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The Effect of Virtual Lab (VL) Game-Based Guided Inquiry Learning on Students' Science Literacy in Indonesia

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Abstract: Indonesian students consider studying science as a challenging subject. They regarded science as a difficult subject to be perceived. Consequently, Indonesian students showed a low result in science performance. The inquiry learning method incorporated in the virtual lab has been used to tackle this issue. However, there is a crucial debate that both teacher and students are not familiar with this integration. Therefore, the aims of this systematic review is to investigate the effect of virtual lab based on Inquiry learning on students' science literacy. This systematic literature method was used to provide evidence from many literatures related to virtual lab and science literacy. This provided an overview of current knowledge of virtual lab effectiveness on student's science literacy and insight into the methodological developments in this field of research. The result indicates that virtual lab can improve students' science literacy. There are three factors to support this findings. First, virtual Lab provides students on learning with a deeper understanding of scientific concepts and critical thinking. Second, virtual Lab provides more interactive and engaging learning experience for students. Third, virtual Lab enhanced collaboration among students, teachers and researchers that improved the learning experience

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Introduction

Science literacy is one of essential things that student need to be conquered when they learn science subject. We use the term of science literacy adapted form OECD (2018) that science literacy is equated with the capability to evaluate, explain, design, describe, and address scientific questions (OECD, 2018). In this condition, students need to engage with the scientific phenomena as they will process all of scientific insights from science subject. This process to work and grasp with scientific knowledge in a practical way on a regular basis, also, can be defined as scientific literacy (Fives et al., 2014). Therefore, students' science literacy appears to be linked to the important of science engagement in science learning.

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On the other side, Indonesian students consider studying science as a challenging subject. The students regarded science as difficult subject to be perceived (Lee & Sulaiman, 2018). As a result, there is a lack of motivation on the part of the students to engage in active learning when studying science (Afriani & Agustin, 2019). The negative impact migh apper on students is lose their intention to learn more about science due to the difficulty of the subject. Whereas, students should be involved in science learning to make it meaningful. (Septiani & Susanti, 2021). Consequently, according to Program for International Student Assessment (PISA) from Organization for Economic Co-operation and Development (OECD) in 2018, discovered that Indonesia showed a low result in science performance. This condition demonstrates a low achievement in science education and affect low students' science literacy (Putri et al., 2021). Challenging and low of motivation in studying science could be associated with a low rate of students' science literacy.

Teaching method is also another aspect that contribute to low rate of students' scientific literacy. In a science class setting, direct teaching lacks the opportunity to develop scientific literacy (Liu et al., 2021). In consequence, students tend to follow the teacher's instruction to acknowledge the pre-defined science concepts. Therefore, it will make the students always relying on command and more dependent. Students must think and behave like scientists in order to be keenly attuned to methodological faults and numerous kinds of mistake, which is one of the obstacles they will encounter (Charney et al., 2007). Furthermore, science teaching only focuses on recognizing scientific explanations, but not helping students think critically instead (Henderson et al., 2015). Additional factors such as school infrastructure, learning models, books, curriculum, learning methods, and human resources also contribute to student's scientific literacy (de Moraes & Castellar, 2010, as cited in Purwani et al., 2018).

Despite this, significant refutation has been we made in many studies that show inquiry learning can be used to provide students in enhancing their scientific literacy. This learning model aims to engage learners in basic concept and integrated science process skills (Ekici & Erdem 2020). According to Rodriguez-Triana et al. (2021), the learners will actively construct knowledge following the methods and practices of scientist. Another study also revealed that there are evidences that inquiry learning embedded with online laboratory can assist student on developing scientific thinking. In short, we found that inquiry learning model is effectively encourage students to engage with science content and lead them act like scientist. This is an important part in science learning that students must be engaged actively in learning process.

Additionally, the study by Ural (2016) and Wen et al. (2020) claimed that laboratory activity integrated with inquiry-based learning allows students construct their experiment and had a long-term effect on the students' scientific literacy. Hence, virtual labs improve scientific literacy through inquiry-based learning (Putri et al., 2021). Moreover, studying with online labs is often effective for acquiring conceptual knowledge embedded with guidance (de Jong et al., 2013; de Jong et al., 2014). Based on these studies, we proposed an

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integration between virtual lab and inquiry learning with their effectiveness and benefit to students' science ability.

