Assessing high school student’s chemical literacy on salt hydrolysis

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Abstract. Each instruction requires appropriate strategies and assessments, including instruction of chemical literacy. The subject matter of salt hydrolysis, which is closely related to daily life, is suitable for the instruction of chemical literacy. The purpose of this research was to produce a valid and reliable chemical literacy test (CLT) on salt hydrolysis to assess high school students' chemical literacy. This study applied the design of research and development and also surveyed. The test development was carried out through five stages, namely (1) literature review, (2) item development, (3) expert judgment, (4) pilot study, and (5) finalization. The survey was carried out integrated with the pilot study phase of the test development stage. The data of the pilot study collected by a valid and reliable test produced in the development stage was analyzed as survey data. The research and development produced a chemical literacy test consists of 24 accurate items with Cronbach's Alpha reliability coefficient of 0.605. Analysis of student performance using valid and reliable tests shown that the respondents' average chemical literacy score was 39.69 from a maximum score of 100. This score belongs to the upper low or lowers moderate category.

1. Introduction

The acceptance of scientific literacy as a transferable outcome of learning has been increasingly widespread [1-4]. Indonesian education has also received scientific literacy as a learning outcome [5]. This acceptance requires the availability of content and pedagogical standards and appropriate assessments [6], including chemical literacy assessment.

Scientific literacy, in this case, chemical literacy, is scientific knowledge, the relationship between science, technology, and social relations, and the ability to apply scientific knowledge to solve real problems [7]. Each level of science education requires scientific literacy [8]. Therefore, scientific literacy needs to be practiced at all levels of education.

Related to the chemical literacy position as learning or transferable outcome, experts have developed several frameworks [3, 9-15]. Among these frameworks, the most popular one is OECD’s framework of scientific literacy. Right now, officially, the OECD scientific literacy framework is used in 36 countries participating in the Program for International Students Assessment (PISA). This study used OECD's scientific literacy framework [3] in which the content knowledge of the framework was replaced from scientific knowledge to chemical knowledge [16] (Table 1).

The subject matters of salt hydrolysis are an aqueous solution of salt and calculation of the pH of an aqueous solution of salt [17-18]. Learning outcomes for the salt hydrolysis topic in the current high school curriculum are (1) students are able to analyze the ionic equilibrium of a salt solution and
determine its pH and (2) report the experimental results on the acid-base properties of various salt solutions \[19\] while the recommended subject matters are the neutralization reaction, the acid-base properties of the salt, and the determination of the pH of the salt solution. The use of baking soda as a fluffiness of biscuits, antacids to reduce the excess of acid in the esophagus, and lemon juice or vinegar to reduce fish odor are the daily life phenomena related to salt hydrolysis. In short, the subject matters of salt hydrolysis are strongly related to daily life phenomena, which can lead to social issues. Therefore, the instruction of salt hydrolysis topics in high school can be used to improve students' chemical literacy, whose assessments require chemical literacy tests. The chemical literacy framework listed ad Table 1.

Table 1. chemical literacy framework used in this study \[3,16\].

| Aspects       | Domains                                                                 |
|---------------|--------------------------------------------------------------------------|
| Contexts      | • Personal                                                                |
|               | • Local/national                                                         |
|               | • Global issues                                                          |
| Knowledge     | • Knowledge of chemical content (salt hydrolysis)                         |
|               | • Procedural knowledge (knowledge of how scientific knowledge is produced)|
|               | • Epistemic knowledge [understanding of the underlying rationale for the use of procedures and the justification for their use] |
| Competencies  | The ability to:                                                          |
|               | • Explain phenomena scientifically                                        |
|               | • Evaluate and design scientific enquiry, and                            |
|               | • Interpret data and evidence scientifically                             |
| Attitudes     | A set of attitudes towards science indicated by:                         |
|               | • an interest in science and technology,                                 |
|               | • valuing scientific approaches to enquiry where appropriate, and        |
|               | • a perception and awareness of environmental issues                     |

Currently, chemical literacy tests have begun to be widely researched and developed \[6,15,16,20-22\]. However, no one has specifically researched and developed chemical literacy tests on salt hydrolysis as content knowledge. This research and development were carried out to develop a valid and reliable chemical literacy test on salt hydrolysis and to apply it to survey the high school students' chemical literacy.

