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STRATEGIES IN MASTERING SCIENCE PROCESS SKILLS IN SCIENCE EXPERIMENTS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Science is a knowledge discipline that is experimentally oriented. The science experiment is one of the core activities in science learning. It is a process that prioritises methods of investigation and problem-solving where the scientific method is employed. In science experiments, mastery of scientific process skills is required. Hence, it is crucial as this will expose students to scientific methods and knowledge. This study aims to identify what are the appropriate strategies that may be employed to augment learners' science process skills. This article conducts a systematic literature review and twenty-two articles have been chosen to be analysed. The current study combined many research designs, where the review fulfilled the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) publishing standard. Web of Science and Scopus, two well-known databases, were used to discover articles for this study. This review includes a topic based on the thematic analysis which is strategies in mastering science process skills. The results show seven sub-themes based on the topic that are 1) Hands-on and minds-on implementation 2) Inquiry-based approach 3) Discovery learning 4) Strategic manipulative skills 5) Argumentation Skills 6) Using Information and Communication Technologies and 7) Implementing Engineering-oriented science, technology, engineering, and mathematics (STEM) Integration Activities. The research's findings may motivate science educators to use the appropriate strategies while undergoing science experiments to improve SPS which are important competencies that can influence student's performance in science learning.

Keywords: science experiments; science process skills; strategies; systematic literature review

INTRODUCTION

The essential skills in science experiments are science process skills (SPS). This phrase is derived from the AAAS's (American Association for Advancement of Science) concept of the Science-A Process Approach (SAPA), which was introduced in 1967 (Fugarasti et al., 2019). SAPA is based on a paradigm that defines science as a process that accentuates the establishment of science process skills as independent and vital qualities from content knowledge (Kind, 2016). SPS are skills used by scientists to analyse or explore a problem, issue, question, or scientific phenomena that occurred throughout the learning process (Duruk et al., 2017). SPS attempts to improve students' sensitivity towards learning experiences through the use of scientific methodologies (Idiege et al., 2017). The SPS were divided into fifteen elements by the AAAS. There are: classifying, observing, communicating, describing, drawing conclusions, developing operational definitions, interpreting data, experimenting, formulating hypotheses and controlling variables (Seetee et al., 2016). SPS is made up of a variety of basic and complicated abilities that are separated into two divisions: integrated and basic process skills (Bahtiar & Dukomalamo, 2019; Elfeky et al., 2020; Fitriani & Fibriana, 2020; Parmin et al., 2021). Table 1 summarises each of the integrated and fundamental process skills.

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Table 1. Science Process Skills. Source: Ongowo & Indoshi (2013)

Basic Process Skills	Description
Observing	To determine the features of living organisms, we utilise our five senses.
Inferring	Data and observations are explained.
Measuring	Dimensions are defined utilising both non-standard and standard measures.
Communicating	To express an event, an object, or an action through symbols or words.
Classifying	Arranging, grouping, and sorting in regard to similarities and differences.
Predicting	Using an evidence pattern to predict the result of likely outcomes.
Integrated Process Skills	**Description**
Controlling variables	Determining variables, ensuring that the variables are manipulating and constant.
Defining operationally	In an investigation, describing how to measure a variable.
Formulating hypotheses	Specifying the predicted result of an examination.
Interpreting data	Making sense of data and organising and concluding from it.
Experimenting	Abiding procedures to achieve verified findings is what testing is all about.
Formulating models	Making a physical or mental model of an event or process.

The nature of science education involves students in conducting science experiments. Science process skills are among the most substantial basic skills required in science experiments (SPS), like inferring, measuring, predicting, observing, communicating and experimenting are just a few examples. Such skills help students to understand scientific phenomenon being investigated, discover information and improve the sense of taking responsibility on own learnings during science experiment activities (Kim, 2018). Furthermore, the SPS emphasises the process of seeking knowledge actively while conducting the science experiment rather than the transfer of knowledge, given the teacher's role is restricted to that of a facilitator who oversees and steers the experiment (Herranen & Aksela, 2019). Previous studies by Darmaji et al. (2019) and Juhji & Nuangchalerm (2020) indicated that conducting science experiments improves SPS and students' positive attitudes about science.

Although many kinds of research have focused on the SPS taught in schools, there is still a shortage of researchers who have examined the available studies in a systematic literature review. Robinson & Lowe (2015) stated that it is necessary to conduct a systematic literature review of previous research as typical literature reviews have numerous flaws, including being rarely complete, being extremely subject to reviewer bias, and failing to account for changes in the study's quality. The goal of this investigation is to include the current body of knowledge by conducting an extensive literature review on guiding SPS in scientific experiments in schools. One way for doing a more extensive review of the current literature is to execute a systematic literature review.

The central research question directs the review: What are the strategies of implementing science process skills in school among teachers and students?. The outcomes from Trends in Mathematics and Science Studies (TIMSS) stated that the passion of students, enjoyment of science and confidence in science are important positive predictors of science achievement (Wang & Liou, 2017; Awang et al., 2021). Learners' comprehension of science concepts and the improvement of SPS that constitute pupils' everyday practise are referred to as science achievement. Therefore, the unplanned process of teaching science in applying SPS to students will lack value in fostering the SPS practices among students (Yumusak, 2016). Hence, the research aims to determine what strategies teachers use to enhance students' mastery of SPS and further raise students' knowledge of science topics and influence their attitude towards science. This research contributes significantly to the corpus of knowledge and practical applications. This study can be utilised as a resource for anyone working in science education, particularly at the secondary school level. The findings of this study may motivate scientific educators to use SPS with appropriate strategies in science experiments to improve SPS which are important competencies that can influence students' performance in science learning.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guided the review. Investigation on a systematic literature review (SLR) necessitates the formulation of specific research questions as well as the use of systematic and explicit methods for identifying, selecting, evaluating, collecting, and analysing data from relevant previous studies. PRISMA covers a wide range of general concepts and topics applicable to any systematic review (Moher et al., 2010). Moreover, Sierra-Correa and Cantera Kintz (2015) asserted that PRISMA has three different benefits: 1) it defines research topics for systematic investigation, 2) it generates inclusion and exclusion criteria, as well as 3) it attempts to analyse a vast database of scientific papers within a specific time limit.