Therefore the virtual lab can assist students to improve their ability in scientific concept and scientific literacy. This investigation will be began with supporting and relevant evidence of the effectiveness of virtual lab to answer the problems. Furthermore, counter argument and refutation respectively also will be discussed. The result of this research will impact on education field, particularly on how teachers can integrate an emerging technology based on inquiry learning to assist them in teaching and learning process. Teachers can use virtual lab as an alternative teaching media to make science lesson more interactive and keep engaging with students.

Research Method

To achieve the aim of the research, researcher conducted a systematic literature review of effect studies. A systematic literature review is a research method for locating, evaluating, and interpreting significant research findings connected to research questions, specific topics, or phenomena (Kitchenham, 2004; Prasetiyo et al., 2021; Suprapto, 2020).

This provided an overview of current knowledge of effective virtual lab on students' science literacy and insight into the methodological developments in this field of research. A systematic review has as an advantage that it surpasses methodological limitations of single studies, thus providing more robust information for future research, and evidence-informed policy and practices (Newman & Gough, 2020).

Reviewers use selection criteria to determine which research studies to include in their review. These criteria establish guidelines for the review process, ensuring transparency and consistency. Systematic reviews emphasize making these restrictions transparent across studies. The selection criteria are shaped by the review question and conceptual framework, specifying factors such as participants, country, and language. Overall, selection criteria play a crucial role in ensuring a systematic and objective approach to reviewing research studies (Newman & Gough, 2020). The stages of this research apply the scheme of Bettany-Saltikov (Bettany-Saltikov & McSherry, 2012) presented in Figure 1

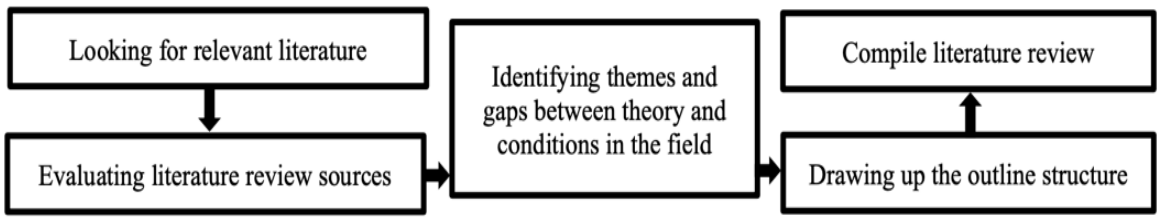

Figure 1. Bettany-Saltikov's literature review step

Result

Based on the literature review, there three domain that emerge regarding to the effectives of virtual lab (VL) examined. There are the effectiveness of virtual lab to provide students with dipper understanding with scientific concepts. The utilization of virtual labs provides students with a means to actively engage in scientific principles and cultivate their critical thinking abilities. Listiani et al. (2022) argued that proficiency in scientific concepts

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holds significant importance for students as they advance their critical thinking skills. It is worth noting that critical thinking plays a crucial role in comprehending science thoroughly (Listiani et al., 2022), thereby establishing a connection between critical thinking and scientific literacy. By actively participating in the 5 learning process through the formulation and resolution of scientific questions, students can enhance their knowledge and understanding, ultimately bolstering their critical thinking capacities (Putri et al., 2021). These research findings substantiate the notion that fostering critical thinking and scientific engagement can enhance students' scientific literacy.

Furthermore, through virtual lab (VL), students can be more attractive and engaging related to science content. Virtual labs increase interaction and engagement in learning for students. Improving a connection and science engagement by using a virtual lab may contribute to a scientific concept development for students. According to Grabau and Ma (2017), a science engagement showed positive impact to student achievement. For instance, in a study by Efstathiou et al. (2018) and Chang et al. (2020), the authors had their students do virtual experiments in virtual labs to learn about relative density, sinking, and floating. Students will be provided with an interactive space to investigate scientific phenomena by embedding the science concepts (Heradio et al., 2016).

