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Development of a Chemical Literacy Assessment on Colloid (CLAC) instrument to measure Chemical Literacy

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ABSTRACT
The 21st century requires four specific skills namely literacy, inventive thinking, effective communication, and high productivity. Literacy includes basic literacy, scientific literacy, economic literacy, technological literacy, visual literacy, information literacy, and multicultural literacy. The purpose of this research is to produce a chemical literacy assessment instrument on colloidal system material that is suitable for use as a chemistry measurement tool for high school students who meet the requirements of feasibility validity, reliability, and level of difficulty. This research is a form of development research or R&D (*Research and Development*). The development model used in this research is the Oriondo and Dallo Antonio instrument development model, which has five stages: 1) planning the test, 2) *trying out the test*, 3) establishing empirical validity (*establishing test validity*), 4) determining reliability (*establishing test reliability*), 5) interpretation of scores (*interpreting the test scores*). The data collection instruments used in this study were questionnaire validation sheets, question validation sheets, and development results questions. The reliability value of the *person* from the score obtained in the trial was 0.55 indicating that the reliability of the *person* or students was in the medium category. Reliability value *item* was 0.48 in the medium category. Overall, the average reliability value or *Cronbach Alpha* is 0.69 in the sufficient category. So it can be concluded that the score obtained from the assessment instrument is reliable because it has fulfilled a minimum coefficient value of 0.60.

Keywords: *Chemical literacy, Assessment, Colloid.*

1. INTRODUCTION

The development of science and technology in information and technology makes education an increasingly serious challenge. One of them, education must be able to produce talented human resources who are fully capable of facing life's challenges [1]–[4]. For this reason, society needs an understanding of science and technology to keep up with the times [5]. The 21st century requires four specific skills namely literacy, inventive thinking, effective communication, and high productivity. Literacy includes basic literacy, scientific literacy, economic literacy, technological literacy, visual literacy, information literacy, and multicultural literacy. Someone who has a high level of scientific literacy can understand the history and nature of science, the relationship between science and other disciplines, and the relationship between science and technology and society [6], [7].

Since the last two decades, scientific literacy has become the main topic in every conversation regarding the goals of science education in schools. Literature in the field of science education also shows that scientific literacy is increasingly being accepted and valued by educators as an expected learning outcome [8], [9]. Scientific literacy is also the gateway to scientific and technological progress as well as economic life, which can be achieved through the teaching of science. Currently, scientific literacy is an important issue that influences human decisions. This is proven at the international level in various science education perspectives [10]. To overcome this, it is necessary to prepare the next generation who can deal with change with the skills to solve real-world problems. Then the need for scientific literacy [11].

Scientific literacy is measured through a PISA study conducted by the OECD (Organization for Economic Cooperation and Development) every three years. The results of the PISA study for the average ability of scientific literacy of Indonesian students from 2000, 2003, 2006, 2009, 2012, 2015, and 2018 were 393, 395, 393, 385, 375, 403, and 396 respectively [12]. The results of students' scientific literacy are still in the low category because the scores obtained are below the average PISA mastery score. This indicates that students in Indonesia have not been able to understand scientific concepts and processes and have not been able to apply the scientific knowledge it has learned in everyday life [13].

Scientific literacy is necessary for students to understand the many problems faced by modern society, such as the environment, health, and the economy [2], [14]–[17]. Besides that scientific literacy is also the ability to engage with scientific topics and scientific ideas, and the ability to think reflexively [18], [19]. Science is a collection of knowledge resulting from research that is comprehensively designed into knowledge that is grouped based on scientific disciplines such as physics, biology, and chemistry [20]. To understand the various components of scientific literacy, it is necessary to study the unique components of literacy in various science subjects, one of which is chemistry which is commonly known as chemical literacy.

Chemical literacy is a student's ability to identify, analyze, and process chemical concepts to solve everyday problems and scientifically communicate chemical phenomena that occur around them. [21]–[23]. So someone who has chemical literacy must understand the basic concepts of science/chemistry [24], [25]. Someone who has good chemical literacy skills can apply aspects of chemical literacy skills, namely the ability to explain events in everyday life in chemical concepts; the ability to solve problems in everyday life by using an understanding of chemistry, as well as the ability to understand and apply chemical applications in everyday life [24], [26]. This condition encourages the need to make efforts to improve the learning of science (chemistry) in schools gradually and continuously. Efforts to improve the quality of learning in schools need to be supported by information about the extent to which students' chemical literacy achievements are viewed from its aspects and must also be adjusted to the goals of Indonesia's national education itself [27].

