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The Use of Science Laboratories with Cookbook and Inquiry-Based Methods to Enhance Students' 21st-Century Thinking Skills

Meissy Nuraini Putri[1)*], Adam Malik[2)]
[1)*2)] Physics Education, Sunan Gunung Djati State Islamic University of Bandung
*Correspondence email: meissynuraini@gmail.com

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ABSTRACT

The present study aims to: 1) interpret the role of laboratories in science learning and 21st-century academic skills; 2) evaluate the effectiveness of laboratories use with cookbook and inquiry-based science learning in improving students' 21st-century thinking skills. The study was conducted using a narrative literature review method, which involves independently collecting, reviewing, and synthesizing various previous studies in the library and journal house of UIN Sunan Gunung Djati Bandung and other reputable sources. The data sources are references (e.g. books and journal articles) from reputable publishers. The results indicate that: 1) the laboratory use with the cookbook method provides structured and easy-to-follow experimental procedures, while with the inquiry method, it encourages students' independent exploration and problem solving; 2) the combination of these two methods can strengthen conceptual understanding and basic laboratory techniques, as well as develop students' critical thinking skills, creativity, collaboration, and digital literacy. The implications of the present study are the need to integrate the cookbook and inquiry methods in the science curriculum to prepare students to face the challenges of the 21st century.
Keywords: science laboratories, cookbook, inquiry, 21st-century skills

INTRODUCTION

The academic world in the 21st century has turned critical thinking skills, collaboration, communication, and creativity into the main competencies expected from students. According to Partnership for 21st Century Skills (P21), such skills are key to success in globalisation, education, and rapidly developing technology (Puspa et al., 2023). Education, as one of the pillars in transforming life, has a significant role in developing skills through innovative and effective learning methods. For example, science learning has constructive and contextual characteristics to train students to independently observe natural phenomena to analyse, conclude, and publicise their findings based on a scientific approach, correlated to skills required in the 21st century.

Science learning generally makes students the centre of learning. However, many teachers still apply conventional science learning, which is passive, lecture-like, and involves demonstration without students' active participation, assuming that students still have not obtained adequate background knowledge about a learning topic or that the learning facilities in the school are still insufficient. It may not be entirely wrong, but it is important to understand that the conventional method is not enough to facilitate the attainment of 21st-century skills, so it is necessary to transform science teaching, one of which with science laboratory.

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The science laboratory plays a significant role in effective science learning. In the laboratory, students are given chances to learn by experience, which is one of the most effective ways to understand scientific concepts. The use of a laboratory can transform the passive learning situation into an active learning situation, where students not only receive information but also participate in the process of discovering knowledge (Simbolon & Sahyar, 2015).

However, it is important to note that the success of using a science laboratory does not rely on the existing facilities but on teachers' ability to design and manage effective activities in a laboratory. A teacher needs to be trained in integrating laboratory activities into the curriculum and ensuring that each student has a chance to participate and learn maximally. In addition, schools need to ensure that a science laboratory is equipped with adequate and safe equipment for the students to use.

A science laboratory can also be integrated with technology and teacher innovation to increase learning progress, such as by using a computer simulation, digital measurement tools, and the use of data analysis software (Afsas et al., 2023). Even if the simple innovation can enrich students' experience while being in a laboratory, it can give students access to relevant knowledge to the current development in science, for example, with the innovation of using a cookbook-based science laboratory.

The cookbook-based science learning in a laboratory is a method in which students follow predetermined experiment steps with detailed instructions. This method is easy to follow and can ensure students obtain the expected result, with convenience in its implementation and a high success rate in its activities implementation. However, the weakness of this method is that this method might not allow sufficient critical thinking and creativity (Rahayu, 2017). This condition might allow a teacher to target success in students' learning outcomes, yet it might not be optimum in improving 21st-century skills. Therefore, teachers need to innovate more in the use of science laboratories by conducting inquiry-based laboratory activities.

Inquiry-based activities in a laboratory emphasise independent exploration and investigation by students. Students are given a problem or inquiry to resolve without a detailed procedure so that they can independently design an experiment, collect data, and draw a conclusion (Saefi et al., 2023). The innovative method is expected to facilitate critical thinking skills, problem-solving, and creativity.

The cookbook and inquiry methods are relevant to science learning in schools, both in biology and physics. In biology learning, the cookbook method allows students to do biology experiments by following clear instructions, such as preparing liquids, isolating DNA, and observing microscopic organisms. Besides, the cookbook method enables students to learn basic techniques in biology with structured steps, as it is essential to understand more complex procedures in the future. Additionally, the inquiry method enables students to design their own experiments to answer interesting biology questions. Also, the inquiry method allows students to apply biology concepts in more flexible and creative contexts, which helps students comprehend the application of biology theory in real situations.