Literatures also revealed that through virtual lab (VL), students still can improve their collaboration with their teachers and peers. These domains are basically contributed to elevate students' scientific literacy. The usage of virtual can improve collaboration among teachers, students and researchers. In the virtual lab, it has a feature that allows student to keep engaging and build social interaction alongside the virtual lab with instructional guidance (de Jong et al., 2014). This study suggests that social engagement and collaboration appear to be linked to one of scaffolding that can be used to assist student to engage in science. In their study, de Jong et al. (2014) also stated that the social features of the virtual lab portal can make a teacher to share material easily. According to this study, teachers will be able to directly add their own lesson material to the repository and find new resources based on how well-liked they are (based on peers' usage, tagging, rating, and comments).

The literature also examined the drawback and challenging about the implementation of virtual lab in the classroom settings. However, many studies give refutation to these counterarguments.

Discussion

Virtual Lab provides students on learning with deeper understanding of scientific concept and critical thinking

According to study by Zhang (2016), which highlights that inquiry-based learning method effectively encourage students to develop their scientific knowledge and investigative skills, it is evident that integrating virtual laboratory activities within an inquiry-based learning framework empowers learners to design their experiments rather than adhering to predefined procedures. This approach enables them to formulate explanations for scientific phenomena, thereby developing higher-order cognitive skills (Ural, 2016). For instance, platforms such as Go-Lab present opportunities for student to engage in pedagogically organized learning spaces, facilitating the performance of scientific experiments using online laboratories (de Jong et al., 2014).

In contrast, some students may face a difficulty when they use the virtual lab for the first time in a learning process. This may not lead to an improvement for students in their

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science concept field. An evidence stated that the complexity of scientific inquiry and virtual labs may prevent virtual labs from having positive effects on students' learning (Akaygun & Adadan, 2019; Wen et al., 2018). Consequently, the virtual lab cannot be used in science teaching optimally to support student in engaging with science material. Furthermore, not all science concepts can be explained by using experiment virtually through virtual lab. There are various restrictions on the virtual lab-based online scientific teaching-learning process. According to Putri et al. (2021), online laboratory cannot conduct experiments directly and the limitation of group work that is quite challenging to perform a hands-on laboratory activity.

Despite these claims, there is evidence to refute that teacher can utilise instructional strategies that support students' usage of virtual lab for scientific research (Liu et al., 2012). Although students face a trouble in using virtual lab, teachers still can use a particular guidance to assist them. Student critique is a crucial component of cognitive apprenticeship approaches to skill acquisition in contextualised contexts among various instructional design formats (Chang & Linn, 2013). By using the appropriate approaches, the student can develop their cognitive skills. Other evidence to tackle the limitation of 6 using virtual lab is that virtual labs are integrating affordance toward their openness. Wen et al. (2020) explained that the implementation of an open-ended inquiry approach in education allows teachers to empower students with the ability to independently conduct scientific investigations.

Additionally, online laboratory platforms provide teachers with authoring features that are pedagogically structured, enabling students to comprehend scientific phenomena more effectively (de Jong et al., 2014; Chao et al., 2016). Moreover, virtual labs have the capacity to explicitly organize the structure of the inquiry process, thereby facilitating students' understanding and modelling of scientific procedures. For instance, Wen et al. (2020) demonstrated in their study that the virtual lab enable students to construct their own inquiry maps, which guided their inquiry process. These findings indicate that virtual labs are equipped with inquiry guidance that can optimize student utilization, irrespective of their complexity or limitations. To summarize, the evidence from these studies show that online simulations contribute to improve the student's science literacy. Furthermore, online labs are often more effective in fostering conceptual knowledge acquisition compared to traditional laboratories, especially when accompanied by instructional support (de Jong et al., 2013; d'Angelo et al., 2014).

