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Effectiveness of Implementing Problem-Based Learning Modules to Improve Students' Science Literacy and Higher-Order Thinking

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Abstract

The autonomous learning curriculum, a recent paradigm shift in Indonesia, guarantees student-centered learning techniques. The goal of implementing the curriculum for autonomous learning is to address t e educational problems of the period of Industrial Revolution 4.0. Using problem-based learning (PBL) learning modules to enhance scientific literacy and high-level thinking skills (HOT) is one of them. The validity of problem-based learning modules on buffer solution content, student responses to the module, the increase in scientific literacy comprehension, the development of high level thinking abilities in students taught with PBL-based modules, and the module's efficacy are all the objectives of this study. The study was carried out in North Sumatra, Indonesia, at SMA Negeri 1 Ronggurnihuta. Purposively, samples were drawn from a single class of twenty-eight pupils. This study used a 4D development approach (Define, Design, Develop, Disseminate) in conjunction with research and development (R&D) development research. Questionnaires and validation sheets served as the study's research tools. According to the study's first phase, the problem-based learning module's average validation scores on the Buffer Solution content fell into the extremely high category of 84.75%. However, the average student response to the program fell into the very good category with 87%. Essay-style questions with distinct indications are used in the Science Literacy and High-Order Thinking Skills assessments. According to the normalized Gain test results, students' high-level thinking abilities increased by 82.16 in the high category and their science literacy increased by 65.83% in the moderate category. This study suggests that the problem-based learning module on the buffer solution material is successful in enhancing students' science literacy and critical thinking abilities based on the gain conversion findings.

Keywords: *Module, PBL, Science Literacy, HOT, Buffer Solution Technology*.

Introduction

T Education in the 21st-century has a number of difficulties. Among these is the ability of the educational system to adapt quickly to changes in curriculum, infrastructure, and the proficiency of its faculty. How to provide comprehensive and fair education at all societal levels is one of the most difficult problems (Lim, 2019). Despite these difficulties, 21st-century education also presents a number of opportunities, particularly in terms of raising the standard of instruction that is more pertinent to demands in the future. When utilized appropriately, technology may foster innovation in media and learning approaches and increase opportunities for broader access to education (Baker, Puchner, & Dubinsky, 2020). In light of this technological advancement, Indonesia has introduced a new paradigm for its curriculum, known as the autonomous learning

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curriculum, which guarantees that student-centered learning techniques are used. In order to address the difficulties facing education throughout the industrial revolution, the autonomous learning curriculum was implemented (Salirawati, 2018).

Lack of expertise in question analysis and identification is linked to inadequate chemical literacy, which prevents students from exploring and answering questions through the scaffolding phases of interpretation, analysis, and evaluation (Zarkasi, Muslihatun, & Fajri, 2022). This makes it challenging for students to locate supporting data for conclusions or to extract the essential information that may be used in different situations. Additionally, poor levels of high-level thinking abilities among pupils are a typical learning issue. According to the findings of the researchers' observations, students typically do not actively participate in discussions, ask questions, or analyze problem-solving during learning activities. Students are still reluctant to voice their ideas when prompted to do so. In the meanwhile, pupils struggle to solve issues and often only read from books when they are studying. The books that are offered at school, on the other hand, are still multiple-choice questions that have nothing to do with scientific literacy and do not include any questions or tools that need higher order thinking skills like analysis, assessment, and creativity. According to the findings of a study by Jamaluddin et al. (2019), junior high school science students had a low literacy profile. One aspect of science literacy and students' thinking abilities that is promoted in this century's education is the relevance of science education that is in line with real-world occurrences (Reimers, 2020). 21st-century education also aims to prioritize critical, creative, collaborative, and communicative thinking abilities (Kim, Raza, & Seidman, 2019)

Using a learning model that works for students is one way to try to meet learning objectives (Salirawati, 2018). The problem-based learning (PBL) learning paradigm is one that can potentially help students develop the abilities needed for 21st-century education. Additionally, it is asserted that education in this century must produce human resources with three distinct skill sets: learning and innovation skills, media and information technology skills, and life and career skills (Trilling & Fadel, 2009). Febrianti (2021) refers to these as high-level thinking skills, which include critical, creative, and problem-solving abilities.

