JPPIPA 10(5) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

How Does "Chemistry Challenge" E-book Affect the Chemical Literacy Profile? A Study to Test Learning Media Effectiveness

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Received: January 22, 2024
Revised: March 27, 2024
Accepted: May 25, 2024
Published: May 31, 2024

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DOI: 10.29303/jppipa.v10i5.7018

Abstract: The appropriate utilization of media can greatly impact one's chemical literacy. A prior study involved the development of an e-book called "Chemistry Challenge," which is specifically in chemical equilibrium. This research aims to evaluate the chemical literacy profile of students who have utilized the "Chemistry Challenge" e-book and determine if there are significant differences between those who have used it and those who have not. The Chemical Equilibrium Literacy Questionnaire (CELQ) was utilized as an instrument for data collection. The CELQ data was analyzed utilizing ideal criteria assessment to evaluate the chemical literacy profile, and the independent t-test was used to see significant differences. The results of the CELQ show that 82% of students have a chemistry literacy profile in the good and very good categories after using the "Chemistry Challenge" e-book, this result is superior to students who learn using student worksheets. Apart from that, statistically, there are significant differences between the two groups of students. Therefore, the use of the "Chemistry Challenge" e-book has a positive effect on students' chemical literacy profiles.

Keywords: CELQ; Chemistry challenge e-book; Chemical equilibrium; Chemical literacy

Introduction

The level of literacy serves as a fundamental parameter for gauging a nation's progress in the field of education. Science literacy ability stands out as a key supporting factor in this regard. It is characterized as the capacity to engage with scientific issues, particularly in a manner that is consistent with scientific methodology (OECD, 2016). Science literacy is thus considered to be a crucial focus area for students to participate in discussions that relate to science, technology, society, and environmental problems scientifically (Yore et al., 2007). Some experts posit that science literacy is an indispensable skill that students must possess to lead effective lives within their immediate surroundings (Garner-O'Neale et al., 2013).

The results of the Program of International Student Assessment (PISA) conducted by the Organization for Economic Co-Operation and Development (OECD) indicate a subpar performance by Indonesia concerning literacy and science education. The country's rankings in the PISA assessments of 2009, 2012, 2015, and 2018 were 402, 396, 397, and 371, respectively, which fell below the average score of 500. A similar trend was observed in the science field, with rankings of 383, 382, 386, and 396 in 2009, 2012, 2015, and 2018, respectively. These findings point to a pressing need for Indonesia to address its educational policies and practices to improve its national standing in this crucial area (Hewi et al., 2020). From the results of the PISA test, it can be said that the literacy level of students in Indonesia is still relatively low (Asikin et al., 2019; Siami et al., 2023). This shows that the majority of students' chemical literacy in Indonesia is still not optimal (Adelia et al., 2023).

Many factors contribute to the low literacy scores of students in Indonesia. One of the main reasons is people's perception that reading skills are only taught in

How to Cite:
Pratama, F. I., & Rohaeti, E. (2024). How Does "Chemistry Challenge" E-book Affect the Chemical Literacy Profile? A Study to Test Learning Media Effectiveness. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2253–2260. https://doi.org/10.29303/jppipa.v10i5.7018

language classes. Additionally, unsuitable activities, lower-order thinking skill exercises and evaluations, and the absence of library services in schools also play a significant role (Tahmidaten et al., 2020). Therefore, the teaching and learning methods need to be modified to develop students' science literacy skills in a multidimensional way (Cigdemoglu et al., 2015).

Science literacy is an essential component of overall literacy. It encompasses the ability to recognize problems, apply scientific knowledge, articulate scientific phenomena, make evidence-based conclusions, comprehend scientific attributes, and appreciate how science and technology have shaped our natural environment, intellect, and culture. Additionally, science literacy involves engaging with and attending to issues about science (OECD, 2016). The various competencies required for science literacy reflect a fusion of cognitive and social skills across the entire knowledge spectrum (Crujeiras-Pérez et al., 2021).