The flow diagram from PRISMA was also applied in the study's article selection procedure for publications that were relevant to the research questions. The prism flow diagram for article selection includes four stages: identification, screening, qualification, and article insertion in the SLR research (Cooper et al., 2018). As a result, the search strategy, selection criteria, selection process, data collection, as well as data analysis for the papers acquired were all included in the SLR research.

This study's research questions were developed primarily using PICO (population, interest, and context) (Mohamed Shaffril et al., 2020). It is a tool that facilitates researchers to come up with acceptable research questions for their reviews. PICO is based on three main ideas: context, interest, and population or problem. First, the authors included three primary components in the review based on these ideas: namely, teachers and students (population), scientific skills' strategies (interest), and school (context). Then, the authors used these ideas to develop their key study question: What are the strategies of implementing science process skills in school's science experiments among teachers and students?

Identification, screening, and eligibility are the three primary steps of the systematic searching techniques approach (see Figure 1).

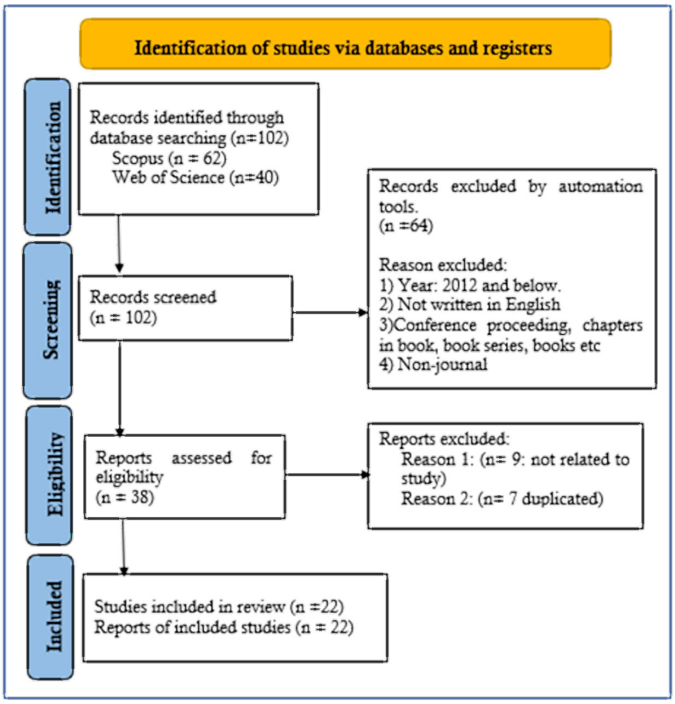

Figure 1. Flow Diagram Detailing The Application of PRISMA 2020 to Studies Published between 2015 and 2021. Source: Page et al. (2021)

The finding's process variations of the study's major keywords, related terms, or synonyms, which are science process skills, science experiment, and school, is known as identification. Its purpose is to give a certain database extra possibilities for discovering similar publications for a review. As suggested by Okoli (2015), the keywords were developed using an online thesaurus, keywords from prior researches, keywords given by Scopus, as well as keywords recommended by specialists. Utilizing the two primary databases, Scopus and Web of Science (WoS), the scholars were able to augment the present keywords and construct a comprehensive search string (obtained from field code functions, wild card, truncation, phrase searching, and Boolean operators) (See Table 2).

Since WoS and Scopus are two of the very well-known and competitive citation databases in the world, they can be the most important in a systematic literature review. For example, in the last 15 years, relatively 3000 papers have been released papers related to WoS, while more than 2500 articles have been released papers related to Scopus (Zhu & Liu, 2020). Additionally, both WoS and Scopus provide metadata on the document type and language of the texts they cover, and both are frequently used in meta-analyses (Martín-Martín et al., 2018). During the search, these two databases, Scopus and Web of Science, returned a total of 97 articles

Table 2. The Search String

Databases	Keywords Used
Scopus	TITLE-ABS-KEY (("Scientific skill*" OR "Science Process Skill*" OR "Scientific Process Skill*" OR "Manipulative skill*") AND ("Hands-on" OR "Science Experiment*" OR "Hands-on Laboratories" OR "Laboratory Activity" OR "Laboratory Activities" OR "Practical Work" OR "Biology laboratory" OR "STEM education" OR "Science, Technology Engineering, and Mathematics") AND ("school"))
Web of Science	TS=(("Scientific skill*" OR "Science Process Skill*" OR "Scientific Process Skill*" OR "Manipulative Skill*") AND ("Hands-on" OR "Science Experiment*" OR "Hands-on Laboratories" OR "Laboratory Activity" OR "Laboratory Activities" OR "Practical Work" OR "Biology laboratory" OR "STEM education" OR "Science, Technology Engineering, and Mathematics") AND ("school"))

The inclusion and exclusion criteria for the review are part of the screening method. Various situations have different needs, and the criteria that have been selected should correspond to research issues. The criteria for article selection were determined by screening all 102 articles using the database's sorting function.

