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Research Article

Validity of instruments for assessment of scientific literacy and critical thinking of students based on multiple intelligence in acid-base material

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Keywords

Acid-base
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Abstract

This research aims to create an assessment tool to evaluate students' scientific reading comprehension and critical thinking ability based on multiple intelligences on acid-base materials and to determine the validity of this study rating tool. The research methodology uses the Borg and Gal research and development model. This research phase continues into the development phase. The assessment instrument developed in this study consists of sixteen items of description test questions that refer to science literacy indicators consisting of four indicators are science as a body of knowledge; science as a way of investigation; science as a way of thinking; and the interaction of science, technology and society. Then the assessment instrument refers to critical thinking which consists of five indicators: providing a simple explanation, building basic skills, inference, providing further explanation, and developing strategies and tactics. This assessment instrument is based on multiple intelligences consisting of five types of intelligence: logical-mathematical, verbal-linguistic, visual-spatial, rhythmic-musical, and naturalistic. The validation of this assessment instrument is carried out by five validators. Validation by material experts is measured using the Guttman scale. Validity according to experts, namely aspects of material, language, and construction, obtained on average expert validation ranges from 90,33 – 94,7% and 16 questions are declared valid. Assessment instruments have been developed to be useful as a measure of a student's creative thinking ability.

Introduction

Education is the spearhead of the progress of a nation. A good education should provide service that is in harmony with the demands of the times. This is so that graduates of the education system can become successful individuals in the 21st century who demand various types of relevant skills that need to be mastered. The increasingly competitive 21st century demands four competencies, namely: Critical Thinking and Problem Solving, Creativity and Innovation, Communication, and Collaboration (Kemendikbud, 2019a).

The fact found in the world of education is known that the thinking ability of students has not developed well. This is reinforced by data from the results of an international study of the Programme for International Mathematics and Science (PISA) reported by the Organization for Economic Cooperation and Development (OECD) showing that Indonesia got an average score of 396 for science, which stated that Indonesia was ranked sixth from the bottom out of 79 member countries. This result has decreased compared to the results in 2015. In general, Indonesia's achievements are still below the average of OECD member countries (Kemendikbud, 2019b). This data is also in line with the results obtained by the National Examination in 2018 This shows that students are still weak in higher order thinking skills such as reasoning, analysis, and evaluation (Kemendikbud, 2019a).

Instruments for assessment that can be used in assessing students' critical thinking skills are essay tests that show proficiency in answering questions and one type of test that prioritizes the subjectivity of students. The description test instrument requires learners to organize ideas, express ideas, express ideas, and analyze in

written form (Farihah and Wildani, 2018). The selection of the type of instrument is adjusted to the characteristics and complexity of each chemical material. Learning chemistry is also a way of learning and thinking, not just memorizing concepts. Studying chemistry involves three aspects of study, including macro, micro and symbolic aspects. Basically, three aspects of learning chemistry require a higher level of thinking in students. Part of higher-order thinking is critical thinking, which is the thought process to make decisions and draw responsible conclusions based on relevant data, including analysis, hypothesis, explanation, reasoning, and analysis thought development (Siahaan et al. 2021). The use of technology as a learning tool also greatly affects learning efficiency and improves students' critical thinking skills (Sholihah et al. 2020).

Acid-base matter in class XI science at the high school level studies the properties of acid-base solutions, pH calculations, indicators for the introduction of solution properties, acidity degrees, strong acids and weak acids, degrees of acid and alkaline dissociation and the reaction between acid solutions and alkaline solutions (Sulistiani and Agustini, 2022). Based on the description of the concept, it seems clear that the concept of acids and bases is basically encountered in the daily life of learners. Natural symptoms such as discoloration of flowers based on planting media are one example of the application of acid-base (Utami et al. 2017). With the very diverse characteristics of this acid-base material, it is necessary to use an approach both in learning and in assessment that is in accordance with the characteristics of the material so that chemistry learning becomes meaningful for students.

As previous research, (Austin et al. 2014) revealed that there is a high correlation between critical thinking skills and chemical literacy. However, the process of assessing cognitive aspects of some skills is carried out separately. Whereas if these skills are interconnected, it would be better if they were assessed together (integrated) in an assessment instrument, in accordance with research conducted by (Sadhu, 2018) which developed an integrated assessment instrument between chemical literacy and critical thinking on chemical equilibrium materials. It also aims to minimize the performance of teachers in the making of assessment instruments.

