

Enhancing Science Process Skills through Inquiry - Based Learning: A Comprehensive Literature Review and Analysis

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Abstract: *The objective of this paper was to examine the impact of inquiry - based learning method on science process skills of the learners. This article did a thorough literature review, and 15 publications were chosen for analysis. The Preferred Reporting Items for Systematic Reviews and Meta - Analyses (PRISMA) method was used in this study. The well - known databases like Springer, ERIC, and Google Scholar were used to find publications for this study. The studies were chosen carefully for research papers published between 2014 and 2023. Those publications were chosen according to some inclusion criteria. The findings revealed that the inquiry - based learning method had a considerable impact on the learners' science process skills. The outcomes of the study may inspire scientific educators to employ inquiry - based learning methods to increase science process skills, which are critical competences that may affect student performance in science learning.*

Keywords: Science Process Skills, Inquiry Based Learning, Science Education, Scientific Skills

1. Introduction

The need for education in the 21st century is to continue producing young people with life skills so that they can survive and compete in the global world. Life skills required include the capacity to think critically, communicate effectively and efficiently, create technology (Silva, 2008), and operate in a flexible, productive, innovative, and responsible manner (Suto, 2013). Science education is built around practice and interpretation. Science education is designed to engage pupils in scientific investigation. Science, not only as a product but also as a process. The process of science studies the natural phenomena by using the skill of the process of science. The goal of science education is to develop scientific skills among students and apply such skills in their daily life in a scientific manner (Opulencia, 2011). Science education aims to create curiosity about the natural world, to develop cognitive competencies in the domain of science, and to provide an understanding of the basic concepts about science through experiments (Kim & Alghamdi, 2019). The field of science education have been stated in the Figure 1.

Science Process Skills (SPS) are cognitive abilities that employ to construct knowledge in order to solve issues and formulate outcomes. Science process skills are integral to science learning (Ozgelen, 2012). Making observations, measuring, classifying, recording data, establishing hypotheses, using data, creating models, making inferences, altering and manipulating variables, and experimenting are all examples of SPS (Koksal et al., 2020). Process skills can assist students in developing a sense of responsibility for their own learning, increasing learning tenacity, obtaining knowledge, thinking about challenges, and formulating results (Karamustafaoglu, 2011). Science process skills include numerous characteristics, but one in common is the capacity to identify and solve an issue logically. Since science is built on inquiry, science process skills rely on it (Ongowo&Indoshi, 2013). Scientific inquiry implies that students can recognize scientific methods of acquiring evidence, thinking creatively, reasoning rationally, responding critically, and communicating results as they encounter life circumstances involving science and technology. (OECD, 2013).

Classification of Science Process Skills

Between the year of 1963 and 1974, the SAPA (Science - A Process Approach) curriculum split these skills into two groups: Basic Science Process Skills (BSPS) and Integrated Science Process Skills (ISPS).

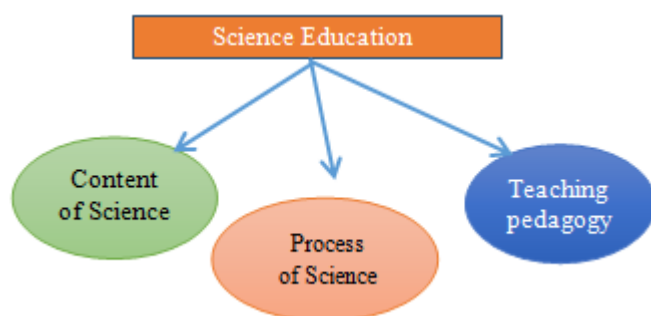
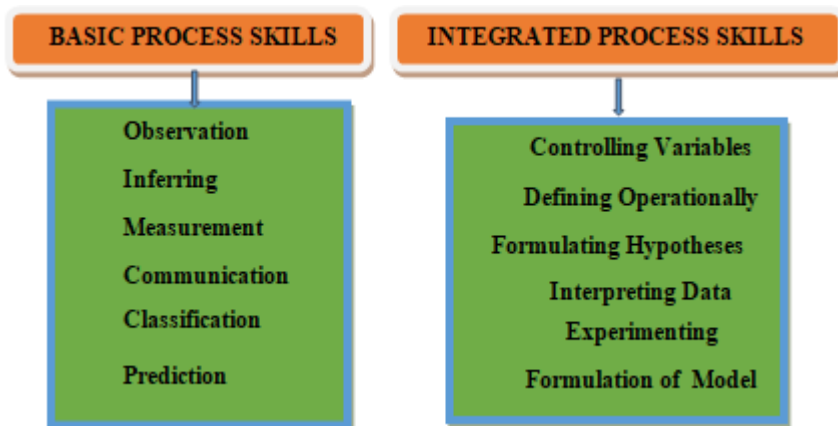


