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Original Research Article

Development and validation of an assessment for measuring chemical literacy in chemical equilibrium

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ABSTRACT

Chemical literacy, the ability to integrate the understanding of chemistry with everyday life phenomena, has become a necessary skill for high school students. This skill is aimed at enabling students to develop an understanding of chemistry concepts about the environment, health, and industrial topics. This research focuses on developing and validating a chemical literacy assessment, specifically on chemical equilibrium. Afterward, the assessment was given the name Chemical Equilibrium Literacy Assessment. The development model is based on modified 4D and consists of two sets of 15 questions each. Content validity was measured using the Aiken V equation with seven expert judgments and four answer categories. To assess construct validity, the Pearson equation was used involving 100 respondents. The reliability of the assessment was calculated using Cronbach's Alpha. The results of content validity, construct validity, and quality of test items indicate that the chemical literacy assessment on chemical equilibrium material on environmental, health, and industrial topics has relatively high results. This assessment can be used to measure the chemical literacy abilities of high school students after studying chemical equilibrium.

Introduction

Educational objectives have consequently been redefined to prioritize the development of capable young individuals who are equipped to face the demands of the contemporary workforce and thrive in the years to come (Pratama et al., 2024). Enhancing the quality of education is one of the most effective ways to improve the literacy skills of a generation (Asykur et al., 2022). However, despite the efforts, the literacy and science scores of Indonesian students remain relatively low, as indicated by the Programme for International Student Assessment (PISA) (OECD, 2019). This underscores the need for a concerted effort towards improving the education system in the country, and providing students with the necessary skills and knowledge to thrive in a rapidly changing global economy. In research studies involving older adults, the Program for International Assessment of Adult Competencies (PIAAC) shows that Indonesian adults continue to struggle with literacy and problem-solving skills (Perry et al., 2020). A total of 70% of respondents from Indonesia have literacy skills at level 1 and below, which means that rural people in Indonesia are only able to read short texts on topics that are familiar to them (Kelair, 2020). Based on the outcome of the assessment of two international scale tests, it is apparent that literacy skills in Indonesia are presently at a relatively low level, indicating a need for significant improvements. In light of this, a concerted effort must be made to enhance the literacy skills of the populace, with particular emphasis on the identification and remediation of identified weaknesses (Siami et al., 2023).

Several factors have been identified as the cause of low literacy skills in Indonesia. These factors include low self-motivation, lack of practice and literacy-related questions, the perception that reading ability is the sole responsibility of language subjects, inadequate use of appropriate media during the learning process, suboptimal library services, and the misconception that literacy is merely an activity of reading (Setiawan et al., 2023; Stasevic et al., 2023). Therefore, ongoing education must be modified to build a deep literacy model (Cigdemoglu & Geban, 2015; Pratama & Rohaeti, 2023).

One part of literacy is science literacy which can be defined as science skills that require students can be able to identify a phenomenon, explain the phenomenon scientifically, and draw conclusions based on an analysis model (Cigdemoglu & Geban, 2015). The series of scientific competencies required for science literacy reflects that science literacy is a combination of social abilities and cognitive abilities in all sciences (Crujeiras-Pérez & Brocos, 2020). Science literacy can reveal a series of themes that cover multiple subjects (Wei & Cen, 2016).

Science literacy can be further narrowed down to chemical literacy which has three components: basic concepts of chemistry; the role of chemistry in academic and environmental life; and chemistry in the social context (Kohen et al., 2019). Shwartz in their research stated that chemical literacy consists of four dimensions: chemical ideas (chemical content); chemistry in context; High-Order Learning Skills (HOLS); and affective aspects (Wiyarsi et al., 2021). Students must have chemical literacy ability because it can be a provision for making decisions, critical, creative, problem solving, deciding on cases involving ethics, and being able to appreciate nature by utilizing science and technology (Setiawan et al., 2023; Pratama et al., 2023). However, in several previous studies, it was found that the level of chemical literacy was still low (Pratama et al., 2024). Students are not yet able to connect the knowledge gained in class with real life and are not used to analyzing complex information or reasoning (Muntholib et al., 2020; Stasevic et al., 2023).

The scope of the research is limited to the topic of chemical equilibrium, given the abstract nature of this concept (Pratama et al., 2024). This decision enables the researcher to delve deeper into the intricacies of chemical equilibrium, while also allowing for a focused and comprehensive analysis of the topic. Another reason is that students have not been able to implement the understanding of chemical equilibrium obtained in class with phenomena or events in everyday life, even though if they are studied in more depth there are many phenomena or events in everyday life that can be developed from the concept of chemical equilibrium. This causes many students to think that chemical equilibrium is a difficult subject, leading to the assumption that chemistry is a difficult subject (Sjöström et al., 2024). There are many examples of phenomena or events in everyday life that involve the concept of chemical balance, such as tooth enamel, coral reefs, hypoxia, ammonia production, atmospheric pollutant gases, ocean acidity, and cutting vegetables (Eny & Wiyarsi, 2019; Fadly et al., 2022).