In physics subjects, the cookbook method can include experiments involving Newton's law, thermodynamic principles, or electromagnetic concepts. With this method, students can do physics experiments on the predetermined procedure, such as measuring force, checking energy conservation law, or determining gravity's acceleration. It gives direct experience with physics concepts. The inquiry method also enables students to design an experiment and test their own experiment on a physical concept, such as the law of motion or the principle of conservation of energy. Therefore, the method is believed to increase creativity and problem-solving, in which students are encouraged to ask questions and design experiments to answer

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them, boosting their critical thinking skills and problem-solving. For example, students can design an experiment to explore the relationship between force and acceleration.

The cookbook and inquiry method should not be judged as an exclusive method. Both methods can be used simultaneously to maximise the science learning (i.e. in biology and physics) in a school. National Research Council (2006) studied various learning methods in laboratories and found that a combination of the cookbook and inquiry-based learning can give optimum results in science learning. The method allows students to obtain basic knowledge through direct instructions; then, they can apply the inquiry method to enrich their knowledge and expand their high-order thinking skills (Windschitl et al., 2011), transforming the learning process to be concrete, real, and contextual. The combination, therefore, is expected to effectively improve students thinking skills in the 21st century.

In Indonesia's education context, there are still few studies about using science laboratories with the cookbook and inquiry methods, which enhance thinking skills in the 21st century. In contrast, past studies mostly discussed the effectiveness of each method separately, without comparing or combining the two. This is understandable, as the two methods are different. The cookbook method is usually more structured and follows certain steps, whereas the inquiry method is more open and allows students to develop exploration and problem-solving independently.

The novelty of the present study, therefore, lies in its focus on comparative evaluation between the two methods in the context of science learning in Indonesia. The present study is a literature study that attempts to fill the gap in analysing and comparing previous studies regarding the two methods, hopefully giving a comprehensive understanding of the benefits and drawbacks of the two methods.

The urgency of the present method cannot be denied as well, considering the importance of preparing the young generation of Indonesia to obtain the required skills to compete globally. As workload demands are increasing and technology is rapidly changing, the ability to think suited to the 21st century becomes crucial. Providing empirical evidence about the effectiveness of the cookbook and inquiry method in science laboratory activities in developing the skills will help science teachers and decision-makers in designing more effective and relevant curricula and teaching methods. Additionally, the present study's findings are expected to promote further studies and innovation in education practice in Indonesia.

RESEARCH METHOD

A. Type of Research

The present study is qualitative research with a review literature narrative method, which involves collecting, reviewing, and synthesizing existing results and reputable references regarding a certain topic (Wahyudin & Rahayu, 2020). The present study is focused on evaluating the effectiveness of the cookbook and inquiry methods in science learning in a laboratory, which affects thinking skills for the 21st century, including being critical, creative, collaborative, and communicative.

B. Location and Time of Research

The research was conducted in various feasible places to obtain data supporting the present study, such as libraries and UIN Sunan Gunung Djati Bandung's house journal. The researchers also conducted it independently, such as via website browsing. The study was conducted from January to March 2024.

C. Source of Data

The data source in the present study is secondary data, which was obtained indirectly by the researchers. The role of the researchers is as a third party, which is to collect all references from reputable publishers, books, and journal articles.

D. Technic of Data Collection

The present study uses documentation as a technique of data collection, including:

1. Printed books and journal articles in libraries
2. Electronic books and journal articles from Google-indexed sources and other indexed sources.

E. Research Instruments

The research instruments of the present study are in the form of data records designed to collect important information from each literature review using the following criteria.

1. Titles of the reference: discussing variables of the cookbook-based laboratory activities and inquiry-based laboratory activities;
2. Types of reference: reputable literature, for example, books with ISBN or journals with ISSN, and other recognized indexed sources such as SINTA, Web of Science, and Scopus;
3. Year of reference publication: literature from journal articles and books published within the last ten years (except for the old-dated theory that is still currently relevant and being used, the researchers will still use such sources);

(Dhamayanti, 2022).

F. Technique of Data Analysis

The present study uses content analysis and comparative analysis by Harefa (2023) as the technique analysis. The content analysis was used to identify the main themes and patterns within the given literature review. The comparative analysis was employed to compare the effectiveness of the use of science libraries with the cookbook-based and inquiry-based methods in improving students' thinking skills in the 21st century.

RESULTS AND DISCUSSION

According to the investigated literature, the researchers outline the results into two types of studies: the role of the laboratory in science learning and academic skills in the 21st century; and the evaluation of the effectiveness of the cookbook and inquiry-based methods in science laboratories in improving students' 21st-century thinking skills.

