supported by scientific ideas. Students can build and acquire new knowledge or reinforce existing knowledge by using science process skills. There are two categories of science process skills: integrated process skills and basic process skills. Basic Science Process Skills are Observing, Measuring, Inferring, Classifying, Predicting and Communicating. Integrated Science Process Skills are Controlling Variables, Hypothesizing, Experimentation and Data Interpreting. All these skills are together known as Science Process Skills. Science process skills help students develop into persons who can access and comprehend information, enabling them to apply the knowledge they learn in practical contexts. These abilities are essential for other cognitive skills like reasoning, problem solving, and logical thinking.

The Science Process Skills are an essential tool for conducting scientific research, producing and utilizing scientific knowledge, and problem-solving. These skills can be acquired by Laboratory experiments where the students learnt problem-solving skills, understanding the concepts of science, handling of some common measuring instruments, equipment and chemicals; setting simple apparatus; handling microscope and preparing slides; making observations; collecting data and presenting it in appropriate format; interpreting and drawing conclusions; and preparation of report.

Grouping of Science Process Skills Research between 2019 to 2022



Science Process Skills at primary school stage

The researcher has identified four researches at primary school level. **E. TAŞ, et al (2022),** investigated the impact of the Argumentation-Flipped Learning (AFL) Model on the scientific process skills and academic achievement of students. Participants are 5th grade students from public school selected by Random Sampling. It was discovered that the strategies applied to the groups did not make a significant impact in the levels of scientific process or in student's academic achievement.

N. Mustafa, et al (2021) measured the science process skills among Malaysian elementary students using a Rasch model analysis. The study intended, to calibrate the test items of science process skills used as a test at primary school students to provide information on the difficulty of each item. The sample were standard five students in a primary school in Penang, with a sample size of 128. A 73-item self-created mixed-format test was used to assess science process skills. It was a Cross-sectional survey design. The results showed that the measurement met both the model-data fit and the uni-dimensionality assumptions. Further investigation revealed that viewing and Communication was rated as the easiest skill to master, while inferring and classifying were seen as the most difficult.

D. P. Parmiti, et al (2021), analyzed the effect of project-based assessment based on local culture on students' scientific attitudes and science process skills in science learning in elementary schools. Fifth grade elementary school students, consisting of 151 students, were the sample. Scientific attitude questionnaires and performance tests, and observation sheets

were utilized for data collection. The findings showed, there are simultaneous effects in scientific attitudes and science process skills between students' learning with local culture-based Project-based Assessment and students' learning with conventional assessment applied.

Suryanti, et al (2020), investigated the development of science process skills in classrooms where the students were introduced to learn science using problem-posing approach incorporated with guided discovery learning. The sample was 5th grade students in Labs Elementary School of Surabaya State University, Indonesia. Science Process Skills Assessment Sheet was used for data gathering. Guided discovery problem-posing appeared helpful to most students for improving both basic and integrated science process skills, specifically higher order thinking skills. Students further recognized that using guided discovery problem-posing made the topics learned become easier and more entertaining.

Science Process Skills at secondary school level

The investigator has identified **eight research** done at secondary school level. They are on students' attitude and learning motivation on science process skills, students' perceived science inquiry skills, benefits of learning tools on science process skills, learning model to scaffold students' science process skills and biology cognitive learning outcomes, metacognitive scaffolding on students' performance and confidence judgments in simulation-based inquiry, critical thinking assessment model integrated with science process skills on chemistry, inquiry based learning model to improve science process skills and scientific creativity, students' conceptual understanding and science process skills in an inquiry-based flipped classroom environment.

Asrial, et al (2022) found the effect of students' attitudes and learning motivation on science process skills. Hundred and fifty-three junior high school students selected through purposive sampling, participated in the survey. The data was collected using, Student attitude questionnaire, student learning motivation questionnaire and science process skills' observation sheets. The results showed that students' attitudes and learning motivation had an effect on science process skills as indicated by the correlation value.

C. Bob Nicol, et al (2022) conducted survey on "Students' perceived science inquiry process skills in relation to school type and gender", with the objectives of comparing the mean scores of perceived science inquiry process skills for Grade 11 students. Six high schools were selected, and the sample size was 360 students. Science Inquiry Process Skills Inventory by Bourdeau and Arnold (2009) was adopted as a tool for data gathering. This study found that government school students have significantly higher perceived science inquiry process skills than their private school counterparts and that an average of 42% of private school students cannot demonstrate any skills related to experimental design, data representation, communication and presentation. Male students indicated having significantly higher science inquiry process skills compared to their female counterparts. However, a varying majority across study groups practice the science inquiry process skills occasionally.