This research aims to develop and validate a chemical literacy assessment on chemical equilibrium in environmental, health, and industrial fields. This study will assess the quality of assessment items, including theoretical validity using Aiken's V, construct validity using Pearson's Product-Moment Correlation Coefficient, and reliability using Cronbach's Alpha calculations. In this research, two sets of assessments were created - set A and set B, each comprising 15 questions. This research is important to carry out to create a quality chemistry literacy assessment, as well as prepare students to face literacy tests.

Materials and Methods

Research participant

A group of 200 grade 12th science students (third-year students) was randomly chosen from different senior high schools in the Special Region of Yogyakarta, Indonesia. The selected students needed to have previously studied chemical equilibrium material. 100 students will take assessment set A, while the other 100 will take assessment set B.

Development model

This type of research is included in development research with a quantitative approach. This assessment development research uses a modified 4-D model developed by Thiagarajan which contains four steps (Rabiman et al., 2024). However, in this research, the chemical literacy assessment instrument was developed in three stages as follows:

Define

The initial phase of developing a chemical literacy assessment involves the define stage. This includes analyzing student characteristics about the design of instrument development and the indicators required to achieve learning objectives within chemical equilibrium material. The next step is front-end analysis, which involves gathering relevant literature. Lastly, the concept analysis is undertaken to identify the subject matter, specifically chemical equilibrium material. This entails scrutinizing content across various fields such as health, environment, and industry while conducting task analysis to determine the necessary indicators of chemical literacy that need to be attained.

Design

The second stage is designing the Chemical Equilibrium Literation Assessment (CELA). This stage is divided into three parts. The first part is to analyze the main learning objectives (In Indonesia they are called Core Competencies (KI) and Basic Competencies (KD)) and class 11th textbooks. From this analysis, researchers can determine the learning objectives to be achieved through chemical literacy assessments. The second part includes describing chemical literacy indicators and designing an assessment. The third part includes writing assessment rubrics and writing assessment items. Assessment rubrics and assessment items are written in Indonesian.

Development

The third stage is developing the CELA. The content validity of the assessment items was determined using the Delphi technique with seven expert judgments from two well-known educational universities in Indonesia. Expert judgment is selected based on experience in the field of educational research, chemical knowledge in the field of chemical equilibrium, and understanding of chemical literacy. Specifically, expert judgment experts are asked to review each assessment item based on the criteria for the substance of the assessment item, the construct of information in the assessment item, and the suitability of the language used.

After reviewing these three aspects, expert judgment then provides an overall assessment for each assessment item developed. This assessment includes assessment items that can be used without revision with a value of 4, assessment items that can be used with a few revisions (minor revisions) with a value of 3, assessment items that can be used with many revisions (major revisions) with a value of 2, and assessment items that cannot be used with a value of 1. In addition to assessment, authors also expect feedback from expert judgment. Feedback from expert judgment is used to refine assessment items. Initial product results from the review will be used in trial implementation.

After revising all comments from expert judgment, paper-pencil administration was carried out for a group of third-year students who had received chemical equilibrium material. The purpose of providing paper-pencil administration is to test the level of difficulty of the test items, calculate construct validity, and calculate reliability. Before carrying out the paper-pencil test, students are given verbal instructions regarding the purpose of the test, how to answer the test, and request to take the test seriously according to their respective abilities. Apart from calculating the quality of the assessment being developed, the researcher also asked for suggestions as material for revision to obtain the final version of the CELA.

Development product

The author developed a chemical literacy assessment tool based on the Indonesian curriculum and combined various existing frameworks (Cigdemoglu, 2015; Shwart,2016). The CELA's final rubric is presented in Table 1.