PBL aims to enhance students' ability to apply concepts to novel or real-world issues, integrate Higher Order Thinking (HOT) concepts, foster a motivation to study, and guide their own learning and development (Norman & Schmidt, 2016). According to the study's findings, using the PBL approach with chemical bonding materials greatly improved student engagement and learning results (Sugiharti, 2023).

The four interconnected components of literacy, on the other hand, are knowledge, context, competence, and scientific attitudes. This is consistent with the 2019 Organization for Economic Co-operation and Development (OECD) opinion that scientific literacy is the capacity to use one's knowledge to formulate new knowledge, identify questions, provide scientific explanations, draw conclusions based on scientific evidence, and cultivate reflective thinking patterns in order to engage with scientific issues and ideas (Suparya et al., 2022).

This scientific literacy places a strong emphasis on students' attitudes and concerns for the environment, as well as their ability to use their knowledge and skills to solve community problems. In this situation, students will apply their analytical, logical, and reasoning abilities to identify issues, solve them, assess performance or provide solutions, and come to a judgment. These capabilities fall under the category of high-level cognitive skills (HOT). To put it another way, pupils require advanced literacy thinking abilities. Students who possess scientific literacy

and advanced thinking abilities are not just able to memorize facts; they can also use science to solve issues and explain them in daily life.

Since it deals with the fundamentals of acids and bases and how they are used in daily life, buffer solution is one of the more complicated chemistry topics that involves understanding the function of buffer solutions in life (Arta & Azhar, 2019). Chemical fields such as biochemistry and medicine, pharmacy, industry, forensics, the environment, and organic chemistry frequently use buffer systems (De Oliveira, 2020). In order to assess the competences assessed by PISA, buffer solutions must satisfy the requirements for scientific content, which include being contextual and applicable to real-world scenarios (Angraini, 2014). Module-based instructional materials will use the PBL methodology in this project.

The aforementioned description demonstrates how problem-based learning modules can be used to enhance scientific literacy and high-level thinking abilities because they encourage students to be active in order to apply the knowledge that will be used in daily life and to think critically and at a high level (scientific literacy). Science content and context are the literacy components of this research that will be enhanced.

Higher Other Thinking Skills are high-order thinking abilities that include the processes of analysis, evaluation, and creation, according to Sugiharti (2021). The primary goal of Higher Other Thinking Skills, according to Hamzah (2022), is to raise students' thinking abilities, particularly those that deal with their capacity to think critically when presented with different kinds of information, to think creatively when applying their existing knowledge to solve problems, and to make decisions in challenging circumstances. According to Jamian et al. (2016), higher-order thinking skills are now the primary focus of education in schools and are emphasized globally. It is also claimed that these skills are what will shape the 21st-century generation, which will be able to compete globally. Higher-order thinking, according to Azieyana (2018), is a mental process that might include active thinking to address issues.

The purpose of this research is to ascertain the validity of the problem-based learning module on buffer solutions, the responses of the students, the increase in scientific literacy comprehension, the development of high-level thinking skills taught by the PBL-based module, and the efficacy of the module in enhancing the literacy and high-level thinking abilities of the students.

Materials and Methods

The study was carried out at SMA Negeri 1 Ronggurnihuta in the North Sumatra Province's Samosir Regency. Two classes made up the population, and 28 students from one class were selected as a sample. In order to create specific products and evaluate their efficacy, this study employed the Research and Development (R&D) 4D paradigm (Define, Design, Develop, Disseminate) (Thiagarajan, 1974). A validation sheet, a literacy questionnaire, and an assessment of high-level thinking skills were all employed in the study. The Percentage Test was used to analyze the questionnaire data, and the following formula was one of the criteria utilized for the questionnaire indicators:

$P = \frac{\mathrm{F}}{\mathrm{n}}$ x 100% (Sugiyono, 2018)

Description:

P = percentage of questionnaire data

F = number of scores obtained

n = maximum number of scores

Percentage (%)	Criteria
80,1-100	Very High
60,1-80	High
40,1-60	Medium
20,1-40	Low
0-20	Very Low

Table 1. Questionnaire Percentage Criteria.