Figure 1: Fields of science education



(Classification of Science Process Skills)

Table 1: Classification of Science Process Skills

Basic process skills	Description
Observation	Use of five senses to derive characteristics of living organism
Inferring	Explanation of observations and data
Measurement	Using standard and non - standard measures to describe dimensions
Communication	Using words or symbols to describe an action, objects and events
Classification	Sorting, grouping and arranging based similarities and differences
Prediction	Stating the outcome of future event based on a pattern of evidence

Integrated Process skills	Description
Controlling variables	Identifying variables, keeping variables constant and manipulating
Defining operationally	Stating how to measure a variable in an experiment
Formulating hypotheses	Stating the expected outcome of an experiment
Interpreting data	Organizing, concluding from data and making sense of data
Experimenting	Testing by following procedures to produce verifiable results
Formulating model	Creating a mental or physical model of a process or event

According to Raj and Devi (2014) science process skills are the transmissible ability to emulate and demonstrate behavior of the scientist. These skills influence students' enduring learning, encourage meaningful student participation. The main objectives of science education in schools are to help students develop the scientific process abilities that lead to the creation and verification of scientific information. The science curriculum in schools must place equal emphasis on science process skills, or the procedures or processes for studying science, as well as science content (NCERT, 2006). Process skills help students keep up with the scientific and technology fields' constant expansion and change. These skills prepare students to succeed in their academic studies as well as equip them to meet the challenges of 21st century (NCREL &Metiri Group, 2003).

Because of the relevance of science process skills, numerous scholars have concentrated on this area. Many research on the learning of basic science process skills (BSPS) and integrated science process skills (ISPS) by students have been undertaken in recent years. However, science education in schools is still centred on the full delivery of learning materials. Eventually, the instructor teaches knowledge according to curriculum. Teachers fail to recognise the relevance of teaching science process skills. The goal of right education is to help students to comprehend science rather than memorize it (Fahmi and Irhasyuarna, 2017). According to the findings of the Programme for International Student Assessment (PISA) study, several nations fall below the PISA average norm in terms of science achievement (PISA, 2016). Because the science

information that must be presented is more than just training science process skills, science process skills are still not fully trained in learning. Science process skills and science products, on the other hand, should be interwoven throughout science lessons. Science process skills are automatically trained in science learning rather of being taught separately as a collection of knowledge. Science process skills are an essential component of science. Nasreen and Naz (2013) discovered that learning models are one of the variables influencing poor learning outcomes. Using a less precise model of learning in the learning process may result in dissatisfaction, a lack of understanding of topics, and rigidity, which forces pupils to lose motivation to learn. Therefore, a learning model like inquiry learning method is required.

Inquiry Learning in Science

As 21st century is considered the knowledge and information era, hence it is obvious that the nations who are enriched with the knowledge domain, would excel and only educationally empowered would lead a productive and qualitative life. The task of the learner has been transferred from that of acquiring knowledge to become skillful, to that of sourcing out knowledge and connect information. Thus, a strong scientific background is required to develop an outstanding technical mind. This understanding involves the development of ideas and concepts linked together make a sense of new experience. This is an essential part of learning science (Behera, 2018). Learning science lessons through comprehension necessitates the use of science process skills (SPS). Science process skills are founded on scientific

inquiry, which is described as the technique that scientists use for conducting research. Inquiry can be a very successful teaching method that aids students in conceptual understanding and the application of process skills (Yager & Akçay, 2010). Learning with the inquiry method allows students to explore and investigate the concept of a procedural, systematic, and interrelated relationship between one topic and another. Learners' learning outcomes can be improved by using the application inquiry learning technique (Untajana, 2014). Inquiry - based learning (IBL) can increase student engagement, allow students to apply their research skills, construct meaning, and gain scientific knowledge (Suduc et al., 2015).