A. The Role of Laboratories in Science Learning and Academic Life Skills for the 21st Century

Laboratories play a central role in science learning, including in the subjects of biology and physics. Through laboratories, students can practice the theories learned in class, develop critical thinking skills, and build deeper conceptual understanding as the indicators of 21st-century skill development (Nababan, 2023). Here are some of the main roles of laboratories in biology and physics learning based on a literature review:

1. Strengthening conceptual understanding. Laboratories allow students to observe natural phenomena directly and conduct experiments to understand scientific concepts. In biology, laboratories are used to observe cell structures, photosynthesis processes, and ecosystem interactions (Shambare & Simuja, 2024). In physics, laboratories help

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students understand the laws of physics, such as Newton's laws, the principles of energy, and the properties of matter (Samad et al., 2019);

2. Developing critical thinking and problem-solving skills. Laboratory experiments encourage students to design and conduct experiments, collect data, analyze results, and draw conclusions. This process develops critical thinking and problem-solving skills that are essential in science. In biology, students learn to identify variables that affect biological processes and how to control them in experiments. In physics, students are trained to solve complex problems using scientific approaches, such as measurement, data analysis, and interpretation of results (Jong et al., 2023);
3. Enhancement of practical skills and techniques. Laboratories provide opportunities for students to develop practical skills important in science, such as using laboratory equipment, measurement techniques, and safety procedures. In biology, students learn laboratory techniques such as microscopy, tissue culture, and DNA analysis. In physics, students are trained to use tools such as oscilloscopes, digital sensors, and other measuring devices (Cossa & Uamusse, 2015);
4. Encouraging creativity and innovation. Laboratories also serve as a place to encourage creativity and innovation. Students are encouraged to ask questions, design their own experiments, and find innovative solutions to problems they encounter. In biology, students can design experiments to test their hypotheses about biological phenomena. Then, open-ended experiments in a physics laboratory allow students to explore new concepts and develop innovative approaches to solve problems (Pellegrino, 2014);
5. Collaboration and effective communication. Many laboratory experiments are conducted in groups, which helps students develop collaborative and communication skills. They learn to work together, share ideas, and manage roles and responsibilities within a team. In biology and physics, students learn to work in teams, communicate their findings, and present their experimental results effectively (Zou et al., 2012).

B. Effectiveness Evaluation of the Cookbook and Inquiry-Based Method for Science in Laboratories to Improve 21st Century Thinking Skills

The era of globalization and rapid technological developments requires science education to always be ready and able to equip students with 21st-century skills, including critical thinking skills, creativity, collaboration, and digital literacy. One effective method for achieving this goal is to combine the cookbook and inquiry learning methods simultaneously. This simultaneous method utilizes the advantages of each method to produce comprehensive and adaptive to students' learning needs (Bertsch et al., 2014), with the following explanation.

1. Cookbook-based learning. The cookbook method in science learning involves step-by-step procedures that students must follow to achieve the expected results. This method teaches basic laboratory skills and ensures a thorough understanding of experimental procedures. However, this method is often considered less effective in developing critical thinking skills and creativity because it is highly structured and limited to predetermined guidelines (Singer & Smith, 2013);
2. Inquiry-based learning. The inquiry method places students at the centre of the learning process. Students are encouraged to ask questions, design experiments, collect data, and draw conclusions. This method encourages students to think critically, creatively, and independently and develop the ability to solve complex problems (Trujillo & Tanner, 2014). Inquiry also promotes collaborative learning and the use of technology to support the experimental process;

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3. Integration of the cookbook and inquiry methods. Combining these two methods simultaneously can produce more balanced and effective learning, deepening conceptual understanding and developing 21st-century skills as follows.
   a. Strengthening conceptual understanding and laboratory skills. By starting laboratory learning using the cookbook method, students can understand the necessary basic steps and experimental techniques. After that, the inquiry method can be applied to allow students to explore further and develop a deeper understanding as well as critical and creative thinking skills (Boholano, 2017);
   b. Development of critical thinking skills and creativity. The inquiry method encourages students to ask questions and design their experiments, which are crucial for developing critical thinking skills and creativity. By integrating the cookbook method, students can start from a solid foundation before exploring more complex aspects (Khalaf & Zin, 2018);
   c. Collaboration and communication. Both methods can be applied in a group setting, which helps students develop collaborative skills. Students learn to work together, share ideas, and communicate effectively to achieve experimental goals (Scager et al., 2016);
   d. Digital and technological literacy. Using technology in both methods helps students develop digital literacy and the ability to use technological devices in data collection and analysis. These skills are highly relevant in the 21st-century context (Linn et al., 2013).

CONCLUSION

Using science laboratories with the cookbook and inquiry-based methods plays a significant role in developing 21st-century skills. By combining these two methods, students can acquire basic technical skills in the form of conceptual comprehension by understanding the required basic steps and the essence of necessary material/experimental techniques through the cookbook method, which are continued by exploring their scientific method abilities through inquiry-based method, while simultaneously developing critical, creative, collaborative thinking skills, and digital literacy which are very much in demands in 21st-century academic life.

IMPLICATIONS AND SUGGESTIONS

This literature review research has implications for biology and physics science learning by providing opportunities for policymakers to develop a science curriculum that integrates the cookbook and inquiry-based methods, improving the pedagogical competence of science teachers, and improving the infrastructure of science laboratories by providing adequate facilities. Therefore, the researchers advise all education parties to create a pilot program for implementing the two methods periodically and in a planned manner within a certain period, collaboration between stakeholders in developing such programs and focusing on developing soft skills in the learning process, so that it has a positive impact on the learning outcomes of biology and physics science and on students' 21st-century skills.

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