Meanwhile, to improve literacy and high-level thinking skills and interpretation of student gains, it was tested using normalized N-gain analysis (Hake, 1999, Meltzer, D. E. (2002). dengan rumus berikut :

$$<g> = \frac{\%<Sf> - \%<Si>}{\%<Smaks> - \%<Si>}$$

Description:

Sf: Pre-test Score

Si: Post-test Score

S_{max}: Maximum Score

< g >	Criteria
< g > ≥ 0,70	High
0, 30 ≤ < g > < 0,70	Medium
0,00 < g > 0, 30	Low

Table 2. Interpretation of Normalized N-gain Criteria (Hake, 1999)

The effectiveness of PBL-based modules is concluded from the interpretation of Gain (Hake, 1999)

Percentage (%)	Interpretation
< 40	Ineffective
40 – 55	Less Effective
56 – 75	Quite Effective
>76	Effective

Table 3. Interpretation Categories of N-Gain Effectiveness

Results

An average percentage value for content suitability of 3.35 (83.75%) with very high criteria,

presentation standards of 87.25% (very high), graphic feasibility standards of 85.75% (very high), and an average graphic feasibility standard of 82.75% (very high) were obtained from the expert validation of the module used to assess students' science literacy and HOTS. With an average percentage of 84.75% and a validity of 3.39, the PBL-based module under analysis fell into the Valid category overall. However, 87% of students on average responded to the program, falling into the extremely high level. The n-gain test results for improving science literacy were 65.83 in the somewhat effective group, while the results for improving high-level thinking skills (HOT) were 82.16 in the effective category. This study suggests that the problem-based learning module on the buffer solution material is successful in raising students' science literacy and critical thinking abilities based on the gain conversion findings.

The aforementioned study's findings suggest that PBL-based modules are beneficial for usage in classrooms. Since the problem-based learning model promotes active investigation, collaboration, and student participation while also having the potential to enhance students' thinking skills, some perspectives on problem-based learning, literacy, and thinking skills include the following: problem-based learning is autonomous learning that permits teamwork (Major & Mulvihill, 2017; Geitz & Kirschner, 2016). (2015) Adiga & Adiga. Additionally, it is stated that the problem-based learning approach is one that employs a variety of thinking abilities from students, either individually or in groups, as well as the actual environment to solve issues in a way that is contextual, relevant, and meaningful (Tan, 2000; Adiga & Adiga, 2015).

Students' low scientific literacy and HOTS scores are partially caused by their lack of experience with scientific literacy questions, which leads in a lack of scientific literacy mastery and an inability to work on discourse-based inquiries. It is necessary to expose students to assessments and questions designed to enhance their chemical literacy and HOT abilities. It is necessary to train science skills in teaching and learning activities so that students are used to performing tasks associated with scientific literacy, such as explaining phenomena scientifically, applying chemical knowledge to solve problems, and evaluating the advantages of chemical applications (Permatasari & Fitriza, 2019).

By employing valid and dependable problem-based learning modules and encouraging students to develop their concepts through a contextual scientific approach, Yusuf et al. (2023) discovered that students' scientific literacy and critical thinking abilities can be enhanced.

Sugiharti (2024), one of the other development studies pertaining to HOTS, discovered that students' thinking abilities while utilizing HOTS-based modules were superior to those when using school-provided textbooks. According to Yusuf (2020) and Panggabean (2021), the creation of general chemistry modules centered on biochemical content can enhance students' high-level thinking abilities. The modules were deemed legitimate and successful in raising students' HOTS and eliciting favorable feedback from them.

Conclusion

According to the study's first phase, the problem-based learning module's average validation scores on the Buffer Solution content fell into the extremely high category of 84.75%. However, the average student response to the program fell into the very good category with 87%. According to the normalized Gain test results, students' scientific literacy increased by 65.83% in the medium group and their high-level thinking abilities increased by 82.16 in the high category. This study came to the conclusion that the problem-based learning module on the buffer solution material is successful in enhancing students' scientific literacy and critical

thinking abilities based on the gain conversion findings.

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