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# Development of Performance Assessment Instruments to Measure Students' Scientific Thinking Skill in the Quantitative Analysis of Acetic Acid Levels

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**A B S T R A C T**

This study aims to develop good quality performance assessment instrument that can be used to measure students' scientific thinking skills. The research method used is Development & validation The study describes the 5 stages of instrument development, namely the analysis of performance assessment journals, analysis of Core Competency and Basic Competency on 2013 curriculum, field surveys, development of indicators and student worksheets, as well as target skills and rubric development. The developed instrument consists of 33 target skills (experimental problem solving) and 9 target skills (quantitative literacy). The expected value in this research is the accuracy of students in performing practical work. In the validity test, it is obtained a CVR value of 1.00 on 42 developed target skills, so that the instrument was declared as valid. Based on the analysis of research data, it can be concluded that the developed performance assessment instruments have good quality to measure students' scientific thinking skills.

## 1. Introduction

In the 21st century, human resources are required to have a variety of high-level thinking skills and abilities as an effort to deal with the demands of global development. The effort is a way to improve the quality of Indonesian education. The high-level thinking ability of students does not grow by itself, but through a process of practice and experience. Therefore, this ability must always be improved since the learning process occur in schools (Fitriyati and Munzil, 2016; Khun, 2004). One of the stages to achieve high-level thinking skills is through the stage of Scientific thinking skills (Jo and Bednarz, 2015). Scientific thinking skills

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will provide experiences for students to think logically and systematically. Scientific thinking skills is started from students' accuracy on observing phenomena, formulating hypotheses, designing experiments, predicting data, analyzing data, and drawing conclusions (Timostusk, 2015). This is in accordance with the value of the 2013 curriculum which emphasizes a scientific approach in the learning process including the process of observing, asking, experimenting, analyzing and concluding experimental data.

Scientific thinking skills begin with open-ended problems in contextual situation that leads to well-structured procedures (Dewi and Riandi, 2015). Students' scientific thinking skills can be seen from the experimental problem solving (EPS) and quantitative literacy (QL) of the students. Experimental Problem solving (EPS) includes defining problems, developing hypotheses, arranging experimental designs, and conducting trial test (Harsh, 2016). Quantitative literacy is the ability to understand numbers, criticize, and use them to solve problems in real situations in everyday life (Speth,et al. 2010). Quantitative literacy indicators can be determined through the ability of calculating, representing and interpreting the experimental data (Harsh, 2016; Nuraeni, et al. 2017). Therefore, scientific thinking skills must be instilled during the learning process to help students to think at a high level.

To determine the achievement of students' scientific thinking skills during the learning process, an assessment must be made. An assessment that can be used to measure scientific thinking skills is called as performance assessment. With the performance assessment, students can apply their skills to complete assignments and problems in real life (Harsh, 2016). Prades and Espinar (2010) add that the assessment is more empirical because it is based on students' skills. According to Ningtyas and Agustini (2014), Performance assessment is an assessment that asks students to demonstrate and apply knowledge into contexts that are in accordance with the determined criteria. Furthermore, Zainul (2001) explained that performance assessment requires students to work, do something and show their abilities, so that they do not only answer the questions nor choose the available answers. Therefore, it is very important to use student performance assessment to measure their competency skills.

According to Firman (2018), the main components in performance assessment are task and rubric. Task is a thing that students must do when doing practical work. Meanwhile, rubric is a guide for the teacher or observer to assess students' skills which contain aspects of performance to be assessed. According to Susilaningsih (2014), rubric has an important role in reducing subjectivity in assessing students. Based on the results of a survey conducted by Chen, et al. (2014), it is explained that not all lab assistants or teachers have attended training to assess the performance of students who are doing the practicum. A scoring rubric is needed to make it easier for teachers and laboratory assistants to measure students' scientific thinking skills.