2. Methods

2.1. Research design

This study applied an integrated research-development and survey design. The development of the instrument was carried out using research and development design, while the survey was carried out integrated with the pilot study phase of test development procedures. Survey data were obtained from the pilot study phase of the instrument development stage. The data included in the analysis of the survey stage was the data collected using the valid and reliable instrument produced in the development stage. Data obtained by invalid items were excluded from the data analysis.

2.2. Development of instrument

The development of the tool was carried out using procedures that had been used by previous researchers \[16, 23-24\]. The procedures consist of five phases; they are, (1) literature review, (2) item development, (3) expert judgment, (4) pilot study, and (5) finalization (Figure 1).

The literature review was conducted to identify the essential concepts of salt hydrolysis, and the relevant context for the problems would be developed. The concepts and contexts identified were then
discussed among the researchers. This phase produced a concept map of salt hydrolysis and six contexts of items that were relevant to the content. The instrument was developed in accordance with the research subject language, that is, the Indonesian language.

![Figure 1. The Phases of Research and Development of Chemical Literacy Test.](image)

The development of items was started with a review of learning goals. This step was intended to produce items with the construct and content in accordance with the learning goals. This process produces a items grid. Items were developed based on the indicators, as stated in the items grid. This phase resulted in an initial draft of the instrument consisting of 28 items.

Expert judgment was intended to get an assessment from experts regarding the validity of the items. Efficacy is defined as the extent to which an instrument measures the magnitude of the construct to measure [25]. This study analyzed the content validity of items only, that is, a judgment of how appropriate the items seem to a panel of experts in the subject matter [26]. The evaluation of content validity was carried out using the index of items-objectives congruence (IOC), which was the ratio between the number of validators, which states that an item is valid to the number of all validators [27]. In the IOC process, experts assess each item with criteria (1) the suitability of items to the subject matter to test, (2) the suitability of each item to their indicators, (3) the truth of content knowledge, and (4) clarity of the used language.

The pilot study of the instrument was conducted to 162 high school students in 11th grade. The evaluation covered the index of difficulty, index of discriminant, point biserial coefficient, and reliability of the instrument.

The finalization of the instrument was carried out by sorting and selecting items that were in accordance with (1) the chemical literacy framework used in this research, (2) standard values of difficulty index, discrimination index, and point biserial coefficient of items, (3) minimum value of instrument reliability, and (4) aesthetic and mathematical calculation aspects.
2.3. Survey on Students’ Chemical Literacy
Respondents of this study were 162 students of 11th grade. Data was collected after students learned the scientific knowledge of salt hydrolysis and completed the final examination of the end year. Data collection was done on Saturdays after students end school activities. Data analysis was performed by calculating the percentage of respondents' responses, both at the chemical literacy level and at the domains level. The determination of students’ level of chemical literacy is carried out using criteria shown in Table 2 [28,29].

Table 2. Level of literacy, argumentation, reasoning, and critical thinking.

| Score (%) | Level         |
|-----------|---------------|
| 80.00–100.00 | Excellent    |
| 60.00–79.99 | Good         |
| 40.00–59.99 | Moderate     |
| 20.00–39.99 | Weak         |
| 0.00–19.99  | Very weak     |

3. Results and discussion

3.1. Development Results of CLT
The draft of CLT consisted of 26 items. The CLT draft was then evaluated to find out the difficulty index, discrimination index, point biserial coefficients, and reliability. The following descriptions describe the results of each evaluation.