Science literacy encompasses the ability to comprehend and apply scientific concepts pertinent to multiple fields (Wei et al., 2017). Within the domain of chemistry, this proficiency is known as chemical literacy, which refers to the knowledge and abilities required for a comprehensive understanding of chemistry-based principles. Chemical literacy is comprised of three fundamental components: basic concepts, including elements, symbols, processes, and models; academic and professional concepts; and social context (Kohen et al., 2020). It further comprises four facets, namely, chemistry as knowledge, chemistry as a context, High-Order Learning Skills (HOLS), and the affective aspect (Shwartz et al., 2006).

Chemical knowledge encompasses the comprehension of general chemistry concepts and critical characteristics that students must possess to explicate chemistry problems. Chemistry in context involves the explanation of the relationship between chemistry and technology in real-life situations, whereby students gain an appreciation of the importance of chemical knowledge and its connection to social and cultural processes. The indicators of high-order learning skills (HOLS) entail posing relevant questions, examining pertinent information, and evaluating the advantages and disadvantages of a phenomenon in everyday life in conjunction with pre-existing chemistry knowledge. The affective aspect refers to students' interest in learning about chemistry in everyday problems related to the subject, especially in non-formal environments (Cigdemoglu et al., 2015; Prastiwi et al., 2018; Pratomo et al., 2020; Shwartz et al., 2006; Wiyarsi et al., 2021). Students need to develop chemical literacy as it serves as a foundation for them to make informed decisions, think critically and creatively, and tackle daily problems or phenomena using their knowledge. This will also enable them to respect and appreciate the natural world by leveraging the power of science and technology (Nisa' et al., 2015; Prastiwi et al., 2018; Wiyarsi et al., 2020). Apart from that, there is a relationship between chemical literacy and the formation of ethics in students (Pratama, Aznam, et al., 2023). Based on this urgency, chemical literacy really needs to be taught to students so they can live in modern society in the 21st century (Primadianningsih et al., 2023).

Chemical equilibrium was chosen as the chemical concept discussed in this study because chemical equilibrium is one of the chemical concepts that has many contexts in everyday life (Eny et al., 2019). Another reason is that the concept of chemical equilibrium is complex and difficult to learn (Kousathana et al., 2002; Tyson et al., 1999). This topic involves defined concepts, abstract ideas, mathematical calculations, and data visualization (Jusniar et al., 2021). The comprehension of chemical equilibrium concepts among students is often impeded by the perception that this topic is not relevant to real-life scenarios. As a result, many students have unsatisfactory grades on this material (Rizki et al., 2021). The lack of connection between chemical equilibrium and everyday life poses a significant challenge for students (Jusniar et al., 2021). Many everyday phenomena or events can be explained by the concept of chemical equilibrium when explored in greater depth. Some examples of such phenomena or events are tooth enamel and dental health, coral reefs, hypoxia, ammonia production, atmospheric pollutant gases, ocean acidity, and even cutting vegetables (Eny et al., 2019; Fadly et al., 2022; Sadhu et al., 2019).

To enhance chemical literacy, it is important to select the appropriate learning resources. An e-book focused on chemical literacy is one such learning resource. However, the availability of e-books that impart knowledge on chemical literacy to students is still quite scarce (Yulianti et al., 2019). Researchers have successfully developed an e-book named "Chemistry Challenge" that teaches chemical literacy to high school students. The e-book was chosen as a learning medium due to its easy accessibility, eco-friendliness, and relatively small size. The "Chemistry Challenge" e-book has passed its usability and readability testing, but it still needs to undergo an effectiveness test to determine its impact in the classroom.