The timeline publication for a mature study may be shorter than a less mature one in which many articles can be tracked, as mentioned by Kraus et al. (2020). Furthermore, Kraus et al. (2020) explained that a longer timeline is required for a less mature study because there are few articles and more research questions are unanswered. The number of research relevant to science process skills gained in school science experiments has increased since 2013, according to search results in the chosen database. As a result, one of the inclusion criteria was chosen for the period 2013 and 2021. Only papers that encompass empirical data and are issued in a publication are incorporated in the review to ensure its quality. Furthermore, to avoid ambiguity, the review only contains publications that have been published in English (Table 3). 64 items were excluded as a result of this procedure because they were unable to meet the inclusion criteria. Thus, for the third process eligibility, the remaining 38 articles were used.

Table 3. The Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication timeline	2013-2021	2012 and before
Document type	Article (with empirical data) and review	Books, book series, chapters in a book, conference proceeding etc
Source type	journal	Non-journal
Language	English	Non-English
Nature of the study	Focus in school	Not focus in school

The eligibility screening procedure is the second screening procedure, in which writers manually check the papers gathered to guarantee that all other papers (after screening) match the requirements. This was achieved by reading the title and abstract of the paper. However, given the concentration on the university level rather than the school setting, nine papers were removed from this process on educational philosophy for culture-based learning and STEM careers rather than hands-on Science experiments. In addition, seven redundant articles were removed, where only 22 articles were selected.

A quality appraisal is an approach for assessing the relevance and validity of study outcomes by recognising the strengths and shortcomings of a research publication (Munn et al., 2020). The most significant components of a critical appraisal are evaluating the suitability of study design for the research issue as well as a comprehensive review of the design's major methodological characteristics. Based on Munn et al. (2020), the author analysed a few questions when critically appraising a research article: 1) Does the research question have any relevance? 2) What kind of research question are you posing? 3) Is the research design suitable for the research question? 4) Did the research procedures address the most significant sources of bias? 5) Did the statistical analysis turn out as expected? 6) Does the evidence support the conclusions? As a result, the assessment was conducted on all 22 of the remaining articles.

The qualitative technique using thematic analysis was chosen for this study. In accordance with Xu & Zammit (2020), qualitative analysis is the same as synthesis through interpretation and explanation. First, the researcher reviewed all 22 publications carefully, paying special attention to the abstract, findings, and discussion sections. The data was then abstracted depending on the study topics. Afterwards, the data from the investigations that can address the research questions were aggregated and abstracted for evaluation. Following that, the author conducted thematic analysis within the abstracted data. We discovered themes and sub-themes through tasks such as noting similarities, counting, clustering, detecting patterns and themes, as well as building linkages. The goal of thematic analysis is to discover and analyse essential elements of the data using the research question as a guide (Clarke & Braun, 2013). Thematic analysis is believed to be the most efficient method for synthesising data from a mixed research design (integrative) (Flemming et al., 2019). The author conducted thematic analysis in two ways, namely deductive thematic and inductive thematic. For a deductive thematic, the author first identified several themes related to the research question. At the same time, inductive thematic involves identifying themes by the author based on previous research patterns.

RESULTS AND DISCUSSION

The review was successful in obtaining 22 articles. Two topics were created based on the thematic analysis: 1) strategies and 2) relevance. Following a deeper examination of the topics, ten sub-themes emerged. Six investigations were undertaken in Turkey, seven studies in Malaysia, two studies each in South Africa, Indonesia and Spain, and one research in each of these countries: Thailand, Taiwan, and the United Arab Emirates (UAE). In addition, two of the 22 pieces chosen were published in 2014, 2015 and 2016, one in 2013 and 2017, five in 2019, three in 2021 and six in 2020.

In a scientific experiment, hands-on is described as an instructional strategy involving action and direct involvement with natural phenomena. This includes any educational experience that actively involves students manipulating things to obtain information or understanding while enduring the science experiment (Gultepe, 2016). Students require practical chances in hands-on science experiments to implement for assistance and information in sharing or integrating the knowledge they gain to understand science concepts as a whole. Furthermore, Shana & Abulibdeh (2020) asserted that hands-on learning is crucial to improving learners' skills and knowledge through the combination of theoretical and practical knowledge. Consequently, they are also developing SPS.

Phaeton & Stears (2016) emphasised that science learning should be viewed through transitional stages based on the learner's cognitive (minds-on) development. Thus, it is important to provide students with background knowledge on the topic they will be researching before beginning any hands-on science experiments. In addition, the task design shall drive learners' efforts toward establishing connections to the knowledge that will be assimilated. Thus, recognising the minds-on transitional stages of science learning has an important bearing on nurturing the learners' SPS development in a science experiment.

The article profile review focused on the strategies used to acquire science process skills in science experiments (Table 4).