**Items difficulty index (P).** The difficulty index was determined by comparing the number of respondents who answered an item correctly with the number of total respondents. The value of the difficulty index (P) varied from 0.0 to 1.0. An item is easy if $P > 0.9$, moderate if $0.9 < P < 0.3$, and difficult if $P < 0.3$ [26]. Figure 2 showed the difficulty index of items of CLT. The figure showed that among 26 items of CLT, 1 item was easy ($P > 0.9$), 16 items were medium ($0.30 \leq P \leq 0.90$), and nine items were difficult ($P < 0.3$). The average value of the CLT items difficulty index was 0.39 (medium). A high proportion of items having a moderate difficulty index indicates that items of CLT were normally distributed. Therefore, the CLT can be used to collect data.

![Figure 2. The Difficulty Index of Items of Chemical Literacy Test.](image)

**Item discrimination index (D).** The item discrimination index was determined based on a score of 25% upper group and 25% lower group respondents [26]. The index is determined by using the equation:
\[ D = p(UG) - p(LG) \]  
(1)

In which \( p(UG) \) and \( p(LG) \) are the proportions of the correct answers of the upper and lower groups, respectively. D value of items range between +1.0 (maximum) and -1.0 (minimum). If all of the upper group members give the correct answer to an item and all of the lower group members give the wrong answer, \( D = +1.0 \).

On the contrary, if all of the upper group members give the wrong answer and all of the lower group members provide the right answer, \( D = -1.0 \). The discrimination index of an item is good if the D value of the item is higher than 0.30, sufficient if the amount of D items 0.20 - 0.30, and weak if the value of D is less than 0.20 [30], [31]. The discrimination index of 26 items of CLT was 12 items greater than 0.3, 5 items between 0.2 to 0.3, and 5 items less than 0.2. The average discrimination index for all CLT items was 0.30. Items number 6, 20, and 25 having discrimination index 0.10 - 0.20 were revised, while items number 7 and 13 having a discrimination index lower than 0.10 was removed.

**Item Validity.** Item validity or point biserial coefficient measures the correlation between the score of an item and the score of the overall items of an instrument. A high value of point biserial coefficient indicates that respondents who answered an item correctly had a higher test score. The acceptable value of the point biserial coefficient of an object is 0.2 [30], [31]. The value of point biserial coefficient of 26 items of CLT was 22 items above 0.20, 3 items less than 0.20 but more than 0.10 (problems 5, 13, 18), and 1 item less than 0.1 (problem 7). Items having point biserial coefficient 0.1 - 0.2 were revised while having a biserial point coefficient less than 0.1 was removed.

The above analysis showed that item number 7 and 13 have low discrimination index and point biserial coefficient. Based on the consideration of the discrimination index of items, the validity of the item, the proportion of the item of each chemical literacy domain, aesthetic, and mathematical calculations aspects, 24 items were used in the CLT. Thus, the final form of CLT consists of 24 items representing all domains of chemical literacy (an example of the problems that can be seen in the Appendix).

**Reliability of the test.** The reliability of the experiment was determined based on the value of Cronbach's Alpha coefficient. Analysis of reliability was carried out using the SPSS for Windows program. Cronbach Alpha coefficient of CLT on salt hydrolysis was 0.605. This value of reliability was the above of the acceptable limit of instrument reliability, i.e., 0.5 [32]. Therefore, the final form of the chemical literacy test on salt hydrolysis consists of 24 items with Cronbach Alpha's reliability coefficient was 0.605.

### 3.2. Students' Chemical Literacy on Salt Hydrolysis

The final form of CLT on salt hydrolysis was then used to analyze the students' chemical literacy. The respondents were 162 students of 11th grade who have learned salt hydrolysis scientific knowledge. The results of the survey were presented in Table 3.