The "Chemistry Challenge" e-book has the following specifications: intended to teach odd semester class 11th high school students; developed in the form of an electronic medium with A4 size (21 cm x 29.7 cm), developed using Microsoft Word, Corel-Draw X7, and Canva, has a .pdf file extension, e-book components include a front cover, foreword, table of contents, Core Competencies and Basic Competencies, work instructions and scoring guidelines, activity, answer keys and scoring, bibliography, about the author, and back cover of the e-book, and the contents of this e-book are discourse or narrative and questions about chemical equilibrium (Pratama & Rohaeti, 2023; Pratama, 2022).

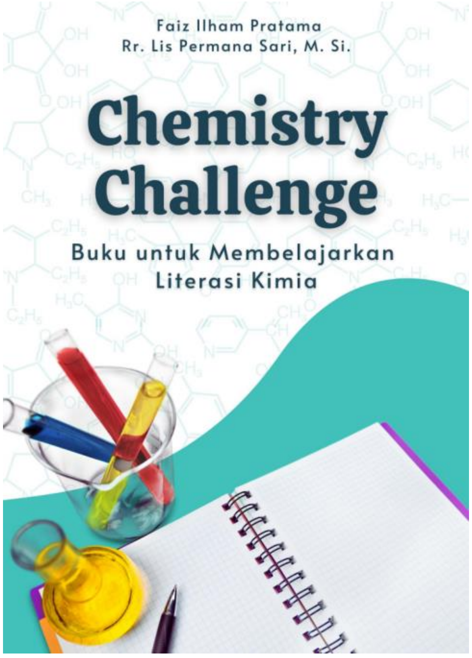

Figure 1. "Chemistry Challenge" e-book

Based on the background, the author conducted an evaluation of the efficacy of the "Chemistry Challenge" e-book in enhancing the chemical literacy of a cohort of 11th-grade high school students. This was accomplished by analyzing the chemical literacy profile of the students post-exposure to the e-book and comparing it to that of another group that utilized student worksheets. The author further examined whether there were any noteworthy distinctions between the two groups.

Method

This research presents a survey methodology with a quantitative approach to investigate the chemical literacy ability of 11^{th}-grade science students. The study was conducted in a state high school situated in Sleman Regency during October-November 2023. To obtain a credible data source, research respondents were a crucial requirement (Arikunto, 2010). The respondents must be representative of the population to ensure comprehensive representation (Creswell, 2012). The study population comprised 142 students, and the minimum requirement of 20% of the population must be fulfilled as respondents (Gay et al., 2012). One hundred students participated in the study, divided into two groups, Group A, which used the e-book "Chemistry Challenge," and Group B, which used student worksheets.

The study aimed to provide an overview of the characteristics of the population based on data collected from the respondents (Lochmiller et al., 2017). Data was collected from a questionnaire administered to students in Groups A and B after studying chemical equilibrium. The study's findings can contribute to improving the teaching and learning of chemical literacy ability in high school students.