Based on the description that has been described, this researchs will focus to conducting a study Validity of Science Literacy Assessment Instruments and Critical Thinking of Students Based on Multiple Intelligences on Acid-Base Material. This research expected to facilitate teachers and schools to meet assessment standards and deliver students to achieve the expected competencies and can measure students' critical thinking and science literacy skills.

Method

Types of research include Research and Development (R&D), which is research on the development of science literacy assessment instruments and critical thinking based on multiple intelligences on acid-base materials. This research refers to the Borg and Gall model development model (Fitriani and Darmana, 2016). The study time from June to December 2022. The following are the research steps according to development using the R & D model modification from Borg & Gall, namely: research and information collection, planning, develop preliminary form of testing, preliminary field testing, preliminary revision product, main field testing, operational product revision, operational field testing, final produce revision, and dissemination and implementation (Mulyatingsih, 2014). However, in this study, only three steps of development stages were carried out according to research needs (Emzir, 2014).

Research And Information Collection

At the research and information collection stage, the following steps are carried out.

1. Literature study / literature review out by analyzing the syllabus as a review of the core competencies and basic competencies that will be used in compiling indicators, collecting reference data and literature through various book sources, the latest research journals on the development of instruments for assessing scientific literacy skills, critical thinking and multiple intelligences, articles and internet media relevant to research;
2. Determining the material;
3. Field studies/empirical studies were conducted by conducting pre-research directly at SMAN Plus Provinsi Riau, SMAN 8 Pekanbaru and SMA Islam As Shofa Pekanbaru with interview methods;

4. This empirical study was used to obtain information about assessments used in some schools. In addition, it serves to find out the obstacles faced in the preparation of assessments in high schools that are the subject of preliminary studies, so that the results obtained from preliminary studies can be used as a reference for assessment development.

Planning

At the planning stage, the steps taken are as follows.

1. Compile indicators of cognitive assessment instruments for science literacy and critical thinking skills, question matrices, question grids, science literacy and critical thinking ability test questions, scoring and assessment rubrics;
2. Validate equipment with the help of a test chemist to validate manufactured equipment;
3. Planning the revision of the instrument in accordance with the advice of validators.

Develop Preliminary form of Testing

At the design development stage (develop preliminary form of product) is the initial design determination of an instrument for assessing scientific literacy and critical thinking skills based on multiple intelligences. Then the initial product validation stage is a step to validate or assess the feasibility of the initial product of the multiple intelligence-based science literacy and critical thinking ability assessment instrument. The design development stage was identified and drafted to obtain agreement among experts (validators) from 2 universities, namely Riau University and Sultan Syarif Kasim Riau State Islamic University. Instrument validation is carried out in two ways, namely expert validity of material aspects, construction and language.

The validity of the content is determined by furthermore the interpretation of the score is calculated based on the obtained score from each aspect.

$$\%\,Validity = \frac{Overall\ average\ score}{Overall\ ideal\ highest\ score} \times 100\%$$

The data from the assessment results that have been known are described and conclusions are drawn regarding each aspect of the assessment. To facilitate the reading of the research results, a table of percentage intervals of product validity levels is used which is presented in Table 1.

Table 1. Product Validity Rate Percentage (Riduwan, 2014)

Achievement Percentage	Interpretation
81% - 100%	Highly Valid
61% - 80%	Valid
41% - 60%	Quite Valid
21% - 40%	Invalid
0% - 20%	Highly Invalid

For validation of measurements of science literacy ability, critical thinking and multiple intelligence by experts are measured using the Guttman scale which consists of two answer choices, namely "yes" or "no" by giving a checklist mark to the answer choices that match the expert validator's responses. If the expert validator chooses "yes" then it is given a score of 1 and if it chooses "no" it is given a score of 0.In addition, on this validation sheet there is also an expert validator room to write down input/suggestions regarding the assessment instrument developed (Widoyoko, 2012). The shape of the Guttman scale can be seen from Table 2.