In the last century, Inquiry learning has been used in junior and senior high schools' classroom (Lati, Supasorn, & Promarak, 2012). Analysis on the survey data shows that 88% of students are comfortable in understanding science (Sheffield & McIlvenny, 2014). Inquiry originated in the science disciplines (Melville, 2015), and has long been advocated as an effective and authentic approach to teaching and learning science.

In numerous studies, it was found that the inquiry based teaching is much more efficient in improving students' science process skills than traditional teaching methods (Lati, Supasorn, & Promarak, 2012; Sheffield & McIlvenny, 2014; Melville, 2015; Nadziroh et. al., 2018). A study was conducted to find the effectiveness of inquiry based teaching methods and the result was found that inquiry based teaching methods significantly enhances students' science process skills and attitudes (Remziye et. al., 2011; Ceylan and Gulsah, 2016). Duran (2014), Bunterm et al. (2014), Kaya and Yılmaz (2016), Yıldırım and Altan (2017), and van Uum et al. (2017) with different age groups, the effect of the IBL approach on SPS is revealed. It is stated that students have made significant progress in understanding the goals of questioning over time, defining questions, explaining their ideas, making controlled comparisons, interpreting the increasingly complex data, supporting claims and making validated predictions, and using the scientific method as necessary to manage their own learning processes. According to Patonah et. al. (2018), inquiry learning can empower science process skills. Students are trained to have simple process skills consisting of: observing, measuring, predicting, communicating, concluding and classifying. Based on observations,

observing skills include abilities that have the highest score, meaning that each student can make good observations. But the ability to predict, including in the category of skills that are still relatively low.

The objective of this paper was to examine the impact of inquiry - based learning method on science process skills of the learners. Despite the fact that numerous types of research have been conducted on the SPS taught in schools, there is still a scarcity of researchers who have conducted a systematic literature review on the available studies. The outcomes of this study may encourage scientific educators to employ SPS in science experiments with proper ways to increase SPS, which are key competences that can influence students' performance in science learning.

Objective

In spite of the existence of many studies to determine the effects of inquiry based learning method on the science process skills, no systematic literature survey has been found on this subject. In this context, the question of "what are the effects of the inquiry based learning method on the science process skills?" is important to answer. The objective of this paper was to examine the impact of inquiry - based learning method on science process skills of the learners.

2. Method

Research Design

The study employed the systematic literature review (SLR) technique to determine the impact of inquiry - based learning on students' science process skills in science education. Dixon - Woods (2010) defined systematic literature review as "a scientific process governed by a set of explicit and demanding rules oriented towards demonstrating comprehensiveness, immunity from bias, and transparency and accountability of technique and execution".

PRISMA or preferred reporting items for systematic reviews and meta - analysis, was used in this study. The PRISMA flow diagram was also used in the study to select article that were related to the study's objective. The PRISMA flow diagram for article selection involves four stages: identification, screening, qualification, and article placement in SLR research (Cooper et al., 2018)