Research Procedure

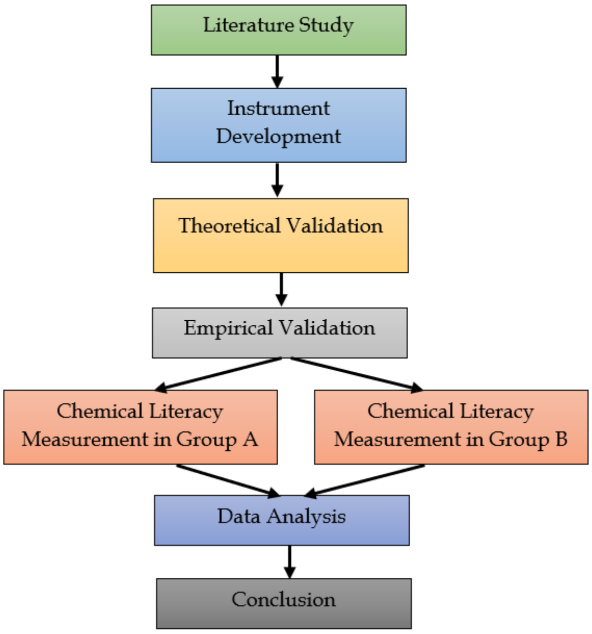

Figure 2. Research procedure

The initial step taken in this research project was to conduct a thorough literature review. This was achieved by delving into various research journal articles on chemical equilibrium and chemical literacy. Subsequently, research instruments were developed based on four fundamental aspects of chemical literacy, including Chemistry as Knowledge, Chemistry as Context, HOLS, and affective aspects. The constructed instrument was then validated by eight experts comprising chemistry education lecturers from two reputable Indonesian universities. Following the validation process, the instrument was tested on a sample of 300 students to determine its validity and reliability. The results indicated that all statement items were constructed as valid and reliable. The next stage involved distributing the questionnaire to students who had studied chemical equilibrium, and the data obtained was analyzed descriptively. The developed research instruments were designed to capture the essence of chemical literacy and its impact on students' understanding of chemical literacy in chemical equilibrium. The instruments were meticulously crafted to ensure that the data derived would be comprehensive, reliable, and valid. The results obtained from the data analysis will provide invaluable insights that will inform future research in this area. The research procedure is briefly illustrated in Figure 2.

Data Collection Technique and Instrument

The present study employs a questionnaire as the data collection technique to assess the chemical equilibrium literacy of the participants. The research instrument used for this purpose is the Chemical Equilibrium Literacy Questionnaire (CELQ), which comprises 25 statements with five alternative answer choices. The questionnaire uses a Likert scale with five alternative answers to evaluate the level of agreement with the statement. The response options available to the participants are Strongly Agree (SA), Agree (A), Fair (F), Disagree (D), and Strongly Disagree (SD). The scoring of the Likert scale answer choices varies depending on the nature of the statement. The highest score, i.e., 5, is assigned to responses indicating Strongly Agree, followed by Agree (4), Fair (3), Disagree (2), and Strongly Disagree (1) in descending order.

Data Analysis Technique

The current study employed a data analysis technique to evaluate the chemical literacy abilities of students based on their responses to a questionnaire. This analysis involved calculating the scores of each student and determining the average score for their chemical literacy skills. The final stage of the analysis entailed assessing the percentage of chemical literacy abilities using an ideal category assessment. To determine whether there was a significant influence, a two-group difference test was conducted. The normality of the data was analyzed using the Shapiro-Wilk test. If the Sig value is greater than 0.05, then the data is considered to be normally distributed. The next step was to perform a homogeneity test to determine whether the data came from a homogeneous population or not. A Sig value greater than 0.05 indicates that the data comes from the same population. If these two assumption tests are fulfilled, the independent sample t-test (parametric test) is performed. However, if the tests are not fulfilled, the Mann-Whitney (nonparametric test) is used. It is essential to note that the use of these tests is dependent on the normality and homogeneity of the data. The following assertion can be inferred from the test results: If the Sig < 0.005, there exists a noteworthy difference between the chemical literacy profiles of group A and group B. Conversely, if the Sig > 0.005, it can be concluded that there is no significant difference between the literacy profiles of group A and group B.

Result and Discussion

The chemical literacy profile of group a who used the e-book "Chemistry Challenge" is shown in Figure 3.