Table 2. Guttman Scale Score Assessment (Arikunto, 2018)

Score	Valuation
1	Yes
0	No

Collected information were analyzed utilizing expressive measurable investigation strategies. The gotten information are handled with numbers within the frame of descriptive percentages. The calculation to urge the validator rating rate employments the equation:

$$\% = \frac{Total\ "Yes"\ answers}{Total\ observed\ aspects} \times 100\%$$

Decision making on validity in terms of aspects of science literacy ability and critical thinking in science literacy assessment instruments and critical thinking based on multiple intelligences on acid-base material developed, namely if the percentage gain of ≥ 50% is relatively good. But on the contrary, if the percentage gain ≤ 50% is classified as a bad category (Riduwan, 2014).

Results and Discussion

The results and discussion are described according to the product development stage, namely the stages of developing the Borg and Gall model as follows.

Research and Information Collection

The process of developing scientific literacy assessment instruments and critical thinking based on multiple intelligences on acid-base materials starts from the Research and Information Collection stage by conducting analysis, namely literature studies and field studies. At the field study stage, an analysis of test instruments that are often used in schools is carried out, while at the literature study stage, it is carried out with syllabus analysis. Beside that on this stage also carried out about material analysis and critical thinking indicators, science literacy indicators, types of multiple intelligences. The last, theories about critical thinking and related (relevant) previous research become an important part to find out.

Field studies are carried out to determine the needs of teachers for the products to be developed. Analysis of test instruments that are often used in schools is a stage carried out in field studies. The analysis of the test instrument is by grouping daily test questions at the cognitive level conducted at SMAN Plus Provinsi Riau, SMAN 8 Pekanbaru, and SMA Islam As Shofa. Based on the analysis, information is obtained in Table 3.

Table 3. Types of Assessment Instruments in Schools

School Name	Types and Number of Questions	Specifications
SMAN (1)	Closed Essay (8 questions)	• Measure memorization and application aspects • Answers are concepts according to reference • The question of already using a stimulus that refers to science literacy
SMAN (2)	Multiple Choice (20 questions)	• Measuring aspects of memorization and comprehension • Using five distracters • Some questions already use the application aspect as seen from using formulas and analyzing tables
SMA (3)	Multiple Choice (15 questions) and Closed Essay (5 questions)	• Measuring aspects of memorization and comprehension • Using five distracters • The question is a combination of several materials other than acid-base matter • Measuring memorization and application aspects and combinations of several materials other than acid-base matter

Based on Table 3, it can be concluded that in general the test instruments that are often used in schools are still at a low cognitive level and have not been oriented towards indicators of science literacy and critical thinking.

Literature studies are carried out by conducting syllabus analysis, material analysis and indicators of science literacy and critical thinking, theories about critical thinking and related (relevant) previous research. The analysis of the syllabus and material is carried out by determining the material and concepts that refer to the 2013 curriculum syllabus so as to produce learning indicators that will be poured into the test instrument. Furthermore, an analysis of science literacy indicators consisting of 4 indicators (Setyorini et al. 2022), critical thinking ability 5 indicators (Rusmansyah et al. 2020; Sari, 2022) and multiple intelligence types consisting of 5 types of intelligence were carried out (Fadloli et al. 2021; Kurniawati et al. 2021).

In addition to the results of the analysis of preliminary documents from research instruments used in each school, at the stage of collecting information, data on the initial conditions of students on chemistry learning are obtained (Table 4).

Table 4. Initial Conditions of Students towards Chemistry Learning

No	Analyzed Indicators	Analysis Results
1	Types of learning approaches applied to chemistry learning	Scientific (Curriculum 2013) and cooperative learning
2	Types of assessment instruments used in the evaluation of chemistry learning	Multiple choice, essay and short fill-ins
3	Assessment instruments provided in accordance with the material taught	The assessment instruments given by the teacher are in accordance with the chemistry material taught in classroom learning
4	The level of difficulty in chemistry learning materials	Chemicals have a high complexity, so that some subject matter has a high level of difficulty
5	The importance of assessment instruments that refer to science literacy skills	Science literacy is important in chemistry learning, because the presence of a stimulus in chemistry can present the real state experienced by students in chemistry learning
6	The importance of assessment instruments that can measure the level of critical thinking of learners	Critical thinking needs to be measured and improved. It aims to train students in decision making and solutions (problem solvers) in learning and in everyday life
7	The importance of assessment instruments that facilitate students according to the type of multiple intelligence possessed	Assessment instruments must be considered based on the type of multiple intelligences possessed by the student, so that not only logical-mathematical intelligence dominates in the assessment instrument

Planning

Based on preliminary research, it is determined that research and development will be carried out with the aim of developing tools for assessing skills in scientific literacy, critical thinking, and multi-intelligence. knowledge on acid-base materials. The planning stage is (1) compiling indicators of cognitive assessment instruments for science literacy, critical thinking and multiple intelligences, question grids, creative thinking ability test questions, scoring and assessment rubrics (Lubis et al. 2022), (2) determining the validity of the instrument with the help of a chemical expert's test to validate the instrument that has been made, (3) planning the revision of the instrument in accordance with the advice of validators.