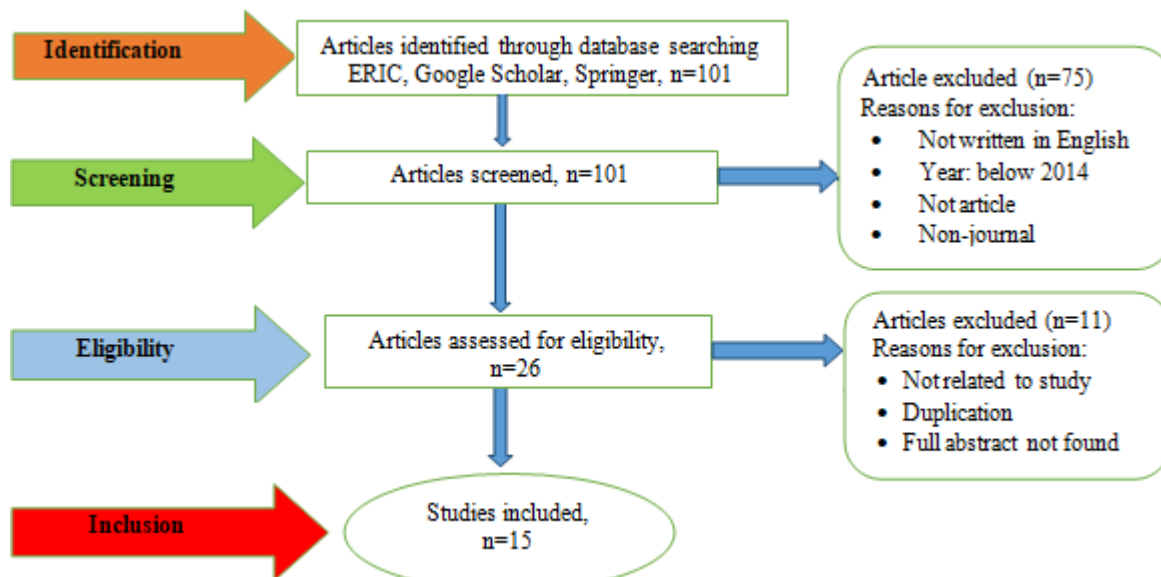


Figure 2: Flow Diagram of PRISMA 2020 to Studies Published between 2014 and 2023

Source: Page et al. (2021)

Data Collection

Some criteria that are used to narrow the scope of review process. The papers chosen for this evaluation are quantitative studies that met the inclusion criteria established at the start of the review process.

Publication dates: Those studies which were carried out between 2014 and 2023 were included in the study.

Publication type: Articles published in scientific journals or databases (ERIC, Google scholar, Springer) were reviewed in the study.

Use of the appropriate teaching method: In the study, it was required that the inquiry - based method was employed in the experiment groups and traditional learning was implemented in the control groups.

Searching Key term: we applied the search terms like “science process skills or scientific process skills”, inquiry learning method, “science process skills and inquiry learning method” to find relevant articles.

After using inclusion criteria, a total of 15 studies were included in the sample of the study.

Table 2: The Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication timeline	2014 - 2023	Below the year 2014
Record type	Original Research Article	Book chapter, conference proceedings, review paper
Language	English	Non - English
Source type	Journal	Non - Journal

3. Result and Discussion

Based on the literature search on Google Scholar, ERIC, and Springer a total of 15 articles related to effect of the inquiry - based method on science process skills of students published from 2014 to 2023 that met the criteria were obtained. The research on the articles were conducted in various countries, such as Indonesia (4), Malaysia (2), Spain (2), Thailand (1), Iran (1), Taiwan (1), and Turkey (4).

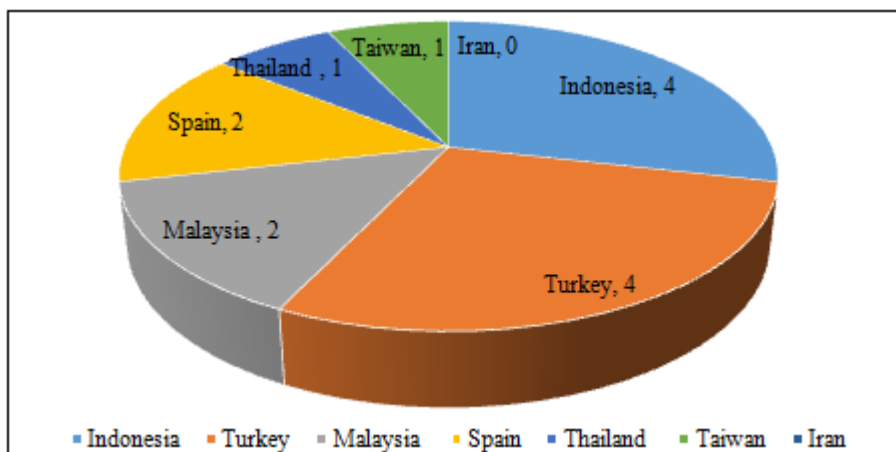


Figure 3: This figure shows no. of studies country wise.