Table 4. Profiles of the Articles

No.	Author (s), Year, Location	Strategies Suggested in the Article(s)
1.	Hidayah Mohd Fadzil & Rohaida Mohd Saat, (2013), Malaysia.	Manipulative techniques in handling the apparatus.
2.	Hidayah Mohd Fadzil & Rohaida Mohd Saat, (2014a), Malaysia.	Acquiring technical skills; 1. Making assumptions 2. Measuring. 3. Scientific drawing.
3.	Hidayah Mohd Fadzil & Rohaida Mohd Saat, (2014b), Malaysia	Acquiring manipulative skills.
4.	Necati Hirça, (2015), Turkey.	1. Constructivist learning approach (5E Model: Engagement phase, Explore phase, Explanation phase, Elaboration phase, Evaluation phase). 2. Inquiry learning
5.	Sanoe Chairam, Nutsuda Klahan & Richard K. Coll, (2015), Thailand.	Inquiry-based teaching and learning methods.
6.	Nejla Gultepe, (2016), Turkey.	1. Hands-on learning. 2. Inquiry and discovery skills, mainly on reasoning skills.
7.	Mukaro Joe Phaeton & Michèle Stears, (2016), South Africa.	Hands-on and minds-on activities.
8.	Hidayah Mohd Fadzil & Rohaida Mohd Saat, (2017), Malaysia.	Technical skills in using basic scientific apparatus.
9.	Muhamad Imaduddin, Fitria Fatichatul Hidayah, (2019), Indonesia.	Inquiry-based Science, Environment, Technology, and Society (SETS) approach.
10.	Irwanto, Anip Dwi Saputro, Eli Rohaeti, Anti Kolonial Prodjosantoso, (2019), Indonesia.	Inquiry-Based Laboratory Instruction (IBLI).
11.	Min-Hsien Lee, Jyh-Chong Liang, Ying-Tien Wu,Guo-Li Chiou, Chung-Yuan Hsu,Chia-Yu Wang, Jing-Wen Lin, Chin-Chung Tsai, (2019), Taiwan.	Open-ended inquiry activities.
12.	Irene Lue Leh Ping, Lilia Halim, Kamisah Osman, (2019) Malaysia.	Modified Argument-Driven Inquiry approach (MADI)
13.	Hidayah Mohd Fadzil & Rohaida Mohd Saat (2019) Malaysia.	Resource guide in assessing students' manipulative skills.
14.	Huseyin Artun, Alper Durukan & Atilla Temur (2020),Turkey.	Virtual reality enriched laboratory activities.
15.	Zuhrieh Shana , Enas S. Abulibdeh, (2020), United Arab Emirates	Hands-on materials approach.
16.	Irene Lue Leh Ping, Lilia Halim & Kamisah Osman, (2020), Malaysia.	Argumentation skills.
17..	Sevinç Nihal Yeşiloğlu & Fitnat Köseoğlu (2020), Turkey.	Discovery learning, process-oriented learning, and inquiry-based learning.
18.	Hicran Özkul & Muhammet Özden, (2020), Turkey.	Engineering-oriented STEM integration approach.
19.	S. Furiwai, A. Singh- Pillay, (2020), South Africa.	1. Teachers use a demonstration. 2. Guided discovery experiment in small groups, engaging in hands-on activities. 3. Learners design and do their open-ended investigations.
20.	Israel Kibirige & David Maponya, (2021), Turkey.	1. An investigation that engages learners. 2. Explorative activities 3. Hands-on.
21.	Anna Borrul & Cristina Valls, (2021), Spain	Inquiry-based learning in laboratory activities.
22.	Cristina Valls-Bautista, Anna Sole-LLussa & Marina Casanoves (2021), Spain.	Inquiry-based learning in laboratory activities.

Technical skills in science experiments include both cognitive (minds-on) and psychomotor (hands-on) abilities. For example, Kibirige & Maponya (2021) highlighted that hands-on and minds-on science experiments are active learning processes. The students learn by doing hands-on science experiments, but they think about what they are learning and doing when practising minds-on learning. Furthermore, when completing certain scientific procedures inside the science experiment, individuals must combine their hands-on skills and minds-on abilities to control certain equipment in order to acquire technological expertise.

The inquiry-based approach is not about memorising facts - it is about formulation queries and finding acceptable resolutions to questions and problems. The inquiry-based approach involves students' curiosity to explore investigation in science experiments. The purpose of this inquiry-based approach is to form the intellectual discipline required in asking questions and seeking answers from students' curiosity based on students' existing knowledge as well as developing reasoning skills (Gultepe, 2016). Intellectual discipline is the practice of obtaining specific information to achieve a particular purpose. This inquiry-based approach differs from traditional learning environments, which focus on transmitting a set of predetermined facts and information from teacher to students. The inquiry-based approach begins by creating situations that arouse students' curiosity to explore. Then, students feel compelled to solve the problem through the implementation of science experiments. Students were engaged in learning chemical kinetics by employing inquiry-based learning activities in executing science experiments (Chairam et al., 2015). A major concept of contemporary initiatives to change scientific education is to engage learners in inquiry-based learning.

Irwanto et al. (2019) revealed that the inquiry-based approach emphasises active usage of scientific process skills by implementing critical thinking compared to memorising the construct in science learning. Critical thinking in an inquiry-based approach can be implemented through four interrelated aspects. Firstly, by shaping the climate to support thinking, teachers can foster a culture of discussion in science experiments related to questions regarding students' daily routines or scientific and technological phenomena. Secondly, by creating opportunities for thinking, teachers present problem-solving opportunities to students for which there is more than one reasonable solution in a science experiment (Kibirige & Maponya, 2021). Thirdly, by building capacity to think where teachers foster helpful habits of mind such as students being attentive to detail during a hands-on science experiment. Fourthly, teachers guide to inform thinking by offering various ways for students to provide evidence of their thinking, such as refining their theories and hypotheses in a science experiment.