Develop Preliminary form of Testing

1. Initial Design Determination

The design development stage is carried out by determining the initial design of the questions in consultation with the supervisor. Compile indicators of cognitive assessment instruments for science literacy and critical thinking skills, question matrices, question grids, creative thinking ability test questions, scoring and assessment rubrics.

2. Validity of the Initial Product

Validate the tool using a chemist's test to confirm the tool was created. The instrument for assessing the ability of science literacy and critical thinking is validated with the help of 3 chemist experts who are lecturers with Doctoral specifications (S3) from 2 universities, namely Riau University and Sultan Syarif Kasim Riau State Islamic University The revision of the instrument is carried out in accordance with the suggestions / inputs given by the validator until the instrument is declared valid.

The results of the design of the assessment instrument on acid-base material are an instrument for assessing the ability of science literacy and critical thinking of students based on multiple intelligences consisting of 16 essay test questions and the material used is acid-base.

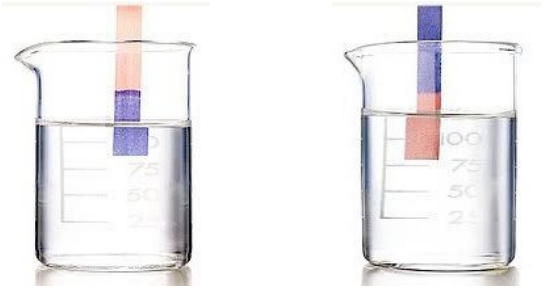
From validation qualitative and quantitative data are obtained. Qualitative data in the form of comments and suggestions from the research results of three validators based on material aspects, constructivist aspects and linguistic aspects. Table 5 shows validator criticisms and suggestions on content validation.

Table 5. Validator Criticisms and Suggestions on Content Validation

	Validation Result 1	Validation Result 2
Validator 1	The questions made do not yet fully refer to critical thinking indicators, especially to questions involving the calculation of chemical formulas.	The revised assessment question instrument can then be used for the next stage.
Validator 2	The question sentence on the question that was made unclear and caused a double meaning. The chemical material or science literacy stimulus shown in the question should have a clear reference source so that the data displayed is valid data.	The revised assessment question instrument can then be used for the next stage.
Validator 3	The problem developed is still too long-winded, the stimulus should not be too long and directly to the point of the problem so that the stimulus does not become useless. The scoring guidelines are not yet clear so they cannot be properly used as guidelines in correcting existing answers.	The revised assessment question instrument can then be used for the next stage.

Table 5 shows criticisms and suggestions from validators. An example of a revision of a science literacy assessment instrument and critical thinking based on multiple intelligences on acid-base materials can be seen in Table 6.

Table 6. Example of Revision of Assessment Instruments

Before Revision	After Revision
In the human oral cavity, there is a liquid called saliva. Saliva is a complex liquid that functions in regulating the degree of acidity (pH) in the oral cavity. The degree of acidity (pH) of saliva under normal circumstances is between 5.6 – 7.0. This degree of acidity can change due to the influence of food or drink that enters the oral cavity. Sweet foods that contain carbohydrates are the main cause of the development of bacteria in the mouth and also cause a decrease in the pH of the oral cavity. The activity of brushing your teeth using toothpaste is an act of preventing the proliferation of bacteria by neutralizing the degree of acidity in the salivary fluid in the oral cavity. Based on this explanation, identify the compounds which are acids and bases in the oral cavity after brushing your teeth, and strengthen the identification results with the properties described!	Saliva is a complex fluid that functions to regulate the degree of acidity (pH) in the oral cavity. The pH value of saliva under normal circumstances is between 5.6 to < 7. Dietary conditions (not eating) cause the mouth to taste sour and the pH value gets lower. The decrease in pH value is overcome by brushing teeth using toothpaste which generally contains fluoride and detergent. This activity can neutralize the sour taste and prevent the development of bacteria that cause sour taste in the oral cavity. A simple laboratory test obtained the following results.  (i) Toothpaste (ii) Saliva From this data, determine: a) Substances that are acidic and substances that are basic b) List the properties of each substance