Virtual Lab provides more interactive and engaging learning experience for students

Students' experiment design skills were enhanced by an inquiry activity with virtual labs (Lefkos et al., 2011) that will enable them to investigate difficult phenomena (Heradio et al., 2016). Based on these evidences, science engagement in learning may lead a significant contributory factor to science literacy improvement. 7 On the other hand, virtual labs cannot afford certain special features that are available in real labs. For instance, physical labs provide a feeling of realism when student doing science experiment (Abdulwahed & Nagy, 2011). It suggests that the physical lab may play a vital role in bringing about scientific phenomena that can be understandable for student. Another key point is that, in Indonesia, teachers have not fully embraced the use of computer technology as a teaching tool, such as the virtual lab (Ismail et al., 2016). According to this finding, insufficient digital proficiency on the part of teachers may impede the optimal execution of the student learning experience.

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Moreover, an additional scholarly investigation asserts that the utilization of virtual laboratories has demonstrated limited efficacy, while physical laboratories have been notably more successful. Zacharias et al. (2008), for example, argue that physical labs have the advantage of facilitating studies that call for tactile sense and kinaesthetic manipulation, serving as a link between concrete and abstract conceptualization. For students, it is quiet challenging for them who have inadequate concept in science subject, because students must first interact with the real world phenomenon or with a replica of the phenomenon in order to retrieve information from the virtual lab (de Jong et al., 2014).

Critics often overlook the fact that virtual labs assist students connect new and prior information by visualising abstract scientific concepts using a variety of representations (Taramopoulos & Psillos, 2017). This research shows that virtual lab can be used to explain about an abstract concept that cannot be carried out by the physical lab. The feeling of realism when using a virtual lab can be modified by teachers. Teachers can adapt guidance types throughout the inquiry process to support students' learning, adjusting as students become more experienced (Chatterje, 2020). Therefore, students can still conduct an experiment in a real setting although it is from virtual lab.

According to research, virtual lab-based inquiry learning is superior to lab approaches that use cookbook procedures or discovery methods (de Jong et al., 2013). This evidence shows that the teacher can use the inquiry learning approaches as their teaching method as they need to make student engage in science, and it can be done by virtual lab. Additionally, research shows that using virtual labs as opposed to conventional instruction environments can help students achieve a greater degree of scientific literacy (Ismail et al., 2016; Jannati et al., 2018; Quellmalz et al., 2020). Hence, the challenges that may 8 appear in utilizing virtual lab still can be tackled by using and optimizing the virtual labs' feature. Inquiry learning spaces have already provided and embedded virtual labs that teachers can use to assist students when conducting science experiments in real settings virtually.

Virtual Lab enhanced collaboration among students, teachers and researchers that improve learning experience

In Virtual Lab (VL), teachers can allow their students access to the virtual classroom by giving them the URL for the resource, a short URL, or a QR code (de Jong et al., 2021). As a result it may be linked to improve teachers and students engagement in inquiry activity involvement. Teachers can socialize with other stakeholders by posting their URL to the virtual lab collaborative tools. They can make their virtual room available to the general public, where other teachers can reuse them—possibly after making some modifications. According to de Jong et al. (2021), teachers must fill out a form with metadata (such as the ILS's length, a subject area, language, etc.) in order to publish. Equally important that virtual labs have their global user that is called as a virtual learning community. It will offer resources for fostering community and support, and it will promote collaboration among educators, students, and researchers (de Jong et al.,2021).

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However, in Indonesia context, it is notable that the teachers have not commonly used the virtual lab on a regular basis. This trend may be attributed to various factors, including limited resources and a lack of emphasis on integrating technology into the classroom within the prevailing digital culture of schools (Alneyadi, 2019). Furthermore, teachers' attitudes toward digital technology, influenced by their level of technological 9 proficiency and acceptance, can also contribute to the underutilization of virtual labs (Alneyadi, 2019; Ismail et al., 2016). Moreover, It is crucial to highlight that teachers are the only one that setting the difficulty level of the material in virtual lab. Since most teachers lack the background and/or training necessary to respond to such activities, this is a problem that requires more research (Zacharia et al., 2015). According to this study, it seems that, due to teachers' lack of preparation and experience in handling such responsibilities, the issue of educators' restricted use of virtual labs calls for additional inquiry. It is possible that many teachers have not had enough professional development or preparation to use virtual labs in their lesson plans. Because of this, they could feel unprepared or lacking in the abilities needed to include virtual labs into their teaching strategies.