Study by Borrull & Valls (2021) found that inquiry-based approach is a type of learning that combines both learning and practise. Furthermore, inquiry-based approach provides students with supporting facts and explanations about natural events, which helps them enhance their SPS. Students are taught how to apply the scientific method by raising questions that they wish to have answered. They are next told to look about them and construct a query. After that, students must consider how they can answer their question scientifically. In order to gather objective evidence that will allow them to accept or reject their hypothesis, they must conduct an investigation to offer an answer and be capable of addressing the query. In contrast, Borrull & Valls (2021) found that one of the primary issues with students' scientific practise exercises in class is that they are disconnected from their daily lives. In contrast, an inquiry-based approach puts the student at the middle of their learning process by enabling them to create decisions and pick variables; it also proves how scientific works result in the investigation. It is an interdisciplinary activity since most experiments necessitate knowledge from various disciplines. The results are in accordance with outcomes of prior research by Valls-Bautista et al. (2021), who recognised an inquiry-based approach as a strong pedagogical method in regards to learning science. Inquiry-based activities assist students to acquire scientific knowledge by allowing them to practise scientific process skills. Students were encouraged to build fundamental scientific abilities through the inquiry process in order to learn science through science experiments. Inquiry-based approach is widely acknowledged as a useful tool for combining theory and scientific practise.

By participating in a science experiment with an inquiry-based approach, students have been provided to experience the procedure for recognising the core of science, phenomena, and scientific concepts, as well as developing their abilities to critically assess scientific evidence and engage in the scientific community. However, based on Hirça (2015), teachers need sufficient experience to use inquiry learning methods in science teaching and not simply use direct instruction in the implementation of science experiments. As a result, the teacher is regarded as a facilitator rather than a mentor, and the students are active learners rather than passive recipients. Similar findings have been shown- in science experiment implementation. As a result, pre-service teachers have a complete understanding of the benefits of teaching and learning science using an inquiry-based approach (Imaduddin & Hidayah, 2019).

A research finding by Yeşiloğlu & Köseoğlu (2020) additionally points towards the most common motive for applying science experiment concerning the science experiment concept that implements learning by discovery. Students create their knowledge through the discovery learning approach, which involves experimenting and inferring from the results through a science experiment. Based on Shana & Abulibdeh (2020), it is important to allow students to create their experiments so they do not merely follow the teacher's directions. During running science experiments, learners are not taught how to follow instructions step by step. Throughout the discovery learning strategy, they are given opportunities to acquire science concepts, enhance scientific process abilities, and detect difficulties.

In another study, Furiwai & Singh-Pillay (2020) stated three ways in the discovery learning approach in science experiments. First, the teacher designs and provides various science experiments to encourage student exploration in discovery learning (Razali et al., 2020; Yeşiloğlu & Köseoğlu, 2020). Next, when participating in a hands-on science project, students use a discovery learning strategy in small groups. Finally, students create a scientific report to support their findings based on the information gathered. The above finding is consistent with the study by Fadzil & Saat (2017), who examined that through the discovery learning approach in a science experiment, students are encouraged to learn by discovering events that occur in their immediate surroundings. The scientific knowledge acquisition, as well as scientific theories understanding, could be aided by such a learning technique.

In a science experiment, manipulative skills are psychomotor abilities that permit students to operate and sketch specimens and science apparatus accurately. Manipulative skills and SPS are frequently gained by implementing a science experiment in the school's laboratory. Manipulative abilities are required for kids to successfully complete science experiments. To gain experience in manipulating specific scientific equipment, students need to perform numerous science experiments by applying the types of equipment. Handling and manipulating scientific equipment with good skill is necessary to minimise, control and reduce misinterpretations and errors in scientific experiments. Hence, Lee et al. (2019) found that students who have personal ideas about learning in science experiments attaining facilitating SPS and manipulative skills may view a real science laboratory environment as an open-ended condition.

Fadzil & Saat (2017) mentioned that mastering technical abilities had a significant impact on students' capacity to learn manipulative skills. Students learn technical skills in a systematic way, serving as a hierarchy (Figure 2). The mastery of technical skills from basic affected the students' capacity to learn advanced abilities significantly. These abilities are acquired in a predictable manner, which may be used to form a hierarchy. Teachers may utilise this hierarchy to teach manipulative skills, where students can benefit from it as well.

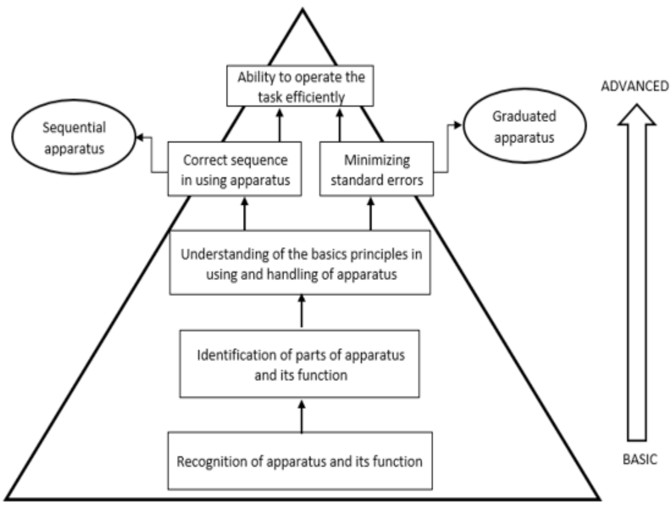

Figure 2. Five (5) Levels Hierarchy of Technical Skills. Source: Fadzil & Saat (2017)

Manipulation skills should be taught to students and empower their favour in science process skills precisely. The students' ability to prepare before undergoing a science experiment depends on their understanding of the concepts and procedures in the execution of scientific experiments to create their experimental procedures. This strategy can only be achieved if students have a preliminary understanding of the necessary manipulative skills in science experiments. The recommended strategy for improving the mastery of manipulative skills is to include pictures showing the equipment used. This is followed by using illustrations of correct apparatus and procedure construction, while thirdly using procedure flow charts that allow teachers to see students' understanding of manual preparation and practical implementation in science experiments.