Performance assessment instruments have been used in some schools, but there has not been any teacher that used performance assessment instruments to measure scientific thinking skills. Even though in fact, the teacher uses a scientific approach in learning activity. That is because there are no examples of performance assessment instrument rubrics that have good quality to measure students' scientific thinking skills. This can be seen from a survey of 10 high school chemistry teachers. The result is that all teachers say that acid-base titration is a practicum that is always conducted by the students of grade XI of the schools. However, 80% of teachers do not know about the performance assessment instruments and how to use it to measure students' scientific thinking skills. Instead, they use assessment system through check-list format and rating scale to assess students' performance. Students' performance is assessed through the visible skills during practicum or just by assessing the report. Therefore, it is very important to do a performance assessment to measure students' scientific thinking skills on acid-base titration. The developed instrument is only limited to the acid-base titration material and the assessment of aspects of experimental problem solving and quantitative literacy. Based on the explanation above, a performance assessment instrument was developed to measure scientific thinking skills in quantitative analysis of acetic acid levels. The purpose of this study is to develop good quality performance assessment instruments that can be used to measure students' scientific thinking skill.

## 2. Methodology

This study uses the Development & Validation research method developed by Adams and Wieman (2010) with some modifications. This development research was chosen because it is more systematic in the process of developing the instrument. Data collection techniques in this study are online questionnaire and validation sheet. The questionnaire was answered by 10 high school chemistry teachers. The questionnaire is distributed through Google Form application. The validation test used is content validity. A total of 6 expert judgments were asked to see the suitability of performance aspects with the rubric. Data analysis techniques on the questionnaire results were used in percentages to describe the application of performance assessment instruments in schools. Data analysis on the validity test used the CVR calculation. The calculated CVR results are then compared to critical values for CVR in table 1 (Wilson, et.al 2012).

Table 1. Critical values for CVR Table 1. The reuse main materials

| | **1** | **.05** | **.025** | **.01** | **.005** | **.001** |
|---|---|---|---|---|---|---|
| ***Two -tailed test*** | | | | | | |
| N | .2 | .1 | .05 | .02 | .01 | .002 |
| 5 | .573 | .736 | .877 | .99 | .99 | .99 |
| 6 | .523 | .672 | .800 | .950 | .974 | .99 |
| 7 | .485 | .622 | .741 | .879 | .911 | .99 |

The stages of research developed as figure 1.

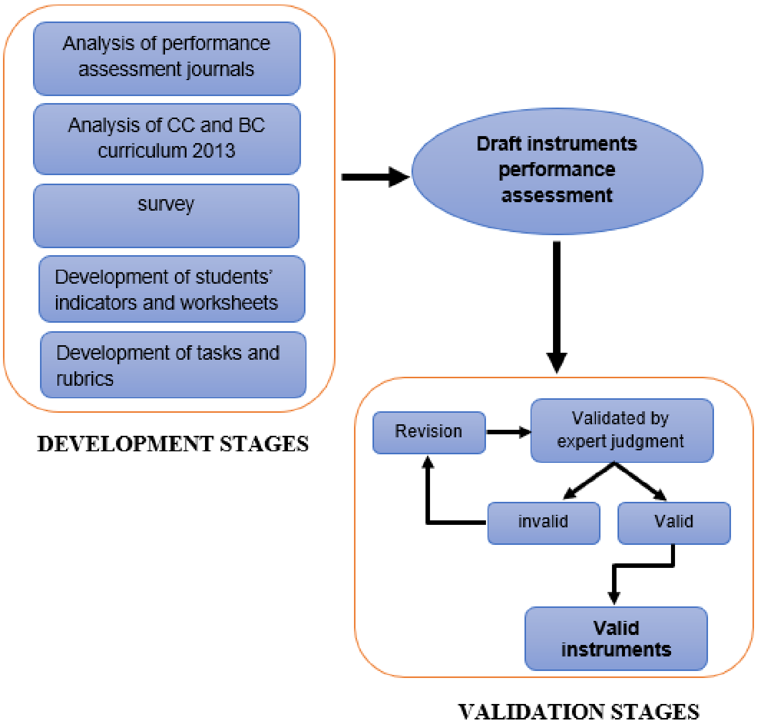



Figure.1 The stages of research

Based on figure 1, obtained 2 stages of research including development stages and validation stages. The development stage include analysis of performance assessment journals, analysis of CC and BC curriculum 2013, survey, development of student indicators and worksheets, And Development target skill rubrics. The validation stage include validated by expert judgment.