Table 3: Profile of the Articles

No.	Author, Year, Location	Country	Field of Study (Level)	Method
01	Sabriye et. al., (2020)	Turkey	Science (Primary)	Inquiry Based Learning Approach
02	Rolando Mango et. al. (2020)	Malaysia	Science (Junior High school)	Inquiry - based flipped learning
03	Panjaitan and Siagian, (2020)	Indonesia	Science (Primary)	Inquiry Based Learning Model
04	Gonul (2021)	Turkey	Science (Primary)	Research - Inquiry Based Activities
05	Ns et. al. (2017)	Indonesia	Science (Senior secondary)	Inquiry Learning Model
06	Ulger and Cepni (2020)	Turkey	Science	inquiry - based science lesson modules
07	Ali Abdi (2014)	Iran	Science (Primary)	Inquiry - based instruction supported 5E learning cycle method
08	Harika et. al. (2023)	Turkey	Science (Pre service Teachers)	Argument - driven inquiry
09	Mutlu, A. (2020)	Indonesia	Science (Primary)	Inquiry - based learning method
10	Baharom, M. et. al., (2020)	Malaysia	Science (Primary)	Inquiry Based Science Education
11	Savitri, E. N. et. al. (2017)	Indonesia	Science (Senior secondary)	Inquiry learning with Green Learning Method (GeLeM)
12	SanoeChairam, Nutsuda Klahan & Richard K. Coll, (2015)	Thailand	Chemistry (Senior Secondary)	Inquiry - based teaching and learning methods
13	Cristina et. al (2021)	Spain		Inquiry - based learning in laboratory activities
14	Min - Hsien Lee et. al. (2019)	Taiwan	Science (Junior Secondary)	Open - ended inquiry activities.
15	Anna Borrul& Cristina Valls, (2021)	Spain	Science (Pre service Teachers)	Inquiry - based learning in laboratory activities.

According to Mutlu, A. (2020), During the inquiry - based learning process, students' scientific process abilities such as describing the topic, generating a hypothesis, observing and evaluating data were emphasised. Students had trouble planning and carrying out experiments. Furthermore, inquiry - based learning remains an important component of science education. Students must not only grasp science topics, but they must also understand and be able to use science process skills, as well as appreciate the nature of science and its impact on society (Cairns, 2019).

Gonul (2021) revealed that students in the experimental group who were taught using inquiry based learning method had improved in observation, drawing inference, making classification, measurement, establishing relationship between variables, define variable operationally, writing hypothesis, conducting experiment, interpretation of data, and formulation of model.

Study by Borrull&Valls (2021) found that inquiry - based method involves both acquisition of knowledge as well as converts this knowledge into practice. Furthermore, inquiry - based method helps them enhance their SPS by engaging them inquiry activities, providing supporting facts and by posing questions.

Lee et al. (2019) mentioned that the ultimate level of inquiry is open inquiry, in which learners determine the techniques to answer their own questions. Students' science process skills can be facilitated by personal ideas of students about learning in science. Tan et. al (2020) emphasized that inquiry - based method is useful in enhancing students' conceptual knowledge and science process skills, but it is capable of being even more efficient depending on the subject matter.

Ulger and Cepni (2020) claimed that although students' basic SPS improved, there was less development in experimental processes. They came to the conclusion that the pupils required more in - depth and difficult exercises. According to Sahhyar and Nst (2017), inquiry - based learning method enables learners to gain intellectual proficiency and science process skill. inquiry - based learning method engages students in the investigation of a genuine problem of inquiry.

Inquiry based learning model allows students to explain, predict, experiment, and make decisions with opportunities to investigate their own questions about science - based topics and problems (Panjaitan and Siagian, 2020).

In accordance with the judgements of Baharom (2020) the incorporation of technological devices in scientific instruction through an inquiry - based science education approach is strongly encouraged since this helps learners comprehend Science Process Skills. Sabriye et. al., (2020) found that inquiry - based learning entails asking questions, conducting investigations, and gathering data. After taught through the inquiry learning method, there was a substantial difference between the experimental and control groups in terms of basic SPS, high level SPS, and general SPS levels. Savitri et. al. (2017) revealed that inquiry learning method emphasizes on the ability of learners to reason, be analytical and scientific.

According to the findings of this study, inquiry - based learning increases students' science process skills. The inquiry - based learning method equips students with experiences of learning that are enhanced by comprehensive insights from their surroundings. As a result, students get the opportunity to participate in actual activities that aid in the development of science process skills. It also excels in learners' ability to study individually and throughout classroom activities. Inquiry activities assist students to develop their cognition of scientific phenomena as well as improve their ability to perform experiments.

4. Conclusion

Inquiry - based learning is more usually supported by the constructivism approach, which allows for the construction of learning and active participation situations with the student as the protagonist, where knowledge is produced and sustained through time (Chairam et al., 2015). Inquiry learning as a pedagogical method enables learners to ask questions, gather knowledge, and develop concepts. Both researchers and educators agree that this method can improve learners' cognitive skills, as well as their psychomotor and affective skills. In the current study, it was

found that the inquiry - based learning method used in science education had much more significant effects on student science process skills.

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