Contrary to what has been discussed, studies have shown that virtual lab can help the teacher with all laboratories and apps needed for classroom design. Virtual labs have designed for providing instructors with a broad educational framework (scenario) within which teachers can construct the available lab(s) and apps (de Jong et al., 2021). Through a web-based interface and community architecture, the virtual labs provide pedagogical "plug, share, and play" for instructors so they may share best practices and find one another support (Gillet et al., 2013). Besides that, according to Gillet et al. (2013), teacher will be able to use and customize their inquiry-learning spaces using the virtual lab portal (front-end), which will offer an easily accessible platform. These findings indicate that although teachers are quite not good enough at technological aspect, the virtual lab constructed by user friendly tools. Moreover, along with accessible laboratories, the portal will also provide tools and scenarios that will help users create their own inquiry-based activities (Gillet et al., 2013). Additionally, since virtual labs provide teachers with space that can build collaboration, they can utilize reviews from other peers when build their virtual room through virtual lab. As stated by Chatterjee (2020) that educator engaged in the creation of online scientific laboratories can greatly benefit from utilizing assistance methods and tools provided through reviews. This evidence show that these valuable resources offer insights into successful design practices that other educators have already adopted. By studying and analysing these examples, instructors can quickly gain knowledge and inspiration to improve their own laboratory designs (Chatterjee, 2020). 10 Based on this refutation, although some teacher may face a challenging such as lack of digital skill in operating the virtual lab, it can be solved by utilize the features that already provided by the virtual labs. Some of them is that collaboration among teachers, peers and researchers which they can assist and help with each other. Another thing is that virtual lab can support the teachers with all elements of apps and labs for designing the classroom easily.

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Conclusion

Science teaching and education In Indonesia are still facing the challenging that need to be considered as revealed by (Afriani & Agustin, 2019; Lee & Sulaiman, 2018; Putri et al., 2019). Students consider science as a difficult subject that hard to understand. This will contribute to a low rate of scientific concept of students. Another challenging is 11 that science teaching method. In science teaching, the teachers always use teaching direct method that does not give an opportunity for student to develop their cognitive skills. Whereas, students have to involve directly in science. So that they can act like a scientist. The two challenging will be considered as obstacles for student to restrict them for developing scientific literacy and engaged with scientific concept.

Therefore inquiry learning integrated with virtual lab can be used to assist student in enhancing their scientific literacy. Many evidences already stated that virtual labs give benefits for student in science engagement. The first point is that virtual lab can help student more understanding in scientific concept and build a critical thinking (de Jong et al., 2021). Another key point is that virtual lab allows student to experience interactive learning. Furthermore, in virtual lab, student can still engage with many stakeholders such as teachers, researchers and peers to improve the collaboration to get a constructive feedback. Teachers can use virtual lab by following several recommendations such us integrate science material with virtual lab, provide clear instruction and guidance, and foster activate engagement in the class. In conclusion, virtual lab is possible to use in science teaching for assisting student to develop their scientific literacy.

Recommendation

The following suggestions can be made for instructors to properly use virtual labs in light of the advantages and possibilities of such labs in boosting students' science literacy. Firstly, incorporate virtual laboratories into the curriculum on a regular basis to enhance traditional laboratory experiences. As a result virtual lab allow student to deeper understanding in science concept (Gillet et al., 2013).

Secondly, provide clear instruction and proper guidance. The goal, criteria, and guidelines for using the virtual lab should be made clearly. Give detailed directions and advice on how to use the virtual lab platform and conduct experiments successfully. In addition virtual lab embedded with features that more interactive for student (de Jong et al., 2013).

The last point, encourage students to participate in the virtual lab by asking and responding to questions of a scientific nature, formulating predictions, and examining evidence. By involving the student into science teaching actively, can help them to escalate their scientific knowledge. Students should be involved in science learning to make it meaningful. (Septiani & Susanti, 2021). This fosters analytical reasoning, problem-solving abilities, and a deeper comprehension of scientific ideas. Additionally, virtual lab can be used to improve collaboration between teachers and students (de Jong et al., 2014). The benefit of using the virtual labs in science teaching can be considered by policy maker in integrating the

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curriculum with online laboratory. Moreover, it also can be used in further research to find another effect on student.

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