Irdalisa, et al (2022), describing the benefits of Teacher's Guidebook and Students' Worksheets created using the Moodle platform. Eleventh-grade students in state senior high schools 13, Bekasi were the sample, and the size of the sample was 102. The results showed that the student learning activities using the developed worksheet in the Moodle platform could be categorized as "very active". The acquisition of students' knowledge dimensions

increased after using the developed Teacher's Guidebook and Students' Worksheets or in the medium category. It also significantly improves the students' science process skills in the learning process.

Senisum, et al (2022), constructed a learning model to Scaffold Students' Science Process Skills. They aimed to determine the effect of Guided Inquiry, Reading, Sharing, Mind Mapping, and Communication learning as a new guided inquiry on students' SPS and cognitive learning outcomes. The sample were Eleventh-grade students and the size of the sample was 126. The result showed that thier learning model had a higher impact on students' cognitive performance and SPS, compared to the traditional learning models.

Hong-Syuan Wang, et al (2021) examined the effectiveness of metacognitive scaffolding in different inquiry tasks related to optics. The sample was 11th-grade students (aged 16–17) at an urban high school in Taiwan, and the size of the sample was 67. The results show that the students' conceptual understanding and confidence judgments on conceptual understanding in both groups significantly increased from the pretest to the post-test. Incorporating metacognitive scaffolds into inquiry-based learning better facilitated the improvement of integrated science process skills as well as the confidence judgment on the process skills, especially in the more complex tasks. The metacognitive scaffolding could be applied to various inquiry activities to enhance students' control of variables, data interpretation, and graph comprehension.

Kriswantoro, et al (2021), designed a development approach to develop: (1) a critical thinking model that is integrated with the science process, and (2) construct validity and reliability instruments that evaluate the integrated critical thinking skills of science process skills in high school chemistry learning. The sample was 289 9^{th} class students. The proposed model has good traits and qualities as a useful model that fits the requirements needed to assess students' abilities.

Panjaitan, et al (2020) found the effectiveness of Inquiry Based Learning Model to Improve Science Process Skills and Scientific Creativity. The purpose of this study was to identify and describe the improvement of students' scientific process skills and scientific creativity. The sample was students of Class VII of the junior high school with a sample size 30. The findings showed, after using inquiry-based learning there is an increase in science process skills and scientific creativity, students who are able to do tasks related to science process skills will also be able to do scientific creativity tasks.

Tan, et al (2020) studied the impact of an Inquiry-based Flipped classroom model on the conceptual understanding and science process skills of junior high school students in the Philippines. The sample was Grade 9 students in a school located outside Metropolitan Manila, Philippines, and the sample size was 55. Inquiry-based flipped classroom did not make students perform better than the non-flipped inquiry-based learning environment in Science Process Skills Test (SPST) where the Flipped Inquiry Group scored significantly higher than the control group. Students' science process skills positively predicted their conceptual understanding in biology.

Science Process Skills at tertiary level

The researcher has identified eleven research at tertiary level with respect to Science Process Skills. They are on students' acquisition of science process skills through computer simulations and animations, instructional activities that could aid students' learning of

science process skills through the use of chemistry-based computer simulations and animations, cognitive reasoning of pre-service teachers' science process skills, pre-service teachers' acquisition of scientific knowledge and scientific skills through inquiry-based laboratory activity, science process skills of chemical education students through self-project-based learning, science process skills through the use of experiments in a science course using a flipped classroom design, improvement of learning outcomes and science process skills of students through the implementation of the guided inquiry model, mastery of process skills in science students' study program, varied inquiry-based science lesson modules for gifted children in their scientific process skills, scientific knowledge and science process skills with scientific creativity in Creative Responsibility Based Learning, science process skill and motivation of the basic science process.

Beichumila, et al (2022) addressed the impact of computer simulations and animation in the acquisition of scientific skills. The sample were Secondary school chemistry teachers, N=20 and secondary school students, N=160. Thematic analysis of data from students focus group discussion indicated that simulations drew their attention to specifics and made the subject easier to grasp than conventional materials. The key findings from the study indicated that computer simulations and animations through instructional activities such as formulating hypotheses, planning experiments, identifying variables, developing operational definitions and interpretations, and drawing conclusions, chemistry-based computer simulations and animations assist students in learning science process skills. More than 70% of students performed well in the aforementioned types of instructional activities during the teaching and learning process, whereas 60% performed well in preparing experiments.