Design development, one of which is qualitative and quantitative studies. Qualitative research includes aspects of the material that are the subject matter of the test kit, the construction of the question items, and the language of writing the question items. In general, it is shown that each question item has been good on acid-base material, the scope of the question indicators with acid-base learning indicators, the suitability between the creative thinking ability assessment instrument and the hydrocarbon material. In terms of construction aspects, it is shown that each question item has been good in construction, including the readability of the assessment instrument for science literacy and critical thinking skills, the suitability of the assessment instrument for science literacy and critical thinking skills with the answers of the instrument, the completeness of the assessment instrument (question grid, question matrix, question items, answers and scoring guidelines) and the relevance of the question scope to the development of secondary school students.

On the language aspects, each item of the question is well represented in the linguistic aspect, including the presentation of cases and articles in the assessment tool, the presentation of language and writing in the assessment tool. price. Quantitative study has 5 assessment criteria, namely very high, high, sufficient, low and very low. The resulting assessment instruments are validated with intensive consultation and revision. Quantitative data is obtained from the calculation of the average value of the validation assessment sheet which includes 3 aspects of criteria, namely: 1) material / content aspects, 2) construction aspects, 3) language aspects and 4) creative thinking ability aspects. The material/content aspect contains 4 assessment items, the language aspect contains 2 assessment items, the construction aspect 5 points of assessment and the creative thinking ability aspect side by side 10 points of assessment. Assessments by subject matter experts emphasize skill match, learning goals, question fit with learning goals. The results of the validation of the instrument for assessing the ability to think creatively on hydrocarbon materials with material aspects are shown in Table 7.

Table 7. Material / Content Validation Results

Question Number	Initial Validation Percentage	Final Validation Percentage	Description
1	71.50%	90.33%	Valid
2	70.90%	93.00%	Valid
3	74.50%	92.00%	Valid
4	75.10%	92.00%	Valid
5	75.70%	92.60%	Valid
6	73.30%	94.70%	Valid
7	74.00%	92.70%	Valid
8	73.90%	92.00%	Valid
9	74.20%	91.00%	Valid
10	74.20%	94.00%	Valid
11	74.80%	93.30%	Valid
12	75.10%	91.00%	Valid
13	74.00%	92.30%	Valid
14	74.50%	91.70%	Valid
15	75.70%	92.00%	Valid
16	75.50%	91.00%	Valid

Table 8. Material / Content Validation Results

Validator	Science Literacy	Critical Thinking	*Multiple Intelligence*
Validator 1	87.50%	87.50%	75.00%
Validator 2	81.25%	87.50%	87.50%
Validator 3	93.75%	81.25%	75.00%
Average	87.50%	85.40%	79.17%

Thus, all question items are valid, there are 16 question items so the questions can be tested on a limited scale. In theory, validity states that the validity of a development product refers to whether the design is knowledge-based and whether the different components of the product are systematically related to each other, system or not (Rochmad, 2012).

The results of the validation analysis on aspects of language, material and constructs show that the questions are declared valid (Fuadi et al. 2022). Furthermore, the validation results of aspects of science literacy,

critical thinking, and multiple intelligence abilities that have been analyzed from the validator assessment score are shown in the Table 8.

The results of the analysis of aspects of science literacy, critical thinking, and multiple intelligence skills showed that the instrument had an average validation of 87.5%, 85.4%, and 79.17%, respectively. This research can be continued in the initial trial to obtain the validation value of the construct, reliability, difficulty level and differentiability of the instrument for assessing the ability of science literacy and critical thinking of students.

Conclusion

This study created a tool to assess students' critical thinking ability and scientific knowledge based on multiple intelligences on acid-base materials. With the development model of Borg and Gall, but using only three phases, which are research and information gathering, planning and preliminary product development form. Based on the results of expert validation from three validators, the instrument for assessing the scientific literacy and critical thinking abilities of students based on multiple intelligences on acid-base material developed is declared materially, constructively, linguistically and creatively valid so that it can be used as a tool to measure the level of critical thinking ability of students, especially on acid-base material.

Conflict of Interests

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

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