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Review Article

Development of test instruments to measure problem-solving and science literacy of grade XI students on ion equilibrium material in salt hydrolysis

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ABSTRACT

Low science literacy in students will have an impact on students' ability to solve problems. To improve it, it is necessary to develop an assessment instrument in the form of a science literacy instrument. This study aims to develop valid, reliable problem solving and science literacy assessment instruments for students. The material chosen is ion equilibrium in salt solution. The research was conducted in high, medium and low ability schools namely SMA Negeri 1 Pekanbaru, SMA Negeri 12 Pekanbaru and SMA Negeri 15 Pekanbaru. There are 16 questions out of 20 questions that are constructively valid with a correlation value> 0.36. The questions developed have met the reliability requirements with a Cronbach alpha coefficient value greater than 0.6, reaching a value of 0.874. The level of difficulty of questions between 0.3 -0.7 is in the good enough category and differentiating power ≥ 0.3. Based on two trials, namely one-on-one trials and limited trials, the same results were obtained that the assessment instruments developed for students had very good readability aspects (85%), good adequacy aspects (64%) and assessment instruments developed for teachers had very good feasibility aspects (91%). There is a significant difference in the ability of students in high schools with medium and low ability schools.

Introduction

The education system in Indonesia continues to be improved, one of which is the curriculum. Currently, the 2013 curriculum is being used. The 2013 curriculum aims to face the challenges of the 21st century which requires students to master high-level understanding competencies, critical thinking competencies, collaboration and communication competencies, and creative thinking competencies. This requires students to have the ability in science literacy. Science literacy is the ability to understand science, communicate science, and apply science skills to solve problems (Tamam et al., 2023).

According to the Program for International Student Assessment (PISA), the science literacy of students in Indonesia is ranked 70th in the PISA scientific skills measurement (OECD, 2019). In order to improve students' science literacy skills, it is necessary to develop assessment instruments in the form of science literacy instruments. Sudiatmika (2010) found that the collection of tests commonly used in schools mostly tested science knowledge from cognitive aspects and mathematical calculations only, while the process and context aspects were missing from the assessment.

One of the sciences related to science is chemistry (Siregar & Silaban, 2023; Asmi et al., 2023). Chemistry is the study of material and its changes (Chang, 2005). The assessment instruments used in the Chemistry learning process should be of high quality. Basically, to conduct an assessment, two forms of instruments can be used, namely tests and non-tests. Test instruments include written tests in the form of choices and essays. Meanwhile, non-tests consist of portfolios, performance, projects, self-assessment, journal assessments and oral tests (Kusaeri, 2014). In this study, the focus is on the assessment of written tests in the form of essays.

The results of interviews conducted by researchers to chemistry teachers at SMAN 1, SMAN 12 and SMAN 15 Pekanbaru obtained information that; (1) most of the questions used are adopted from several sources and not the results of their own development, (2) most of the test questions given to students are questions in the form of multiple choice, medium and low thinking ability, (3) test questions used to measure science literacy and problem-solving skills have never been done. Based on information obtained from journals and interviews and field observations by researchers, there have not been many studies that apply test instruments to measure students' problem-solving and science literacy skills in chemistry subjects.

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The subject was chosen based on the details of the indicators contained in the chemistry syllabus of the 2013 revised curriculum 2017, namely the material of Ion Equilibrium and pH of salt hydrolysis. The material of Ion Equilibrium and pH of salt hydrolysis is one of the abstract chemical materials which certainly not only requires understanding and memorization, but also requires thinking skills in order to solve the problems given properly. Students must have good analytical and mathematical skills in order to solve the questions correctly. The test instrument needed is an instrument that can measure problem-solving skills and scientific literacy. In general, the purpose of this research is to develop a problem-based test instrument to measure problem solving ability and science literacy in the material of Ion Equilibrium and pH of Salt Solution in class XI SMA Pekanbaru.