Hacıemino glu, et al (2022) assessed pre-service science teachers' degree of science process skills and described how these skills are represented in their learning method during the knowledge acquisition process. Furthermore, to investigate the factors used by pre-service teachers during science experiments conducted at home in terms of SPS attainment. Pre-service science teachers were the sample and the sample size were 36. The data show that the highest point averages went to the subcategories of proof via experience and communication, while the lowest point averages went to the formulation of prepared predictions and experimentation. After reviewing the project reports, numerous pre-service teachers realized they had made mistakes during the experiment's design phase and returned to the beginning. Others made mistakes in their explanations of variables, conclusions, and inferences, with the lowest fraction making mistakes in their observations. Students who used a meaningful learning technique were considered to have internalized and remembered knowledge in a meaningful way.

Bautista, et al (2021) analysed pre-service teachers' scientific knowledge and scientific skills through the application of an inquiry laboratory activity. The sample was students seeking the pre-service primary teacher's degree at the Rovira i Virgili University (URV) in Tarragona, Spain. The sample size was 82. The results demonstrate that pre-service teachers could improve their scientific skills and knowledge through inquiry-based laboratory activity.

Rusmini, et al (2021) analysed of Science Process Skills of students through Self-Project Based Learning. The sample was Chemistry Education Study Program of Surabaya State of University in 4th semester students, the sample size was 94. The results of this study indicate the low ability of students in science process skills although students gave a positive response to project implementation during a pandemic. An effort is needed to train science

process skills to prospective chemistry teachers in order to produce teachers who have good science process skills.

Cakiroglu, et al (2020) investigated the development of science process skills through the use of experiments in a science course using a flipped classroom design. Third- Grade science teacher candidates were the sample, with the sample size of 38. The result proved that, the experimentation method was positively influenced by flipped learning, particularly in developing and articulating hypotheses and operationally defining science process abilities. It was discovered that the providing of the necessary prior conceptual and procedural knowledge. Knowledge gained from watching films as after-school activities was an effective method of inverting the experimenting process. The affordances of videos and the instructor's direction were critical in the teacher candidates' laboratory-oriented learning journey.

A. Juniar, et al (2020) found the effect of Guided Inquiry Model on Improving Student's Learning Outcomes and Science Process Skills. Students at Department of Chemistry Education, Universitas Negeri Medan, participated in the research, with the sample size of 27. SP Skills test & Learning Activity test were the data gathering tools. Student's learning outcomes which taught by applying the guided inquiry (GI) model increased from pre-test to post-test with average N-gain approximately 20% and found that communicating is the most developed indicator of science process skill.

Maison, et al (2020) determined differences in mastery of process skills in science students' study program in both experimental & control group. The sample was students of physics education study programs and all students of chemical education study programs who contracted basic physics course. The sample size was 201 (N=108 physics students, N=93 chemistry students). The results of this study indicate that there are differences in the mastery of science process skills between students who use practicum guides and inquiry models based on science process skills and students who use conventional practicum handbooks.

Ulger (2020) conducted a mixed method research with a purpose of looking at how varied inquiry-based science lesson modules for gifted children affect their scientific process skills. The sample was Gifted students in Science and Art Centers, with the sample size of 16. The findings showed, SPS improved significantly, this development in students is in basic and causal SPS, there is less development in experimental processes. Gifted students needed more in depth and challenging activities in longer periods using modules like given in this study.

Zainuddin, et al (2020) found out the correlation between scientific knowledge and science process skills with scientific creativity in Creative Responsibility Based Learning. Students of science, physics, chemistry and biology education at Lambung Mangkurat University, Indonesia, were the sample. The sample size is 83. Scientific knowledge tests, Science process skills tests, and Scientific creativity tests were used as instrument for data gathering. The result showed, (1) scientific knowledge and scientific creativity have a positive, but not significant, relationship. Even though, the mastery of scientific knowledge was needed as a connector of science process skills with scientific creativity; (2) science process skills were positively and significantly correlated with scientific creativity; and (3) both scientific knowledge and science process skills had a simultaneous correlation to scientific creativity.