Assessment literacy emerged as an early contribution to the general education literature [28], [29]. Regarding the development of students' scientific literacy, the development of scientific literacy assessment tools is very important to familiarize students with issues in the field of scientific literacy [30]–[32]. Assessment activities carried out by teachers are generally designed to measure cognitive aspects only. Cognitive assessments carried out in routine assessment activities often only measure low cognitive levels. As a result, students have little opportunity to think analytically and optimally. Teacher assessment provides a great opportunity to encourage chemical literacy skills in students [33]. The instrument used is still in the form of routine questions so it does not yet support the development of student literacy. Implications are needed in the form of appropriate assessment questions to measure chemical literacy [34].

2. METHOD

Development of chemical literacy instruments using the Research and Development (R&D) model. The development of this product adapts the steps for developing an instrument [35] which includes 5 stages, namely 1) planning for making an assessment instrument, 2) testing the instrument, 3) determining validity, 4) determining reliability, and 5) interpreting scores. The chemical literacy research instruments that have been compiled and used are validated using content validation based on the review of five expert judgments. The validity index used to prove content validity uses Aiken's index [36]. After content validation, empirical validity was carried out to analyze the quality of the CLAC instrument. Analysis of the empirical validity scores obtained from trials using the Rasch model analysis with the help of the Ministep program.

3. RESULT AND DISCUSSION

3.1. Development of the CLAC Instrument

Development of the CLAC instrument which is used to measure students' chemical literacy skills in colloidal material, includes five stages, namely 1) planning for making an assessment instrument, 2) testing the instrument, 3) determining validity, 4) determining reliability, and 5) interpreting scores. The planning stage for making the assessment instrument consists of determining the objective/preliminary study as a guide in making the instrument grid, determining the form of the items, writing the items along with writing the answer key with scoring guidelines, then validating and improving the product. The planning stage conducts a literature study and analyzes aspects of chemical literacy according to the OECD and Shwartz, which refers to 3 aspects of content, procedural knowledge, and epistemic knowledge [37]. The quality and validity of the instruments developed can be assessed by analyzing the test results. Testing activities are carried out using validated research tools. The empirical test of the instrument involved 75 students with details of 40 Lhokseumawe MAN students and 35 East Aceh Insan Cendikia MAN students. The trial was conducted to empirically test the items to obtain evidence of the quality and characteristics of the items on the chemical literacy assessment instrument on colloidal system material. The chemical literacy assessment instrument product consists of 25-item descriptions and multiple choices. Students who have finished studying colloidal system chemistry are tested for their chemical literacy

skills by working on chemical literacy assessment instruments on colloidal system material. Time to work on the questions required 90 minutes.

3.2. Determination of Validity, Reliability, and Quality Analysis of CLACInstruments

3.2.1. Content Validity

The development of the CLAC instrument was carried out using content and empirical validation. Content validity was carried out to obtain an assessment from the expert, while empirical validity was carried out to obtain an assessment regarding the quality, characteristics of the items, and conclusions regarding the feasibility of the developed assessment instrument. The final product obtained is used to measure students' chemical literacy skills on colloidal system material which consists of 25 questions from 10 texts. Analysis of content validity scores uses the Aiken formula adjusted to the Aiken index. Based on the analysis using the Aiken index, the items are valid and appropriate to use if the value of V = 0.80 for five raters [36]. The results of the validation score analysis with the Aiken formula for the chemical literacy assessment instrument on colloidal system material can be seen in Figure 1.