Table 1. The CELA's final rubric

Number	Discourse Field/Topic	Aspect	Sub-Materials	Indicator
1A,1B	Environmental/ Coral reef formation	1,3	Basic concepts of chemical equilibrium	Integrating basic concepts of chemical equilibrium based on exposure to environmental discourse
2A,2B		2	Chemical equilibrium reaction equations	Identifying reaction equations from data in environmental discourse
3A,3B		2,3	Chemical equilibrium graph	Identifying the products and reactants on the chemical equilibrium graph presented in the environmental discourse
4A,4B		2	Types of chemical equilibrium	Classifying the types of chemical equilibrium from several chemical reactions
5A,5B		3	Application of chemical equilibrium	Integrating the concept of chemical equilibrium can help maintain the sustainability of coral reefs
6A,6B	Industrial/ Ammonia industry	2	Chemical equilibrium reaction equations	Identifying reaction equations from in ammonia industry discourse
7A,7B		2	The concept of K_c and K_p	Calculating the K_c if the data is presented in the ammonia industry discourse
8A,8B		2	The direction of shift in chemical equilibrium	Identifying the direction of shift in chemical equilibrium due to a certain treatment
9A,9B		1,2,3	The direction of shift in chemical equilibrium	Integrating the concept of shifting chemical equilibrium so that industrial product production can be maximized
10A,10B		3	Application of chemical equilibrium	integrating the concept of chemical equilibrium with the principles of production effectiveness
11A,11B	Health/ Blood pH	2	The concept of K_c and K_p	Calculating the K_p if the data is presented in the blood pH discourse
12A,12B		1,2,3	The direction of shift in chemical equilibrium	Identifying the direction of shift in chemical equilibrium due to a certain treatment
13A,13B		1,2,3	The direction of shift in chemical equilibrium	Identifying the direction of shift in chemical equilibrium due to a disease
14A,14B		1,2,3	The direction of shift in chemical equilibrium	Identifying the relationship between certain medical procedures and the use of chemicals as a factor that influences the pH balance of human blood
15A,15B		3	Application of chemical equilibrium	Integrating the concept of chemical equilibrium so that blood pH remains stable

Note: 1: Chemistry as context; 2: Chemistry as knowledge and science; 3: High Order Learning Skills (HOLS)

Analisis data

The content validity of two sets of chemical literacy assessments was tested on seven expert judgments using the Delphi technique. The data obtained are assessment data and suggestion data for development. The assessment data is then analyzed using the Aiken V value (Setiawan et al., 2024). The suggestion data is used as consideration for developing a better literacy assessment. After revising the literacy assessment, a paper-pencil assessment was carried out to see empirical validity and reliability. Empirical validity is measured by calculating the Pearson correlation coefficient (PCC) value and comparing it with the value from the r table, while reliability is calculated using Cronbach's Alpha equation. If the alpha value is in the range of less than 0.20, then the item has very low reliability. If the alpha value is in the range of 0.21 to 0.40, then the item has low reliability. If the alpha value is in the range of 0.41 to 0.60, then the item has fair reliability. If the alpha value is in the range of 0.61 to 0.80, then the item has high reliability. Reliability can be said to be very high if the alpha value is above 0.81 and above (Taber, 2018). The application used in data analysis is SPSS version 25.

Results

Content validity

This study involved validating two sets of initial versions of a chemical literacy assessment using the Delphi technique and expert judgment. The responses from the experts indicated that the assessment was highly suitable. The findings of the Aiken V analysis can be viewed in Fig-1.

Construct validity

Construct validity in this research states the extent to which the instrument developed is valid in measuring aspects of chemical literacy. The construct validity of two sets of chemical literacy assessments was calculated using the Pearson Correlation Coefficient (PCC). The results of the PCC calculation for chemical literacy assessment set A and set B are shown in Table 2.

Table 2. PCC results

Item	Pearson Correlation	R-Table Value	Result	Item	Pearson Correlation	R-Table Value	Result
1A	0.373	0.195	Valid	1B	0.670	0.195	Valid
2A	0.510	0.195	Valid	2B	0.539	0.195	Valid
3A	0.507	0.195	Valid	3B	0.792	0.195	Valid
4A	0.355	0.195	Valid	4B	0.440	0.195	Valid
5A	0.384	0.195	Valid	5B	0.565	0.195	Valid
6A	0.399	0.195	Valid	6B	0.662	0.195	Valid
7A	0.553	0.195	Valid	7B	0.678	0.195	Valid
8A	0.295	0.195	Valid	8B	0.658	0.195	Valid
9A	0.467	0.195	Valid	9B	0.678	0.195	Valid
10A	0.379	0.195	Valid	10B	0.526	0.195	Valid
11A	0.517	0.195	Valid	11B	0.692	0.195	Valid
12A	0.365	0.195	Valid	12B	0.602	0.195	Valid
13A	0.249	0.195	Valid	13B	0.396	0.195	Valid
14A	0.421	0.195	Valid	14B	0.597	0.195	Valid
15A	0.350	0.195	Valid	15B	0.519	0.195	Valid