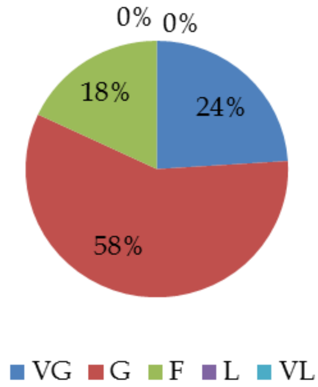

Figure 3. Chemical literacy profile of group A

According to Figure 3, students who used the "Chemistry Challenge" e-book showed a chemical literacy profile dominated by the Good (G) category, with a percentage of 58%. The remainder of the students were in the Very Good (VG) category, making up 24%, and the Fair (F) category, making up 18%. None of the students fell into the Low (L) and Very Low (VL) categories. When the percentage of students in the Very Good (VG) and Good (G) categories is added up, it amounts to 82%. Comparatively, students who used both textbooks commonly used in schools and the "Chemistry Challenge" e-book had a much better chemical literacy profile than those who only used student worksheets. Analysis showed that 6% of students who only used textbooks were in the Very Good (VG) category, 40% were in the Good (G) category, 48% were in the Fair (F) category, 6% were in the Low (L) category, and none were in the Very Low (VL) category. When the percentage of students in the Very Good (VG) and Good (G) categories is added up, it amounts to 46%. The chemical literacy profile of Group B, based on questionnaire scores, is illustrated in Figure 4.

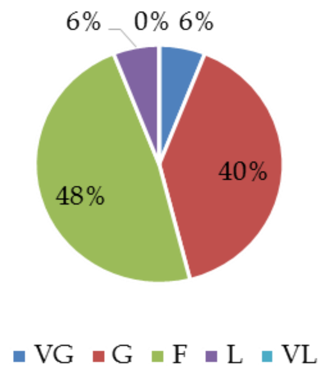

Figure 4. Chemical literacy profile of group B

An analysis was conducted to determine the percentage of students falling in the Very Good (SB) and Good (B) categories. Additionally, the overall chemical literacy profile was also assessed. The group that used commonly used school textbooks and the e-book "Chemistry Challenge" scored a total of 4,843 with an average score of 96.86, placing them in the Good (B) category with a percentage of 77.49%. Similarly, the group that used only school textbooks scored a total of 4,292 with an average score of 85.84, placing them in the Good (B) category with a percentage of 68.67%. Furthermore, the chemical literacy profile of each aspect was analyzed, and the results can be seen in Figure 5 and Figure 6.

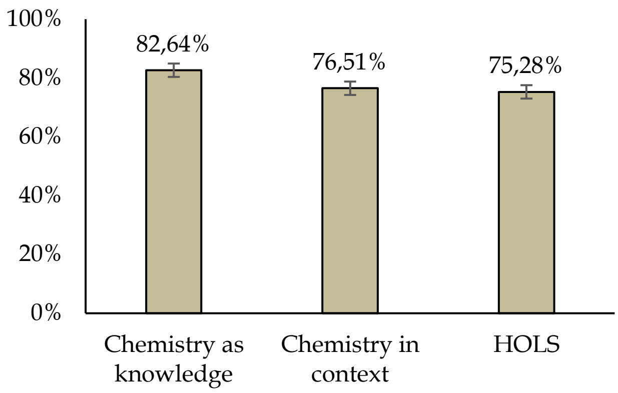

Figure 5. Chemical literacy for each aspect of group A

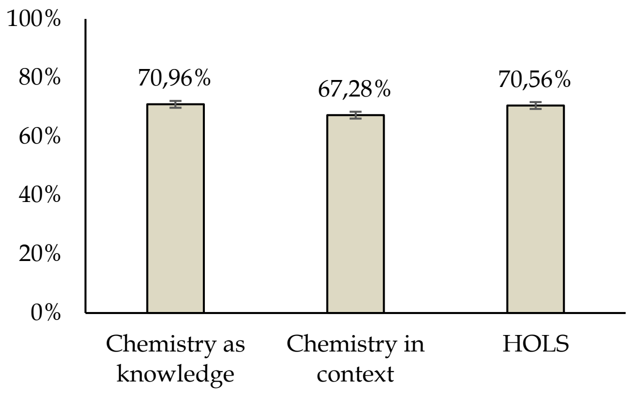

Figure 6. Chemical literacy for each aspect of group B

After analyzing the chemical literacy questionnaire results, it was found that there is a significant difference in the average score of the questionnaire between group A and group B. The average chemical literacy questionnaire score of group A students is 96.86, while group B students have an average score of 85.84. The results indicate that the chemical literacy profile of group A students is better than that of group B students, particularly in the concept of chemical equilibrium. Additionally, when comparing the percentage results for each aspect of chemical literacy between the two groups, it was found that group A outperforms group B in all aspects.