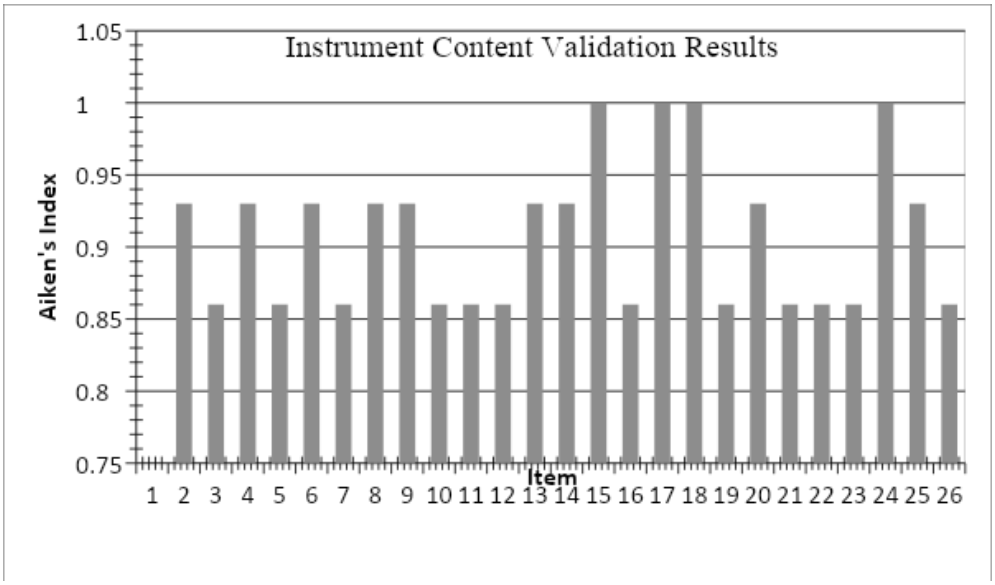

Figure 1 Diagram of Analysis Results Score Content Validity of Instrument

Items validation results are divided into three types or categories, namely without revision, revision, and cannot be used. In detail, the categories for all item items are presented in Table 1.

Table 1. Category Item Number Content Validity of Instrument

Analysis of empirical validity scores obtained from trials of 150 students using the Rasch model analysis with the help of the Ministep program.

3.2.2. Quality Analysis of Chemical Literacy Assessment Instruments

Analysis of the quality of the Chemical Literacy Assessment Instrument using a unidimensional assumption test in the trial. The trial results were then analyzed using the grain response theory or Modern Item Response Theory (IRT), the Rasch model with the help of the Ministep program 3.73. According to [38] explained that IRT uses the unidimensional concept of items used to measure something latent or in this study is the ability of students' chemical literacy.

The instrument unidimensionality test in the trial was obtained at 36.9%. Instrument trials have fulfilled the unidimensionality requirements with a minimum prerequisite requirement of unidimensionality of 20% [39],

[40]. The objective of instrument analysis is to obtain the characteristics of each item so that the instruments used are of good quality. The quality of the instrument can be seen from the analysis of 1) unidimensional trials, 2) the suitability of the items to the Rasch model as a normal function of the items seen from the output tables 10 item column: fit order, 3) Reliability and separation or groups of items and students, and 4) bias analysis of the items.

The level of suitability of the items to the Rasch model uses item fit. Analysis of measurement accuracy can be done by looking at the values of the outfit mean square, outfit z-standard, and PT measure correlation. Items that meet the accuracy of measurement can be accepted or used as an instrument to make the desired measurement, namely measuring students' chemical literacy abilities. If the item is not fit (misfit), then the item may indicate a misunderstanding by the respondent. Criteria for the value of outfit mean square, outfit z-standard, and PT measure correlation can be determined from 1) the value of the outfit mean square (MNSQ) is acceptable if it is between 0.5 to 1.5; 2) the z-standard outfit value (ZSTD) is accepted if it is between 2.0 to +2.0; and 3) the value of Point measure Correlation (Pt Mean Corr) is between 0.4 to 0.85 [38], [40], [41]. If the item does not meet at least two of these criteria, then the item is said to be unfit (misfit) so it is eliminated or needs to be replaced. The results of the item fit analysis of the test items are presented in Figure 2.