Methods

The research approach used is Research and Development (R&D), which is adapted from the Borg & Gall Model (Bennett et al., 1984). The steps used in the research are based on the needs of the researcher. This is in accordance with Bennett et al. (1984) opinion that the steps of the Borg and Gall Model are not standard things that must be followed, the steps taken can be adjusted to the needs of the researcher. The research method used several steps as illustrated in Fig-1. The stages consist of preliminary and information collection stage, planning stage, initial product development stage, initial trial stage, initial trial revision stage, field trial stage, final product after revision.

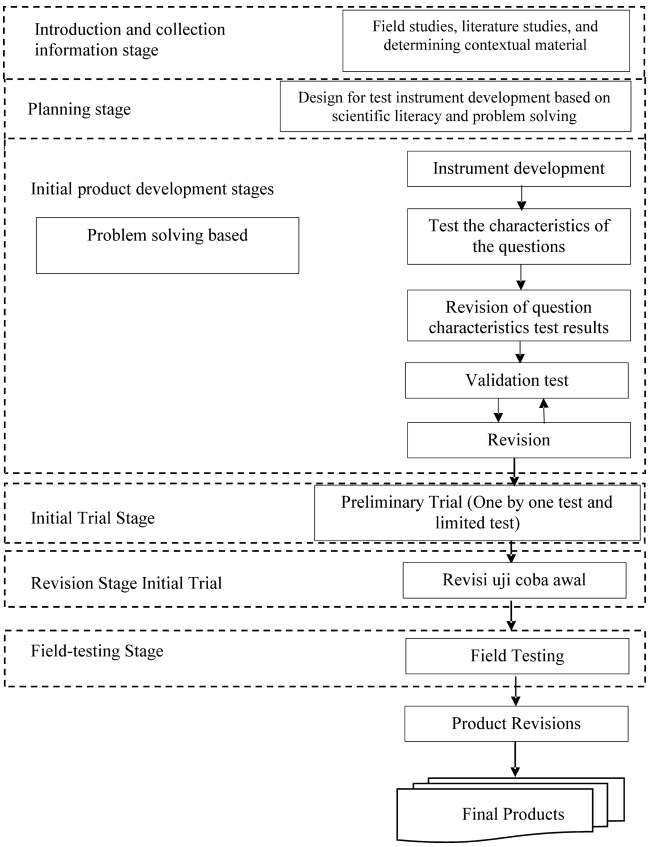

Fig-1. Flowchart of research procedure.

Population and Sample

The population in this study were students in 3 public high schools in Pekanbaru City, namely SMA Negeri 1 Pekanbaru, SMA Negeri 12 Pekanbaru and SMA Negeri 15 Pekanbaru. The research sample consists of students of class XI IPA SMA Negeri 1 Pekanbaru, SMA Negeri 12 Pekanbaru and SMA Negeri 15 Pekanbaru. The sampling method was randomized.

General Procedure

The sampling technique in this study was purposive sampling technique by selecting three high schools in Pekanbaru City. The selection was based on the researcher's consideration.

The data collection techniques used the following methods:

a. Interviews and analysis of daily assessment questions during the preliminary study conducted to find out information on instrument techniques used by teachers and learning models used in learning activities;
b. Test the characteristics of the questions (validation, reliability, difficulty level and differentiating power) of the question instruments developed;
c. Expert validation. In this technique, a validation sheet is used as a measuring tool for assessing the feasibility of instrument products. Data obtained from the validation results of 3 chemistry lecturers;
d. Questionnaire of students' responses to readability and adequacy of time on a limited scale test;

e. Teacher response questionnaire on the feasibility of problem-solving and science literacy assessment instruments in the limited scale test;
f. Tests in the form of problem-solving skills and science literacy items on the subject of Ion Equilibrium and pH of salt hydrolysis.