## 3. Results and Discussion

The research will explain the development process and instrument quality from performance assessment to measure students' scientific thinking skills. The development process includes analysis of performance assessment instrument journals, analysis of Core Competency (CC) and Basic Competency (BC) on 2013 curriculum, field surveys, development of student skills indicators and worksheets, as well as target skills and rubric development.

The first stage in the development process is the analysis of a performance assessment journal. The purpose of this analysis is to compare usual performance assessment instruments with performance assessment to measure students' scientific thinking skills. Based on the research conducted by Nahadi, et al. (2016; 2017), the development of performance assessment instruments includes the development of indicator of skills, target skills and rubric. This is in line with research developed by Harsh (2016) regarding performance assessment instruments to measure students' scientific thinking skills which developed based on indicators of skills, target skills and rubrics. Therefore, there are similarities in the instrument development process. The difference in the instrument at the context of the measured performance assessment. The differences between the two instruments can be seen in the Table 2.

Table 2. Comparison of usual performance assessment with performance assessment to measure scientific thinking skill

| **Usual Performance Assessment (Nahadi, et al. 2016, 2017; Karviyani. et al. 2015)** | **Performance Assessment to Measure Scientific Thinking Skills (Harsh, 2016)** |
|---|---|
| 1. Only experimental problem solving | 1. Experimental problem solving and quantitative literacy |
| 2. Focusing on assessing aspects of skills only | 2. Focusing on aspects of skills and problem solving with analytical methods |
| 3. Not assessing research design to be conducted by students | 3. Assessing research design to be conducted by students |
| 4. Not assessing the research problems and research hypotheses that will be made by students based on a given phenomenon | 4. Assessing the research problems and research hypotheses that will be made by students based on a given phenomenon |
| 5. Not assessing relevant information collected by students before conducting an experiment | 5. Assessing relevant information collected by students before conducting an experiment |
| 6. Not assessing alternative explanations for the results obtained by students | 6. Assessing alternative explanations for the results obtained by students |
| 7. Not assessing the visualization of students' data from the data obtained | 7. Assessing the visualization of student data from the data obtained |
| 8. Not assessing the identification data obtained by students based on experimental data | 8. Assessing identification data obtained by students based on experimental data |

Based on table 2, it can be concluded that the performance assessment to measure students' scientific thinking skills is in accordance with the spirit of the 2013 curriculum which emphasizes a scientific approach. That is because in the performance assessment to measure scientific thinking skills, an assessment of the process of formulating problems, hypotheses, conducting experiments, data analysis and drawing conclusions is conducted. Therefore, the performance assessment instrument to measure scientific thinking skills is appropriately used by teachers to assess student performance when conducting practicum.

The second stage is analysis of Core Competency (CC) and Basic Competency (BC) on 2013 curriculum to determine which material used in performance assessment instruments to measure students' scientific thinking skills. According to Harsh (2016), performance assessment instruments to measure scientific thinking skills must function as a measurement of experimental problem solving and quantitative literacy. The material selected is acid-base titration on basic competencies 3.13 and 4.13. The content of basic competence of 3.13 is to analyze the results of various types of acid-base titration. The type of weak acid titration by a strong base is chosen, namely quantitative analysis of the determination of acetic acid levels. This material was chosen because of the discovery of falsification of acetic acid levels on vinegar label in a market. Thus, the phenomenon can train students to think logically and analytically in solving problems. In BC 3.13 there is the verb "analyze" which shows that the cognitive level at the C4 level requires students to think at a high level. This material is suitable to be developed because scientific thinking skill is one of the stages for high-level thinking (Jo and Bednarz, 2014). BC 4.13 shows that the acid base titration material has skills aspects that students must have. This material requires students to have some basic skills. The skills include: the skill of making solution, piping solution (moving solution), using a burette and observing and determining the end point of titration (Kurniawan, et al. 2016). The basic skills must be possessed by students in order to obtain precise conclusions from the results of the experiment. The aspects of skills in the acid-base titration experiment show that this material can be assessed for the performance. This is in accordance with Firman (2013), that performance assessment must include measurable knowledge and skills.