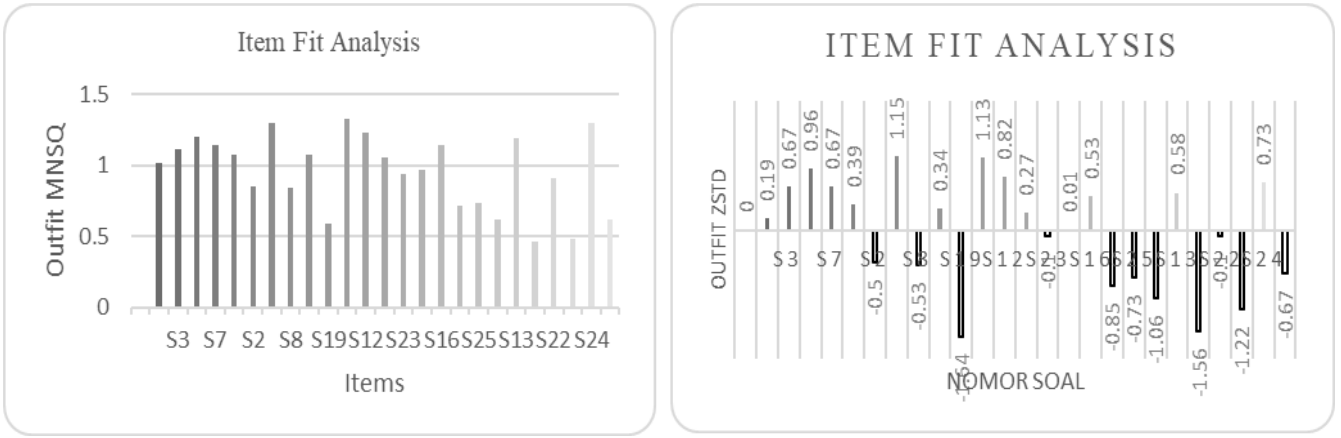

Figure 2 Diagram of item fit analysis

Based on the figure, 25 items meet the MNSQ score criteria between 0.5 and 1.5; ZSTD values are between -2.0 to +2.0; and/or the Pt Mean Corr value is between 0.4 to 0.85 (Bond & Fox, 2015; Sumintono & Widhiarso, 2014; Park & Liu, 2019). In general, of the instruments tested in the tryout, 25 items met the criteria for the MNSQ, ZSTD, and/or Pt Mean Corr scores. The requirements for suitability of the items with the Rasch model also show that the items used can measure students' chemical literacy abilities well. A total of 25 questions were then used as the final product of developing an assessment instrument.

3.2.3. Reliability Test in Summary Statistics

The reliability value of the person (students) from the score obtained in the trial was 0.55. The value of 0.55 indicates that the reliability of the person or student is in the medium category. The item reliability value was 0.48 in the medium category. Overall the average value of reliability or Cronbach Alpha of 0.69 is in the sufficient category [42], [43]. The reliability value indicates the constancy, reliability, or consistency of the test and the appropriateness of the test when tested on students. So it can be concluded that the score obtained from the assessment instrument is reliable because they have fulfilled a minimum coefficient value of 0.6 [44] [44]. Reliability values and constancy categories are presented in Table 2.

Table 2. Reliability Values in the Reliability Test

3.2.4. Bias on Items (Differential Item Function/DIF)

DIF is one of the results of the analysis to find out whether the items or items have a bias or tendency towards certain categories of respondents or not, for example, a tendency towards men or women [40]. How to find out can be seen from the probability value of the items. Items are biased if the probability value is less than 5% or 0.05 [45].

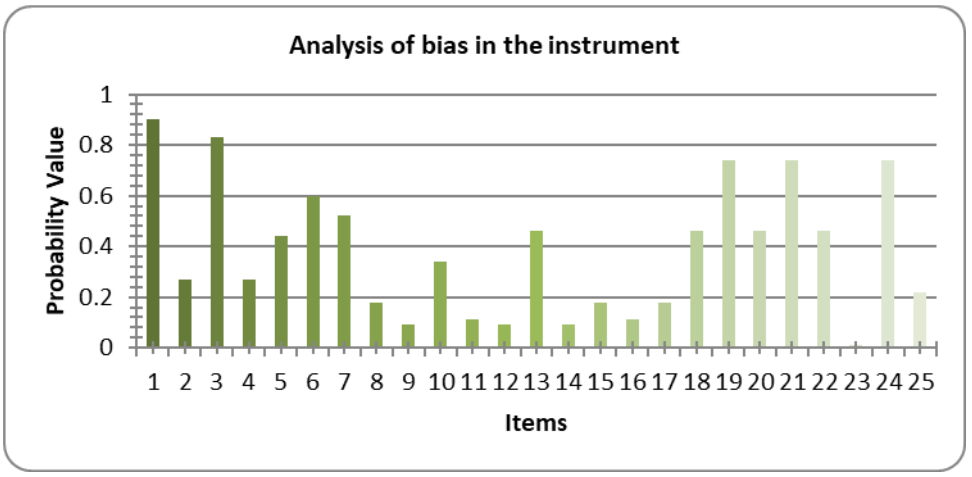

Figure 3 Diagram of the results of the analysis of bias in the instrument towards

3.2.5. Difficulty Level of Item

Each item has a level of difficulty based on the response of students' abilities as indicated by the *logit* in the Rasch model. The difficulty level of the item items is generated in the *output tables 13 items: measure*. The error rate can also be seen at once. scale *logit* divides the level or difficulty group of the items and the respondents (students). Information about the level of difficulty of the *item* and the ability or ability of students to answer better if the *logit* is getting bigger. *a* good item is an *item* with a smaller error rate. As well as good items are items that can be used to measure as well as differentiate the abilities of each student. Whether the item is good or not can be seen from the value of the *standard error* (*SE*). Items are said to be good or ideal if *SE* <0.5-1.00.