Data Analysis

The collected research data is processed by in-depth study by looking at the type of research data. The data analysis techniques used in this research are qualitative and quantitative. Qualitative analysis was carried out descriptively according to the results of questionnaires, documentation, and observations. In the limited trial and broad trial, the data were analyzed using a qualitative approach. It aims to evaluate the design of the material to assess the weaknesses, shortcomings, to improve the design of the material, to assess the achievement of the implementation of the assessment design, and to measure problem-solving ability and science literacy. Quantitative analysis is used to determine the difference in the results of product trials of problem-solving ability assessment instruments and science literacy on learning outcomes and positive responses from students.

Results and Discussion

The subject chosen is Ion Equilibrium and pH of salt hydrolysis which consists of the nature of salt hydrolysis, salt hydrolysis reactions and pH of salt hydrolysis, experiments on the acid-base properties of various salt hydrolysis. The basic competencies have 5 indicators of competency achievement (Ye et al., 2021). The results of the analysis resulted in indicators of problem-solving ability assessment instruments consisting of 4 indicators and science literacy indicators consisting of 3 indicators (Table 1).

Table 1. Indicators of problem-solving and science literacy abilities.

Indicator of problem-solving abilities	Indicators of scientific literacy abilities
Defining the problem	Explaining phenomena that occur in everyday life scientifically
Formulate problem-solving	Identify scientific issues
Determine and implement problem-solving strategies	Prove it scientifically
Conduct evaluation	

Test the Characteristics of the Questions

There were 20 questions developed as an initial product. The assessment instrument is specifically designed to measure students' problem-solving abilities and scientific literacy. The revised assessment instrument was tested on 33 students of SMA Negeri 1 Pekanbaru, SMA Negeri 12 Pekanbaru and SMA Negeri 15 Pekanbaru class XI Science for the 2022/2023 academic year. Students worked on 20 problem-solving skills and scientific literacy questions. The results of the initial trial were analyzed to determine the characteristics of the assessment instrument product for measuring students' problem-solving abilities, namely: construct validity, reliability, level of difficulty and distinguishing power. The results of the characteristics of the instrument for assessing problem-solving abilities and scientific literacy on the material Ion equilibrium and pH of salt hydrolysis are shown in Table 2.

Table 2. Characteristics of assessment instruments.

Question (Q)	Validity	Reliability	Question Difficulty	Differentiating Power	Category
Q1	0.443	0.878	0.75	0.92	Qualify
Q2	0.527	0.870	0.64	1.04	Qualify
Q3	0.211	-	-	-	Not qualified
Q4	0.607	0.867	0.64	0.95	Qualify
Q5	0.520	0.869	0.61	0.25	Qualify
Q6	0.658	0.864	0.28	0.72	Qualify
Q7	0.635	0.864	0.56	1.10	Qualify
Q8	0.722	0.856	0.30	1.51	Qualify
Q9	0.652	0.860	0.29	1.36	Qualify
Q10	0.482	0.872	0.53	0.32	Qualify
Q11	0.345	-	-	-	Not qualified
Q12	0.579	0.868	0.47	1.35	Qualify
Q13	0.516	0.871	0.64	0.64	Qualify
Q14	0.119	-	-	-	Not qualified
Q15	0.028	-	-	-	Not qualified
Q16	0.549	0.868	0.63	0.49	Qualify
Q17	0.547	0.867	0.75	1.74	Qualify
Q18	0.725	0.858	0.29	1.60	Qualify
Q19	0.563	0.868	0.81	1.15	Qualify
Q20	0.604	0.863	0.73	1.58	Qualify

The construct validity test uses Pearson correlation. After the validation coefficient value of each item is obtained, then the results are compared with the r value of the table at the 5% significance level and 1% significance level with df = N-2. If r count> r table then validity at significance is used (Arikunto, 2015). Pearson correlation of item validity is shown in Table 6. The validity column shows the Pearson correlation value of each item > 0.361. Therefore, the data that can be used are 16 valid questions.