According to Fadzil & Saat (2019), creating a resource guide is beneficial and helps in assisting teachers in showing students' manipulative abilities ability during science projects. The resource guide was made up of three primary components: (i) description of competency level in manipulative skills, (ii) manipulative skills rubric, and (iii) diagnostic tests. Teachers from this analysis agreed that one of the resource guides, the manipulative skills rubric, was relevant and sensible to be enforced as a resource guide in a science experiment. To put it another way, this rubric can be employed to establish adequate manipulative skills standards that are both detailed and clear for students and teachers. Students may easily comprehend the units of performance expectations that must be met in order to achieve a high level of performance, as well as how they will achieve it. This resource guide may also function as a beneficial tool for teachers to help students improve their science manipulative abilities, depending on expert feedback.

The findings of Fadzil & Saat (2013) clearly shown that the students' manipulative skills may be greatly improved, and that their lack of skills is most likely due to present procedures that place an excessive emphasis on knowledge retention. This issue may obstruct students' development toward the automation stage, in which recurrence and repetition of the learning process were deemed necessary for the manipulative skills acquisition. Fadzil & Saat (2014a) highlighted the significance of students mastering the technical skills of scientific drawing with labels in order to enhance students' ideas on sketching the layout of apparatus and materials in science experiments. Furthermore, manipulative skills are strongly intertwined to measuring skills in science process skills. To avoid reading mistakes on the equipment, students must make accurate measurements. Therefore, students should be provided ample opportunity to practise manipulative skills in order to develop them gradually. Providing additional opportunities for students to participate in science experiments will facilitate students to perceive procedural knowledge and technical skills as something they can utilise most of the time, and that normally cultivates (Fadzil & Saat, 2014b).

Argumentation skills that are exhibited during the science experiment process involve the justification of assertions based on evidence. Explicitly teaching students how to defend assertions based on evidence is one method to scaffold their development of argumentation skillfulness. Here, the use of science process skills aids in the development of statements based on evidence. As a result, acquiring argumentation skills alongside science learning might help students build science process skills. Carrying out science experiments is one approach to directly educate students on argumentation skills in science learning (Ping et al., 2020). For example, students are involved in systematically tabulating and analysing data to provide evidence to justify the arguments associated with the data collected from the science experiment.

Students will need argumentation skills to complete their science experiments. These capabilities permit students to ultimately help science advance and evolve, solve problems, improve their scientific literacy, and question scientific discoveries and hypotheses. As a result, given the importance of reasoning abilities, such behaviours must be encouraged and fostered among students in science classrooms. Furthermore, according to Yeşiloğlu & Köseoğlu (2020), argumentation-based teaching is an effective pedagogic technique for providing students with possibilities to acquire science facts since rather of expecting students to feign to obtain knowledge, it gives the rationale for assertions.

In their findings, Ping et al. (2019) claimed that argumentation skills could be produced by providing argumentation sessions that allow the students to justify their hypothesis with evidence and assess the reasons provided by their peers through a vigorous method. This helps to confirm that the science process skills are captured directly. Furthermore, creating argumentation sessions in science experiments offered opportunities for students' involvement in questioning, revising their knowledge regarding evidence, evaluating their peers' explanations, interpreting and analysing information, and considering alternative explanations. As a consequence, the students began to take a more active part in assessing their observations, analysing data, as well as deciding how to present their findings. Based on the findings, SPS will increase in time as students can deploy the science process skills in various manners during the argumentation session and with the help of student activities. Students could, for example, use SPS (operational defining) to formulate answers to questions, SPS (constructing hypotheses, drawing inferences) to rationalise their positions, SPS (planning the study) to explain procedures, and SPS (interpreting the graphs) to interpret and explain data.

Fadzil & Saat (2017) found that functioning, communicating, and cooperating in teams do not inevitably result in students being capable of forming outstanding written and verbal scientific reasoning. Via argumentation sessions, students must be involved in the construction and development of evidence-based rationalisations or arguments for the scientific phenomena being researched. Students can raise questions to evaluate arguments of their peers, analyse and interpret data, as well as think and consider various possibilities by creating argumentation sessions in science experiments. Students can also utilise operational definitions to generate responses to questions, develop inferences and hypotheses to validate their positions, justify procedures using the research style, and interpret and explain knowledge using graph interpretations. Students are provided ample chance to create their minds regarding the experiment by linking a science experiment and argumentation session. When argumentation is made expressly in a science experiment, students are properly guided, ultimately perceiving higher science development.

Information and communication technologies (ICT) are abbreviated as ICT. It mixes communication technology and digital telecommunications, including cell phones, computers, the internet, and other digital networks. This review has two usages of ICT in science experiments: integration of communication technology and virtual reality technology.

The use of communication technology such as computers and the internet as teaching aids are alternatives to addressing the practical implementation constraints that teachers face. The use of communication technology can further encourage the teaching and learning process, making it more effective and enjoyable. It is also a good alternative to carrying out real science experiments in the laboratory. Lee et al. (2019) indicated that using communication technology in a science experiment-led inquiry environment could be a realistic option for students to develop advanced academic self-efficacy in science learning. Moreover, the finding of the research by Imaduddin & Hidayah (2019) also points towards planning and completing science experiment through online activities that involve the use of the internet in blended learning, which can also overcome space and time constraints.