Table 3 shows that the respondents' chemical literacy average score is 39.69 (upper weak or lower moderate). This result needs to be seen from two aspects. First, the aspect of the level of students' chemical literacy. From this aspect, the results of this study may be less representative. The research data was collected at the wrong time, i.e., (1) on Saturdays, (2) outside school hours, (3) after students take part in recreational activities of social and religious ceremonies, and (4) when the annual academic activities have ended, after students have completed their final semester exams. Therefore, an average test score of 39.69 does not mean that the test results are not satisfactory.

Second, aspects of the domain literacy level. From this aspect, the results of this study provide valuable information for the world of education, especially chemistry learning. Students' understanding of scientific knowledge was quite weak; it was 38.58%. The weakness of this understanding was followed by their weakness in using the knowledge to interpret data and evidence (33.99%), in understanding epistemic knowledge (36.17%), and in explaining phenomena scientifically (36.42%). These results reflected the learning processes that bombards students with all factual and conceptual knowledge, without distinguishing between the essential conceptual knowledge and accurate knowledge. Factual knowledge, data, and evidence were the foundation upon which conceptual
knowledge was built. New knowledge was developed from evidence and theories or existing knowledge [2, 33-35]. Learning that only emphasizes memorizing facts and concepts was less effective in building students' higher-order thinking skills and creativity. The result of the PISA survey, which placed the scientific literacy of Indonesian students in 62nd out of 70 countries or economic groups participating in the survey reflects this situation [36].

Students' mastery of procedural knowledge was quite good (44.09) and their ability to evaluate and design scientific inquiry was good (76.34%). This reflects the students' conditions that have not experienced many difficulties in understanding of procedural knowledge and in designing and evaluating scientific inquiry. This knowledge and abilities were common sense and logic. The properties of these domains help students answer questions about procedural knowledge and the ability to design and evaluate scientific inquiry. The same results of this study have also been reported by the same researchers on different topics [16]. The implications of these findings are scientific knowledge, competence, and attitudes having logical and common sense properties that do not need to be taught in all content knowledge. Teaching scientific knowledge having reasonable and common sense characteristics is sufficient to be guided through appropriate content knowledge only.

### Table 3. Level of Respondent’s Chemical Literacy.

| Aspects/Domains                  | Number of items | Average Score (%) | Level of Mastery |
|----------------------------------|-----------------|--------------------|------------------|
| **Scientific Knowledge Aspect**  |                 |                    |                  |
| • Content Knowledge              | 12              | 38,58              | Weak             |
| • Procedural Knowledge           | 7               | 44,09              | Moderate         |
| • Epistemic Knowledge            | 5               | 36,17              | Weak             |
| **Competency Aspect**            |                 |                    |                  |
| • Explain phenomena scientifically| 4               | 36,42              | Weak             |
| • Evaluate and design scientific inquiry | 3     | 76,34              | Good             |
| • Interpret data and evidence scientifically | 17  | 33,99              | Weak             |
| **Average Score of Chemical Literacy** |            | 39,69              | Weak/Moderate    |

### 4. Conclusion

The chemical literacy test (CLT) on salt hydrolysis developed in this research and development consists of 24 valid items with Cronbach's Alpha reliability coefficient of 0.605. These results suggest that the developed CLT can be used to collect research data.

The average score of respondent’s chemical literacy is 39.69% (upper weak or lower moderate category). At the level of domains, the respondents’ average rating from the lowest to the highest are (a) competency to interpret data and evidence scientifically (33.99%); (b) epistemic knowledge (36.17%); (c) competency to explain phenomena scientifically (36.42%); (d) content knowledge of salt hydrolysis (38.58%); (e) procedural knowledge (44.09%); and competency to evaluate and design scientific inquiry (76.34%). These results indicate that it is sufficient if the instruction of procedural knowledge and competency to assess and design scientific inquiry carried out in selected topics of content knowledge. However, the direction of critical thinking or using content knowledge to interpret data and evidence, to explain phenomena scientifically, and to understand the rationale underlying applying any procedures in scientific inquiry need to be given more attention in instruction.
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