The reliability test used the Cronbach Alpha correlation. The results of the reliability test can be seen in the Reliability column in Table 3. The reliability test results shown that the tested variables produce a Cronbach alpha coefficient value of 0.874. So it can be concluded that the instrument is reliable and suitable for use. Opinion from Madan and Kensinger said that if the coefficient produces above 0.8, it is considered very good (Madan & Kensinger, 2017).

The level of difficulty analysis was carried out on 16 valid question items. The results obtained 25% of the easy category items (4 questions), 50% of the medium category items (8 questions) and 25% of the sound category items (4 questions). The results of the question differentiator analysis of 16 questions obtained 12 items in the excellent category (75%), 2 items in the good category (12.5%) and 2 items in the sufficient category (12.5%). Based on the results of the characteristics of the problem-solving and science literacy assessment instruments. It can be concluded that of the 20 items of the assessment instrument, only 16 items were used for limited scale and broad scale testing.

Validation of Questions by Experts

The validators who conducted the correction consisted of three lecturers who were experts in the field of chemistry. The material validation assessment by each validator was carried out twice until the question was declared valid. The data obtained from the validation results through the validation sheet were analyzed descriptively by percentage.

The first stage Aiken's score (V) ranged from 0.71-0.79. This value is classified as a good category, but still needs revision. There is still writing that is not in accordance with the content, not classified as problem-solving and the mismatch between learning indicators and the questions developed, so this requires revision again. For some questions must be corrected based on expert revision. The second stage Aiken's (V) value ranges from 0.88-0.97. This value is declared valid and meets the minimum acceptable validation qualification. The instrument developed was declared valid because the Aiken V value was greater than 0.86. Question items with a validation index below 0.86 are not used (Ad'hiya & Laksono, 2018).

The percentage results of expert validation can be seen in Table 6. The results of the analysis of the problem-solving ability aspect show that the instrument has an increase in validation value from 70% to 92% (very high category). While science literacy skills show an increase in validation value from 72% to 90% (very high category). So that the question is feasible to use in the initial trial to get the value of construct validation, reliability, difficulty level and distinguishing power of instrument products. Arikunto (2015) said that a test is declared good if it has high validity.

Table 3. The expert validation results.

Validator	Problem-solving ability		Science literacy ability	
	1st validation score	2nd validation score	1st validation score	2nd validation score
I	15	19	16	20
II	15	20	12	17
III	12	16	15	17
Total	42	55	43	54
%	70	92	72	90

Initial Trial

In the one-by-one test, the problem-solving ability assessment instrument, totaling 10 questions, was tested face-to-face (offline) on 3 class XI students. The students selected are students with high, medium and low abilities. These three students provided responses according to the questions asked by the researcher in the interview after completing all the questions.

The results of interviews with test participants obtained the following information. The message or information conveyed in the instrument is easy to understand and the sentences in the questions are effective and have a good structure. The images on the instrument were clear, interesting and related to the questions in the instrument. The grammar and spelling used in the questions were correct. Test participants stated that the problem-solving and science literacy assessment instruments were very suitable for measuring cognitive aspects and very useful. Based on the results of the test participants' responses to the product, the assessment instrument was declared good to use with minor revisions for the next stage.

Assessment instruments that meet the Qualify validity, reliability, level of difficulty and distinguishing power, then will proceed to a limited test conducted on 10 students in class XI in the 2022/2023 academic year and 3 chemistry teachers who teach in class XI IPA SMA 12 Pekanbaru. The results of the Limited Scale Test of students, namely the readability of the question is worth 85 (very good category), and the adequacy of time is worth 64 (good). The results of the teacher response questionnaire get a question feasibility score of 91 with a very good category.

Revision of the Product

Based on the initial product trial in the form of small groups, the assessment data is then used as a reference in revising the product. The result of the revision is the final product of the assessment instrument of problem-solving ability and science literacy on the material of Ion Equilibrium and pH of salt hydrolysis. The product has been tested both feasibility and usage, so that the product of the assessment instrument of problem-solving ability and science literacy on the material of Ion Equilibrium and pH of salt hydrolysis is very feasible as an evaluation guide that can help to measure the problem-solving ability and science literacy of high school students in class XI IPA.