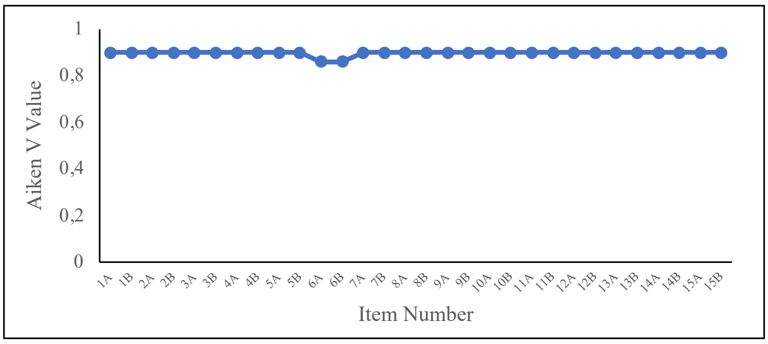

Fig-1. Aiken V Value for each item

Based on Table 2, the average Pearson correlation value for the CELA set A is 0.408, while the average Pearson correlation value for the CELA set B is 0.601. When compared with the R-Table value for 100 respondents as a minimum limit, the average of set A and set B is above this value. Based on these findings, it can be concluded that CELA set A and set B are valid and can be used for further research.

Reliability

Once the empirical validity results were determined, the reliability of the chemical literacy assessment was determined. The reliability of two sets of chemical literacy assessments was calculated by Cronbach's Alpha equation. The results of calculating the reliability of CELA set A and set B along with their reliability categories are shown in Table 3.

Table 3. Cronbach's Alpha results

Item	Cronbach's Alpha	Result	Item	Cronbach's Alpha	Result
1A	0.586	Fair	1B	0.824	Very High
2A	0.567	Fair	2B	0.833	Very High
3A	0.564	Fair	3B	0.818	Very High
4A	0.598	Fair	4B	0.838	Very High
5A	0.585	Fair	5B	0.833	Very High
6A	0.583	Fair	6B	0.825	Very High
7A	0.642	High	7B	0.860	Very High
8A	0.594	Fair	8B	0.825	Very High
9A	0.576	Fair	9B	0.826	Very High
10A	0.584	Fair	10B	0.833	Very High
11A	0.576	Fair	11B	0.828	Very High
12A	0.589	Fair	12B	0.829	Very High
13A	0.601	High	13B	0.838	Very High
14A	0.579	Fair	14B	0.829	Very High
15A	0.588	Fair	15B	0.833	Very High

Based on Table 3, the average value of the CELA set A is 0.587. This states that the chemical literacy assessment set A has a fair level of reliability. In contrast to set A, the CELA set B had better results. The average Cronbach's Alpha of the chemistry literacy assessment set B is 0.831 so it is included in the very high category.

Discussion

Assessment of students is carried out to determine students' progress and performance and as a guide in designing learning (Hagos, 2023). The results of the content validation stated that all CELA items had a value of 0.90 except for items number 6A and 6B which received an Aiken V value of 0.86. The reason why items 6A and 6B have a smaller score than the other numbers is because of the assessment of one of the expert judgments which states that the level of difficulty of the language used is too high for high school students. The use of inappropriate language can be a bias in the development of assessments (Solano, 2001). After receiving this suggestion, the author revised items 6A and 6B before carrying out the construct validation test.

Construct validation was carried out to find out how influential the questions that had been created had on students' chemical literacy (Hamed, 2016). Measurement of PCC construct validity. In the chemical literacy assessment, set A received an average Pearson correlation value of 0.408, and set B was 0.601. Based on the average Pearson correlation value, it can be concluded that set A and set B are valid. Chemical equilibrium chemical literacy questions in the environmental, health, and industrial fields are ready to be used in learning.

The next stage is to determine reliability using the Cronbach's Alpha equation. The average value of the chemistry literacy assessment set A is 0.587, which states that the reliability is at a sufficient level. The set B assessment produced a very high reliability value with an average value of 0.831. Based on the results of these calculations, it can be stated that the assessments for set A and set B are good and can be used as an evaluation of chemical literacy learning in chemical equilibrium material by the abilities needed in the disruption era of the 21st century. The development of this chemical literacy assessment also makes students more able to integrate their understanding of chemistry with everyday life so that they can appreciate nature by utilizing science and technology (Setiawan et al., 2023). Students' abilities will be more suited to 21st-century learning if they are integrated with technology (Hagos, 2023), certain appropriate learning media (Cahyana, 2019; Pratama & Rohaeti, 2024), and certain efficient learning models (Rahmawati, 2023).

Conclusion

The findings in this study confirm that the chemical literacy assessment developed has relatively high validity and reliability. The researcher drew this conclusion because content validity, construct validity, and reliability showed figures above the standard average. Overall, the chemical literacy assessment can be used to test chemical literacy skills in one test. There were two sets of CELA, each set consisting of 15 questions. The material tested is chemical equilibrium in the environmental, health, and industrial fields. Thus, researchers believe that chemical literacy assessments in the fields of health, environment, and industry can be used for second-grade students at the senior high school level. The implication of this research is those valid assessments can be applied in the learning process by using certain teaching models and methods to improve students' chemical literacy skills appropriately.

Conflict of Interests

The author declares that there is no conflict of interest in this research and manuscript.

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