Gultepe (2016) study analysed teachers' opinions about what environments could be most effective to develop SPS. More than half of chemistry and biology teachers said they attempted utilising integrated communication technologies in a pre-programmed computer environment where teachers and students were actively engaged. Furthermore, teachers in the study indicated that they regularly conducted science experiments in classrooms or laboratories to enhance SPS using a computer environment in which teachers and students collaborated. The finding mentioned above is consistent with Shana & Abulibdeh's (2020) study, which proposed the role of a programmed computer environment in science learning to explain science experiments that are challenging to resolve practically in the laboratory.

Science learning is challenging because it includes numerous dynamic and abstract processes and is frequently misinterpreted by students as subjects requiring memorising information. Virtual reality (VR) applications could help students understand abstract scientific concepts that internalise and organise knowledge structures. Abstract scientific concepts (such as energy and electricity) are difficult to concretise in traditional classrooms, and students struggle to understand terms, concepts, and formulas. Compared to traditional teaching methods, students' acquisition of SPS was aided considerably by the VR application in understanding abstract scientific concepts while undergoing science experiments. The study by Artun et al. (2020) in quantitative findings showed science learning supported by comprehension of abstract scientific concepts using three dimensions (3D) representations in VR aided in a science experiment, the SPS pre-service science teachers were established. In comparison to the common technique, VR-enriched scientific experiments contribute greatly to the development of SPS.

Figure 3. Accessible VR Glasses Formed with Lenses and Cardboard. Source: Artun et al. (2020)

VR indicates 3D interactive interfaces that combine augmented reality and virtual properties, as illustrated in Figure 3. As a result of the audio-visual environment that users can witness by gazing in different directions, consumers feel as if they are in an actual setting. Artun et al. (2020) posited that, during VR implementation in a science experiment, participants' views supported that the basic SPS they obtained were observing, inferring, classifying and predicting. At the same time, the integrated SPS they obtained was experimenting, formulating hypotheses, operating variables operationally and interpreting data. Thus, the SPS is widely used in science experiments enhanced with VR applications. Learners in the VR-based laboratory felt like they were in a real lab, according to the findings. Furthermore, the students' interactions in the VR environment were equivalent to those in outdoor learning situations.

Engineering-oriented STEM integration comprises engineering practices, which include science, mathematics, and technology principles. As engineering practices necessitate mathematics and science technology production, they can raise awareness and interest in a purposeful science experiment. In addition, engineering practices allow students to discover the links between engineering and science, whereas employing SPS and scientific knowledge to resolve engineering issues in science experiments. Engineering practices are performed by giving students with design tasks. Design tasks are suitable for a hands-on science experiment since design tasks provide context for comprehending the basic content concepts in science learning.

Özkul & Özden (2020) discovered that engineering-oriented STEM integration activities improved the SPS of the students. The qualitative findings proved that respondents utilised science process skills to learn meaningfully through hands-on activities, including a science experiment. The participants revealed that the engineering-oriented STEM integration activities were acclaimed from common guided-science experiments. They said that they were given ready-made experiment papers and that the results of the experiments had already been learned in their normal science learning. They did admit, though, that they were unaware of the results of engineering-oriented STEM integration activities employed in a science experiment. Moreover, the design's shape was not given. Hence, their creativity and imagination could cultivate, and they could get a versatile perspective in their daily life application. Furthermore, students made meaningful observations, predictions, inferences, created experiment settings, and determining variables throughout the experiment. The implementation result of engineering-oriented STEM integration activities in a science experiment causes the students' SPS has been improved.

The goal of producing quality students' performance in science learning is by developing mastery of science process skills and a good attitude towards science. Pareek (2019) discovered that science experiments directly impacted students' scientific attitudes and academic success using learning interaction teaching theory. When undergoing science experiments, students who practice scientific attitudes produce more transparent and comprehensive findings, are more open to change and adapt to new ideas, become strong problem solvers, and become methodical and innovative researchers. Additionally, SPS in science experiments has been proven to possess a high positive relationship with the academic achievement of the students (Antonio, 2018). The reinforcement of the SPS in these science experiments depends on how the teacher provides an effective laboratory environment. Besides, a good setting of science laboratory atmosphere influence students' engagement while undergoing science experiment. A good scientific laboratory atmosphere is where students learn observations, inquiries, accurate reporting, creativity, generalisations, and the importance of safety and caution, which are essential to improving student performance in science learning.

Students with excellent basic SPS do better in psychomotor learning (Suryanti et al., 2020). This refers to developing organised hands-on science experiments that provide students with valuable experience handling laboratory equipment, procedures, and reactants. Students use laboratory types of equipment and learn how to use it by physically operating it in the lab. Students learn to utilise chemicals and laboratory equipment safely and responsibly via direct investigations in a hands-on science experiment. The only way to acquire psychomotor learning and improve organisational abilities is to apply SPS. In a hands-on science experiment, students get the chance to develop psychomotor learning by measuring using standard tools and units with proper techniques and handling variables (Burkett & Smith, 2016).

Based on (Figure 4), the least successful means of learning include learning through written and spoken symbols, such as reading and listening. In contrast, the most effective techniques in learning are direct, intentional learning experiences, for instance, hands-on science experiments. In a science experiment, the interaction between students and the teacher becomes crucial in involving students in the participatory learning process.