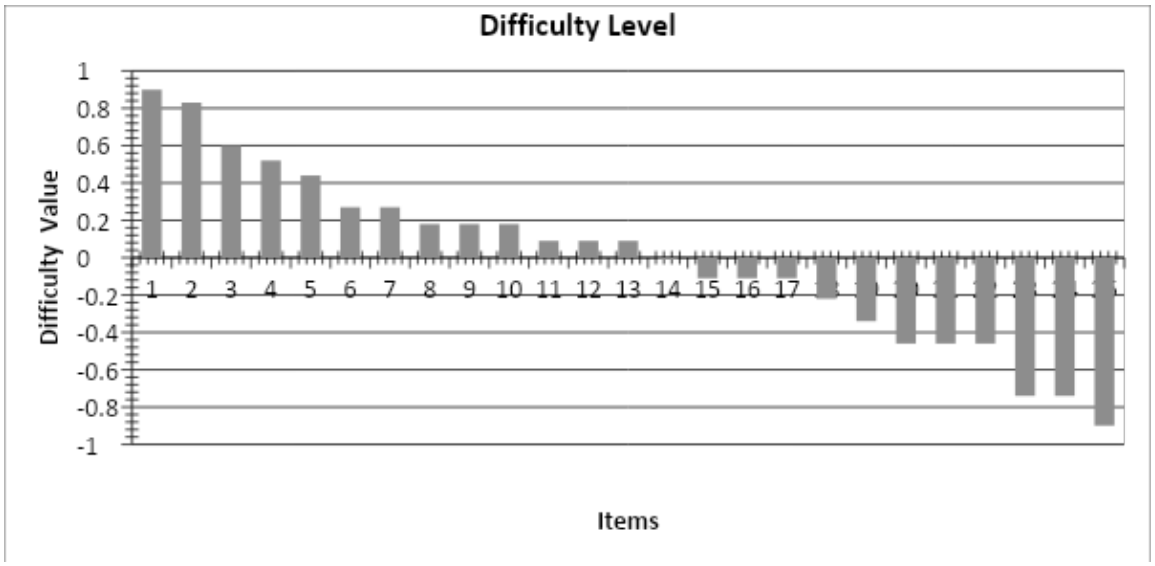

Figure 4 Diagram of Difficulty Level of Items

The acceptance criteria for the item difficulty index based on the Rasch model's item response theory are -2 to +2 [46], [47]. So it can be concluded that as a whole the items meet the index of difficulty level according to the Rasch model theory item responses. All items have good discrimination because they have a value of SE<0.5-1.00 so it can be concluded that the questions have good accuracy in measuring students' chemical literacy abilities. The categories for each item are also presented in Table 3.

Table 3. Categories of Tryout

Based on the responses from students, the items which are considered difficult are the items that explain the understanding of the colloidal system based on available readings, solving problems, interpreting scientific data, and evaluating scientific investigations. Items that are considered easy relate to students' opinions to explain phenomena about the colloid system with phenomena that are often encountered.

4. CONCLUSION

Based on the analysis of the developed CLAC instrument, there are 25 statement items consisting of 3 aspects covering aspects of content, procedural knowledge, and knowledge that are of good quality in terms of content validity and empirical validity. The results of content validity conducted by 5 expert judgments showed that the CLAC instrument that had been developed received an Aiken V index of 0.91, this indicated that the CLAC instrument was proven to be valid in content, in terms of empirical validity, including a unidimensional test that met the minimum requirements of 10%, suitability of the items against the Rasch model, good reliability scores, and unbiased items. The assessment instrument developed has the characteristics of the items that can distinguish the ability of students with difficulty levels that meet the *ZSTD output* between -2 to +2 on the map Wright or *person-item map*.

AUTHORS' CONTRIBUTIONS

1. Isna Rezkia Lukman as reseacrh data analyst
2. Mellyzar as Lead researcher and compiler of chemical literacy instrument
3. Sirry Alvina as compiler of chemical literacy instrument
4. Nailis Saa'dah as research assistent

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