After analyzing the performance assessment journal with Core Competency (CC) and Basic Competency (BC) analysis, the next step is to conduct a field survey. The survey was conducted by distributing online questionnaires to 10 regular high school and vocational high school chemistry teachers. Based on the survey, all teachers stated that the acid-base titration material was a material that was carried out by practicum methods so that performance assessment could be carried out on the material. 80% chemistry teachers stated that they did not know about the performance assessment instrument to measure students' scientific thinking skills, even though the learning implementation was carried out with a scientific approach. Therefore, it is very important to develop a performance assessment instrument to measure students' scientific thinking skills that are valid so that the teacher could know the steps of developing a valid instrument that can be used in each school.

The fourth stage is making of the skills indicators and student worksheets. According to Harsh (2016), skill indicators must include experimental problem solving (EPS) and quantitative literacy (QL). There are 10 indicators of EPS and QL skills listed in table 2. Skills indicators 1-7 are EPS skills indicators, while 8-10 are QL. The skills indicators developed are based on basic competencies in the 2013 curriculum. These indicators are then developed into a performance aspect (Table 3)

Table 3. EPS and QL Skills Indicators

| No | Skills Indicators | Number of target skills |
|---|---|---|
| 1 | Designing a quantitative analysis experiment of acetic acid levels determination | 9 |
| 2 | Preparing a quantitative analysis experiment of levels of acetic acid determination | 4 |
| 3 | Making oxalic acid solution as primary standard solution | 6 |
| 4 | Preparing for the burette | 5 |
| 5 | Conducting the standardization titration of secondary standard solution | 3 |
| 6 | Conducting Titration of the acetic acid levels determination in sample | 5 |
| 7 | Maintaining cleanliness after conducting quantitative analysis experiments of acetic acid levels determination | 3 |

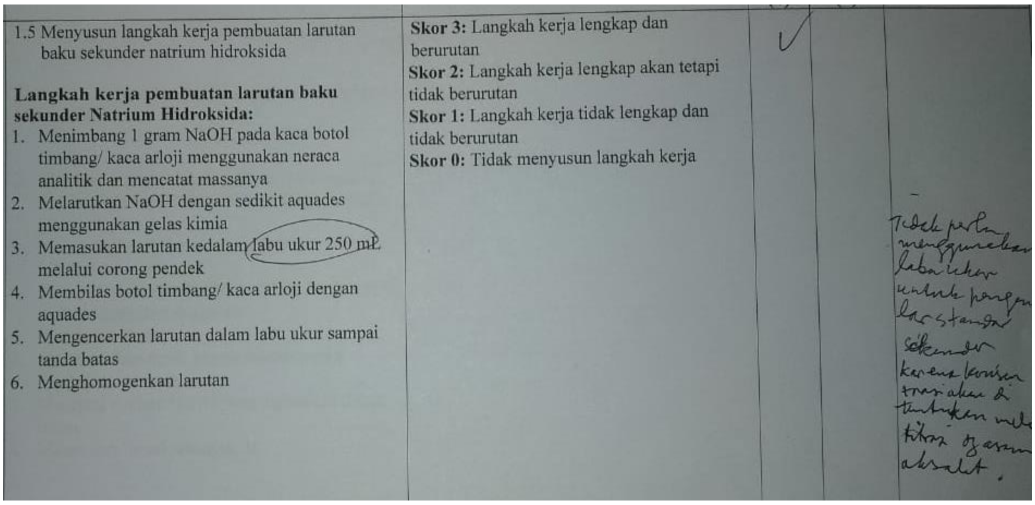
| No | Skills Indicators | Number of target skills |
|---|---|---|
| 8 | Visualizing data | 3 |
| 9 | Using statistical data | 4 |
| 10 | Interpreting data | 2 |

Student worksheets were developed to support the assessment of scientific thinking skills. The worksheet must guide students based on the scientific approach: solving problem formulations, making hypotheses, conducting experiments, analyzing data and concluding data. To support that, it must be supported by phenomena that can stimulate students to solve the problems. The phenomenon designed in this development is:

> "*Vinegar used as a flavor enhancer for food is a trade name of acetic acid. Generally, the acetic acid sold in the market is 25%. As with other merchandise, vinegar falsification is often found, especially in terms of levels. Therefore, the control analysis of the purity of acetic acid must be continuously monitored so that consumers are not harmed. Chemically, the easiest analysis of acetic acid is by acid-base titration. Perform acetic acid analysis on the vinegar found in market by conducting acid-base titration using standardized sodium hydroxide.*"

The fifth stage is the development of target skills and rubrics based on skills indicators. The total of 44 target skills were developed. Details of the target skills can be seen in Table 3. target skills developed according to the steps carried out by Cody (1966) that are summarized as follows: the determination of basic competencies and subject matter; determine the context; determine the clarity of the target skills; determine the subject to be assessed; and developing scoring guidelines; then do a target skills review. After developing the target skills, then the scoring rubric was developed. The type of rubric is rating scale. Firman (2018), states that the rating scale can reduce the potential for subjectivity in scoring. The developed rubric score range is 4,3,2,1. Score (4) shows superior, score (3) is good, score (2) is sufficient and score (1) is less. The results of the development in the fifth stage will produce a draft performance assessment instrument to measure students' scientific thinking skills.

At the validation stage, the instrument validity test is performed. The validity used is content validity. This validity will be performed to see the suitability of the target skills with the rubric. There were 6 expert judgments consisting of 2 chemistry education assessment lecturers and 4 analytical chemistry lecturers.



| | | | | |
|---|---|---|---|---|
| 1.5 Menyusun langkah kerja pembuatan larutan baku sekunder natrium hidroksida<br><br>**Langkah kerja pembuatan larutan baku sekunder Natrium Hidroksida:**<br>1. Menimbang 1 gram NaOH pada kaca botol timbang/ kaca arloji menggunakan neraca analitik dan mencatat massanya<br>2. Melarutkan NaOH dengan sedikit aquades menggunakan gelas kimia<br>3. Memasukan larutan kedalam labu ukur 250 mL melalui corong pendek<br>4. Membilas botol timbang/ kaca arloji dengan aquades<br>5. Mengencerkan larutan dalam labu ukur sampai tanda batas<br>6. Menghomogenkan larutan | **Skor 3:** Langkah kerja lengkap dan berurutan<br>**Skor 2:** Langkah kerja lengkap akan tetapi tidak berurutan<br>**Skor 1:** Langkah kerja tidak lengkap dan tidak berurutan<br>**Skor 0:** Tidak menyusun langkah kerja | ✓ | | Tidak perlu menggunakan labu ukur untuk pengenceran larutan standar sekunder karena konsentrasi akan di tentukan melalui titrasi dengan asam oksalat. |

Figure 2. Validation sheet

In Figure 2. Expert judgment evaluates the compatibility between target skills and rubric. Expert judgment can write comments in the suggestion column. These suggestions are summarized in the table 4.

Table 4. Expert Suggestions

| Target Skills | Suggestions |
|---|---|
| 1.1 Write a problem statement based on the phenomenon | Give a real example on each rubric score. |
| 1.5 Arrange the work steps of making a secondary standard solution with sodium hydroxide | Replace the measuring flask with a beaker when dissolving Sodium hydroxide |
| 3.4 Dry the inside neck of the burette with a tissue | Change tissue with suction paper |
| 4.1 Wash and check for burette leaks<br>4.2 Rinse the burette before use | These are put together due to the same skills |
| 4.4 Dry the inside neck of the burette<br>4.5 Mark the limit of the solution | These are put together due to the same skills |

The CVR value is calculated for each target skills. Calculation results show that all target skills have a CVR = 1. This shows that the instrument is declared as valid. After the validation, there are 42 valid target skills with several revisions on each target skills.

## 4. Conclusion

Based on the results of the data analysis and discussion, it can be concluded that the performance assessment instruments to measure students' scientific thinking skills have good quality. The quality can be seen from the validity of the contents of the instrument. All target skills have a CVR value of 1. This shows that the instrument is declared as valid.

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