Development of High Order Thinking Skills Based Assessment Test on Reaction Rate

Nevia Pradani, Suharti Suharti, Hayuni Retno Widarti
Universitas Negeri Malang

Email: nevia.pradani@gmail.com

Abstract: This development aims to produce a product in the form of a HOTS-based assessment test on reaction rate. The development was done according to the ADDIE development model. However, due to the limited situation implementation and evaluation stages were not yet completed. The developed instrument consists of 15 items in the form of multiple-choice with 5 possible choices. The content of the assessment instrument was validated by three experts and empirical validation was done by subjecting the test to 29 students of the 3rd semester majoring in Chemistry and 61 high school students majoring in science. Content validation showed the instrument was 93.33% valid which fell to very good criteria. Empirical validation showed that all 15 items were valid and reliable. Item validity had r_{count} value between 0.225 and 0.737 (r_{table}= 0.207) at 95% confidence level, while reliability test gave *Cronbach's Alpha* value equal to 0.805. In terms of item difficulty, 10 items were classified as moderate, 1 item was classified as easy, and 4 items were classified as difficult. As to the effectivity of distractor effect, 3 items out of 15 items contained ineffective distracting effect, which had been revised. Based on these results, it can be concluded that the assessment test was suitable for further stages, implementation and evaluation. However, the last two stages of ADDIE would be better to perform with the prerequisite condition when the students are learning in an environment that is constructed to developed HOTS.

Keywords: HOTS Instruments, High Order Thinking Skills, ADDIE, Reaction Rate.

Currently, the Indonesian high school learning process refers to the 2013 Indonesian curriculum. The affective and psychomotor aspects are more emphasized compared to the previous national curriculum (Ministry of Education, 2013). According to Rochman & Hartoyo (2018), the 2013 curriculum aims to improve high-order thinking skills of human resources, which are very important provisions for students to compete in the 21st century. The results of the 2015 Program for International Student Assessment (PISA) showed Indonesia's reading score was ranked 72 out of 77 countries, mathematics scores were ranked 72 out of 78 countries, and science scores were ranked 70 out of 78 countries (OECD, 2015). The results reflected low cognitive abilities (knowing, applying, and reasoning) for most Indonesian students which important aspects in high order thinking skills.

The Ministry of Education (2013) states that the 2013 curriculum in Indonesia could be implemented properly using the scientific approach. The scientific approach has five stages that can be applied in the learning process, namely observing, questioning, experimenting, associating, and communicating (Ministry of Education, 2013). The stages of the scientific approach implemented in learning require a change in the learning paradigm because students are trained to observe, actively ask questions, collect data, analyze, and communicate their learning outcomes. The scientific approach is a characteristic of the 2013 curriculum which aims to support students to be active, creative, and able to think critically in solving problems (Widyaningrum et al., 2021). The ability to think critically is a part of high-order thinking skills. Brookhart (2010) states that there are six aspects of high order thinking skills (HOTS) including transfer, critical thinking, creative thinking, judgment, logic and reasoning, and problem-solving.

HOTS is the thinking ability of students at higher levels (Ichsan et al., 2019). HOTS includes problem-solving, creative thinking, critical thinking, reasoning skills, and decision-making abilities (Dinni, 2018). According to Krathwohl (2002), in the revised Bloom's taxonomy, thinking ability is divided into two dimensions, lower order thinking skills (LOTS) and HOTS. LOTS include the ability to remember, understand, and apply, while HOTS include the ability to analyze, evaluate, and create. The process of analyzing, evaluating, and creating is part of the cognitive taxonomy created by Benjamin S. Bloom in 1956. In the end, it was refined by Krathwohl (2002) to become C1 (remembering), C2 (understanding), C3 (applying), C4 (analyzing), C5 (evaluating), and C6 (creating). Students must have good HOTS skills in terms of analyzing (C4), evaluating (C5), and creating (C6). C6 on HOTS is the highest ability which must be mastered by students in the 21st century (Chalkiadaki, 2018; Saputri et al., 2018; Talmi et al., 2018).

According to Krathwohl (2002), Bloom's taxonomy consists of two dimensions, the knowledge dimension and the cognitive process dimension. Two dimensions of HOTS and the operational verbs to describe the ability can be seen in Table 1.

Table 1. Table 1. C4-C6 Level Taxonomy of Dimensional Revision and Examples of Operational Verbs for HOTS

The Knowledge Dimension	The Cognitive Process Dimension		
	C4 Analyze	C5 Evaluate	C6 Create
Factual Knowledge	Making, structure, classifying	Comparing, correlating	Joining
Conceptual Knowledge	Explain, analyze	Examine, interpret	Planning
Procedural Knowledge	Distinguish	Conclude, resume	Arrange, formulate
Metacognitive Knowledge	Create, find	Make, assess	Realization

Source: (Krathwohl, 2002)

Based on the results of research conducted by Yuliati & Lestari (2018), it was stated that 80% of respondents did not know the concept of HOTS as a whole and 95% of respondents did not have references about HOTS. According to Harta et al. (2020), one of the schools in city X has provided several exam questions in HOTS form, but the results were still below the average. The results in good agreement with the research conducted by Ichsan et al. (2019), that the HOTS ability score of students in science learning was still low. The root of the problem might the fact that the learning process starting from the elementary school level to the university level has not implemented HOTS-based learning.

We have observed that most high schools in Malang have not applied HOTS-type questions for practice and exams. Until now, both in learning processes and exams still focused on the C1 to C3 categories, therefore students were not trained and skilled when faced to HOTS problems. Barnett & Francis (2012) stated that HOTS-questions might encourage students to think critically and deeply about the subject matter, where HOTS-based practice questions provide stimulation for students to develop HOTS. The HOTS-based practice question and assessment test could be applied in chemistry, such as in studying the reaction rate.