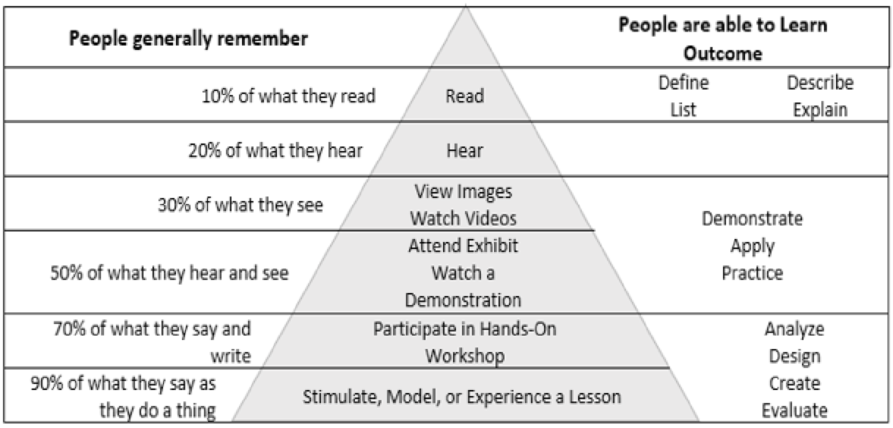

Figure 4. Edgar Dale's Cone of Experience (Dale,1969). Source: Rusmini et al. (2021)

Figure 4 depicted Edgar Dale's Cone of Experience supports the benefits of hands-on science experiments since students learn by experimenting. Science experiments evolve into a systematic learning method that engages students in exploring knowledge and developing SPS through an extended inquiry and discovery approach centred on complex, authentic questions and carefully designed procedures. Students gain meaningful experience in science experiments by implementing SPS elements such as designing procedures, evaluating, and analysing data from observation. In consonance with Dale's Cone of Experience, once an educational approach is chosen, such as science experiments, students must be actively involved in the process to maximise knowledge retention (Shana & Abulibdeh, 2020).

The integration of technology in science experiments adds value to the learning experience for students. In this digital era, integrating learning with the internet and network such as virtual reality (VR) learning will significantly impact the efficacy and efficiency with which learning outcomes are achieved (Afrianto, 2018). VR learning is viewed as a method that benefits both teachers and students in implementing science experiments. VR's nature lends itself to science learning by enabling students to view dynamic virtual things and establish tangible and visible models while undergoing a virtual 3D science experiment. (Chen et al., 2020). Hence, students will be more engaged and interested in learning on exploration and investigation in a science experiment. As a result, using VR in undergoing science experiments can better help students comprehend ideas (Arista & Kuswanto, 2018).

Some recommendations were made in this study for future researchers to consider. First, additional research is needed to examine the techniques and approaches used by students and teachers to acquire science process skills, emphasising distinct levels of student achievement in primary and secondary school. The research is essential for a variety of reasons. First, mastery of basic science concepts varies by age, which corresponds to a different standard level in school; second, to learn concepts at different standard levels, students must master appropriate science process skills; and third, the approach of teachers who have been given autonomy varies depending on the current situation and student needs.

As a consequence, future research should consider the use of various approaches. The future concept uses a remote and hybrid learning approach to implement science experiments using discovery learning. The science process skills development, for instance, may be scaffolded by applying a discovery learning module or particular software to cater virtual learning in flexible times as well as the chance to perform experiments at home to counter time limitations (Figure 5).

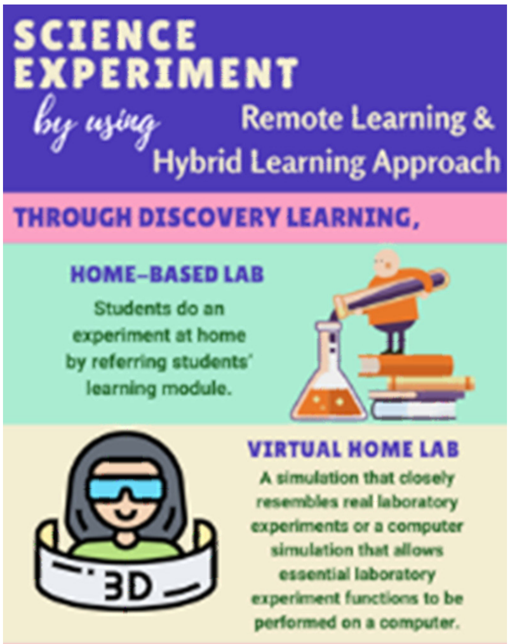

Figure 5. Recommendation for Future Studies in Mastering SPS through Science Experiment

This further study is relevant to be examined based on prior research by (Burkett & Smith, 2016; Zulirfan et al., 2017; Moosvi et al., 2019; Wijayanti et al., 2019). Methodologically, it is suggested that search strategies be diversified by adding more than two databases and diversifying terms to add additional and relevant evidence to databases. Cooper et al. (2018) advised that researchers vary their sources and search strategies rather than relying solely on database searches.

CONCLUSION

The main objective of this investigation is to study the importance and tactics of incorporating science process skills into science experiments among teachers and students. The research makes various key additions to the corpus of knowledge and for practical reasons. The interested parties, particularly policymakers, science experts, researchers, and the general public, may form long and short-term complications from the approach outlined as a result of the review. First, this review mentioned seven main strategies in mastering SPS that are 1) Hands-on and minds-on implementation 2) Inquiry-based approach 3) Discovery learning 4) Strategic manipulative skills 5) Argumentation Skills 6) Using Information and Communication Technologies and 7) Implementing Engineering-oriented STEM Integration Activities. In involving the whole school to make plans for the success of science achievement requires a high level of collaboration among teachers in general. In addition, almost all schools plan to mirror the structure and language of the scientific curriculum and reiterate important ideas of the science curriculum. Thus, effective planning is needed to take place in the school to improve science teaching and learning quality.

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