Maison, et al (2019) found the science process skill and motivation of the basic science process from Physics education students. It was an associative quantitative research method with a correlational research design. Students of Physics Education Study Program of Universitas Jambi, were the sample, with the sample size of 130, chosen by purposive sampling technique. Likert scale, observation sheet, questionnaire were the data gathering instruments. Pearson Correlation was used for analyses. The result of the research stated that the basic science process skill of physics education students as a whole is not good because of lack of experience in doing a practicum and their understanding of lab topics.

Inferences Obtained on Science Process Skills at Three Levels

At primary level, research reveal that, Argumentation-Flipped Learning strategies applied to the groups did not make a significant impact in the levels of scientific process or in student's academic achievement. Viewing and Communication was rated as the easiest skill to master, while inferring and classifying were seen as the most difficult. There are simultaneous effects in scientific attitudes and science process skills between students' learning with local culture-based Project-based Assessment and students' learning with conventional assessment applied. Guided discovery problem-posing appeared helpful to most students for improving both basic and integrated science process skills, specifically higher order thinking skills. Students further recognized that using guided discovery problem-posing made the topics learned become easier and more entertaining.

At the Secondary level, the research disclosed that, students' attitudes and learning motivation had an effect on science process skills. The government school students have significantly higher perceived science inquiry process skills than their private school counterparts and that an average of 42% of private school students cannot demonstrate any skills related to experimental design, data representation, communication and presentation. Male students indicated having significantly higher science inquiry process skills compared to their female counterparts. The student learning activities using the developed worksheet in the Moodle platform is "very active". The acquisition of students' knowledge dimensions increased after using the developed Teacher's Guidebook and Students' Worksheets are in the medium category. It also significantly improves the students' science process skills in the learning process. The improvement occurs in every aspect of science process skills, including observing, classifying, predicting, inferencing, hypothesizing, interpreting data, planning experiments, and communicating. The GIReSiMCo (Guided Inquiry, Reading, Sharing, Mind Mapping, and Communication) learning model can enhance students' SPS and cognitive learning outcomes. Incorporating metacognitive scaffolds into inquiry-based learning better facilitated the improvement of integrated science process skills as well as the confidence judgment on the process skills, especially in the more complex tasks. Critical Thinking Assessment Model has good traits and qualities as a useful model that fits the requirements needed to assess students' abilities. Inquiry-based learning improves science process skills and scientific creativity, students who are able to do tasks related to science process skills will also be able to do scientific creativity tasks. Students' science process skills positively predicted their conceptual understanding in biology.

At the tertiary level, the research proved that, chemistry-based computer simulations and animations assist students in learning science process skills. Students who used a meaningful learning technique were considered to have internalized and remembered knowledge in a meaningful way. Pre-service teachers could improve their scientific skills and knowledge through inquiry-based laboratory activity. An effort is needed to train science process skills to prospective chemistry teachers in order to produce teachers who have good science

process skills. The experimentation method was positively influenced by flipped learning, particularly in developing and articulating hypotheses and operationally defining science process abilities. Student's learning outcomes which taught by applying the guided inquiry (GI) model increased and communicating is the most developed indicator of science process skill. Mastery of science process skills is better among students who use practicum guides and inquiry models based on science process skills than students who use conventional practicum handbooks. The students basic and causal SPS, improved significantly, there is less development in experimental processes. The scientific knowledge and scientific creativity do not have significant relationship. Even though, the mastery of scientific knowledge was needed as a connector of science process skills with scientific creativity; science process skills have significant relationship with scientific creativity; and both scientific knowledge and science process skills had a simultaneous correlation to scientific creativity. The basic science process skill of physics education students as a whole is not good because of lack of experience in doing a practicum and their understanding of lab topics.

SUMMARY AND CONCLUSIONS

A reasonable portion of the science curriculum should emphasize science process skills, according to the National Science Teachers Forums. In general, the research literature indicates that when science process skills are a specific planned outcome of a science program, those skills can be learned by students. This was cited in many places in this research. i.e., at the primary level, research reveals that new strategies did not make a significant impact on the scientific process. At the secondary level, the research disclosed that students' attitudes and learning motivations influenced science process skills. At the tertiary level, the research proved that computer simulations and animations and inquiry-based laboratory activities assist students in learning science process skills. Hence, curricula should emphasize science process skills and give an opportunity to focus on inquiry-based learning, guided inquiry, and digital applications to enhance the students' science process skills.

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Conflict of Interest

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