The normality and homogeneity tests were conducted to measure the two groups. The results of the normality test are presented in Table 1, while the homogeneity test produced a Sig value of 0.405 for the two groups. The normality test was conducted to evaluate whether the data in the sample followed a normal distribution. The homogeneity test, on the other hand, was carried out to determine the equality of variances between the two groups. The Sig value of 0.405 indicates that there is no significant difference in the variances of the two groups. Thus, the data can be considered normally distributed and homogenous.

Table 1. Result of Normality

Group	Sig.
Group A	0.069
Group B	0.130

Given that the normality and homogeneity tests have been fulfilled, the recommended statistical approach is to implement an independent t-test. The outcomes derived from the independent t-test are presented in Table 2.

Table 2. Result of Independent t-Test

Group	Sig.
Group A	0.000
Group B	0.000

The Sig. value of both groups is less than 0.005. The appropriate conclusion to describe the test results is that there is a significant difference in the chemistry literacy profile between the group that uses the "Chemistry Challenge" e-book and the group that uses student worksheets.

The implementation of the "Chemistry Challenge" e-book has resulted in a commendable improvement in the chemical literacy skills of its users. The e-book effectively encourages students to apply their knowledge of chemical equilibrium to practical scenarios presented in the text. This unique approach compels students to complete all the activities in the e-book, which in turn, allows them to actively engage in problem-solving relevant to the real world. Consequently, students can significantly enhance their chemical literacy skills through hands-on learning. (Bruine de Bruin et al., 2007; Salmawati et al., 2019). Using an appropriate learning model can lead to better results (Asrizal et al., 2018, 2023).

To improve students' chemical literacy, it is crucial to incorporate learning activities that prompt them to make connections between the subject matter and the everyday occurrences they observe. This approach not only helps students recognize the relationship between the two but also enables them to build their knowledge more effectively. The focus of these activities should be on developing students' scientific skills, enabling them to provide explanations for various phenomena, apply their chemical knowledge to solve problems and evaluate the benefits of chemical applications. Ultimately, students should be assessed on their chemical literacy skills through tests and questions that assess their comprehension (Pratama & Rohaeti, 2023; Thummathong et al., 2018).

In the chemical equilibrium material, many topics can be applied to everyday life and can be considered as questions that can develop students' chemical literacy skills, for example, the formation of coral reefs. This topic can be made into an interesting discourse for students. It must be noted that the development of questions that can be used to measure chemical literacy needs to pay attention to the criteria for creating scientific literacy questions from the Program for International Student Assessment (PISA) organized by the OECD so that the chemical literacy abilities of students in Indonesia become better (Pratama & Rohaeti, 2023; Suwahyu et al., 2023).

Conclusion

The effectiveness of the e-book "Chemistry Challenge" in improving students' chemical literacy profiles in chemical equilibrium material has been tested successfully. The CELQ results show that 82% of students using the e-book had a good or very good chemistry literacy profile, which is higher than the 66% of students who used only worksheets. The results were analyzed to determine whether there were any significant differences between the two groups. The independent sample t-test showed that there were significant differences between the two groups. Based on these results, it can be concluded that the e-book "Chemistry Challenge" has a positive impact on students' chemical literacy profiles. Learning models may also influence chemical literacy profiles. The use of appropriate learning models can support the use of the "Chemistry Challenge" e-book. Therefore, research on the use of the e-book "Chemistry Challenge" by integrating it into several learning models can be carried out. This is the implication that the author can convey for future research.

Acknowledgments
Our gratitude goes to the Chemistry Education Department, Faculty of Mathematics and Natural Sciences, Yogyakarta State University for support in publishing this article.

Author Contributions
F.I.P..; methodology, format analysis, investigation, data curation, and paper preparation E.R.; methodology, validation, data curation, paper review, and editing. All authors have to read and agree to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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