Field Test

The implementation stage in this study consists of learning observation activities and ends with a daily assessment. The broad scale test is a measurement test of problem-solving ability and science literacy of students on the material of Ion Equilibrium and pH of salt hydrolysis which is carried out directly. The sample in this measurement test involved 25 students each in SMA Negeri 1 Pekanbaru, SMA Negeri 12 Pekanbaru and SMA Negeri 15 Pekanbaru from class XII IPA in the

odd semester of the 2023/2024 academic year. The sample selection is based on the criteria of high, medium and low schools obtained from the UTBK ranking in 2022.
The average percentage of students' mastery of the indicators of problem-solving ability and science literacy for each question in the field scale test is 58.7 (medium category). The results of the Kolmogorov Smirnov normality test analysis are shown in Table 4.

Table 4. Broad scale data normality test.

Value	Category	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
	High- ability school	0.141	25	.200*
	Medium-ability school	0.109	25	.200*
	Low- ability school	0.140	25	.200*

Based on Table 4, the significance value of broad-scale test data in each school category > 0.05. It can be concluded that the broad-scale test data is declared normally distributed data and continued with the statistical test of homogeneity.

The result of homogeneity test of wide scale is sigmoid 0.657, using Levene Statistic (value is 0.422). Based on it, the significance value for broad-scale test data > 0.05, it can be concluded that the broad-scale test data is homogeneously distributed data or comes from the same variant group. Homogeneously distributed broad-scale test data can be continued with the analysis of differences in problem-solving ability and science literacy in high, medium and low ability schools using One Way Anova difference test. In this study, the broad-scale test data was analysed with One Way Anova because it had three different groups of variants with the same dependent variable. The results of the Anova test of the broad-scale data from the three schools are shown in Table 5.

Table 5. One-way ANOVA test results for large scale data.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2955.387	2	1477.693	7.470	0.001
Within Groups	14242.800	72	197.817		
Total	17198.187	74			

Table 6 shows that the difference in problem-solving ability and science literacy of students in high, medium and low ability school categories with a significance value<0.05 then H0 is rejected, meaning that there is a significant difference between problem-solving ability and science literacy of high, medium and low category school students from the problem-solving ability and science literacy questions that have been developed. Analysis of differences in problem-solving ability and science literacy of students between high and medium ability schools, medium and low ability schools and high and low ability schools. Analysis of differences in problem-solving ability and science literacy of students is presented in Table 6.

Table 6. Analysis of differences in problem-solving abilities and scientific literacy.

School		Significance
High	Medium-ability school	0.024
	Low- ability school	0.001
Medium	High- ability school	0.024
	Low- ability school	0.538
Low	High- ability school	0.001
	Low- ability school	0.538

Table 6 shows that the problem-solving abilities and scientific literacy of students from high-ability schools with medium-ability schools and low-ability schools are significantly different. This can be seen from the significance value <0.05, so there are differences between the three school categories. The differences in problem-solving ability and science literacy of students in high, medium and low ability category schools are influenced by several factors, including differences in the intelligence level of each student from each school, the psychological condition of students, the condition of supporting facilities and infrastructure, material and material support from parents and environmental conditions when learning takes place.

Conclusion

An assessment instrument for problem-solving ability and science literacy on the material of Ion Equilibrium and pH of salt hydrolysis that meets the characteristics of a good question has been produced. The assessment instrument developed has been assessed as valid by experts. There is a significant difference between the problem-solving ability and science literacy of high, medium and low ability category school students from the problem-solving ability and science literacy questions that have been developed. There is a significant difference in the ability of students in high schools with medium and low ability schools. However, it cannot differentiate the problem-solving ability and science literacy of students in medium ability schools with low ability schools significantly.

Conflict of Interests

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

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