The rate of reaction is one of the subjects that is difficult for students to understand because the subject is abstract which can lead to misconceptions (Taştan Kırık & Boz, 2012). The involvement of several representations in the topic of reaction rate makes it difficult for students to understand the subject (Jusniar, 2020). In addition, the concept of reaction rate is closely related to everyday life. According to Sinaga (2006), almost half of students have difficulty understanding the concept of temperature and catalytic factors in reaction rate. Heong et al. (2012) states that students' HOTS abilities must be trained to be able to answer exam questions that require thinking skills. Therefore, understanding this concept requires HOTS and an assessment test is an important instrument to measure students' HOTS

Implementations of HOTS-based assessment tests at high school provide stimulation in learning to develop students' HOTS. The HOTS based instrument could train student's critical thinking skills and increase student creativity. In addition, it also trains students' flow of thinking in solving the problems. The lack of HOTS-based assessment instruments causes students to be less trained in dealing with problems that require HOTS. We report our HOTS-bases assessment test development, which was constructed based on the revised Bloom's taxonomy.

METHOD

Research Design

This developmental research was designed to produced HOTS based assessment test on reaction rate. This development referred to the ADDIE development model which consists of five stages including analysis, design, development, implementation, and evaluation. However, the implementation and evaluation stages were not yet carried out due to limited situation. Figure 1 showed the flow of the ADDIE development model.

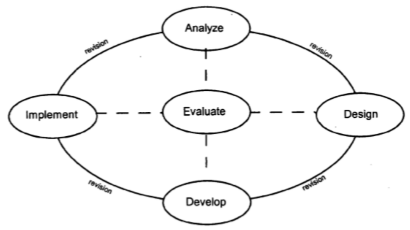

Figure 1.Figure 1. ADDIE Model Development Flow

Source: (Gustafson & Branch, 2022)

The data were collected using questionnaires and the developed HOTS-based assessment test on reaction rate. The questionnaire was used to determine the level of content validity of the HOTS-based assessment test that had been developed, while the developed HOTS-based assessment test was subjected to the XI grade of high school students and the 3rd semester of chemistry students at the State University of Malang to determine the empirical validity of the developed assessment test.

The number of subjects in this study was 90 students consisting of 29 students in the 3rd semester of Chemistry Department, State University of Malang, and 61 students of class XI MIPA at one of high school in Malang. Gender research subjects consisted of 24 male students and 56 female students aged 17-20 years. All students had been studied the reaction rate prior to the test.

Data Analysis Technique

The data analysis technique to analyze the validity of the content of HOTS-based assessment test percentage score (Equation 1).

$$P = \frac{\Sigma X}{\sum Xi} \times 100\% \qquad \text{[Equation 1]}$$

Information:

P : percentage score

Σx : total score of answers from the validator

$\sum Xi$: the maximum number of scores

The percentage scores were categorized according to Table 2. The items which were categorized as very good and good were directly chosen and used for empirical validity test. The final product was used as a HOTS-based assessment test.

Table 2. Table 2. Product Validity Criteria

Percentage (%)	Category
80 - 100	Very Good
66 - 79	Good
56 - 65	Quite Good
50 - 55	Less Good
30 - 39	Very Poor

Source: (Arikunto, 2013)

Empirical validity included item validity, reliability, difficulty level, and distractor effectiveness. The data were collected from student answers toward the HOTS-based assessment test. The data were analyzed using *Pearson Correlation Product Moment* was done at the 95% confidence level (α = 0.05) while items that were declared valid were tested using *Alpha Cronbach's*, both of which were done using *SPSS 25.0 for Windows.* The difficulty level of the items was analyzed using equation 2.

$$P = \frac{B}{Js} \qquad \text{[Equation 2]}$$

Information:

P : difficulty index

B : number of students who answered correctly number of students taking

Js : total the test

Furthermore, the results were qualified according to the item difficulty index criteria in Table 3.

Table 3. Table 3. Difficulty Index Criteria of Items

P Value	Criteria
0,00 – 0,30	Difficulty
0,31 – 0,70	Medium
0,71 – 1,00	Easy

Source: (Arikunto, 2013)

The distractor effect analysis was carried out following the difficulty level determination. The distractor effect aims to determine the distractor function of the answer choices. The distractor effect was analyzed using equation 3.

$$ED = \frac{\Sigma X}{n} \times 100\%\% \qquad \text{[Equation 3]}$$

Information:

ED : distractor effect

Σx : the number of students who chose the answer choice

n : total sample

RESULTS AND DISCUSSION

Results

The developed HOTS-based assessment test instrument on the reaction rate consists of four sub-concepts: reaction rate, reaction order, collision theory, and factors that affect the rate of reaction. The detail of item test indicators of the question in the assessment instrument is listed in Table 4.

Table 4. Table 4. Detailed concepts and Indicators For Each Item Test

No. Item	Targeted Concepts	Indicator
1	Concept of reaction rate	Analyse the rate of product formation and decomposition of the reactants
2	Concept of reaction rate	Determine the rate equation for the reaction
3	Concept of reaction rate	Evaluate the rate equation for the reaction
4	Concept of reaction rate	Formulate the equation for the rate of the reaction, the rate constant, and the rate of the reaction
5	Reaction order	Determine the value of the reaction order
6	Reaction order	Analyse the reaction order in graphical form
7	Collision theory	Determine the statement regarding the rate factor of the reaction rate and the collision theory
8	Collision theory	Categorizing impact is effective
9	Collision theory	Predicts the impact orientation effectively
10	Reaction rate factor	Summing up the effect of the rate factor
11	Reaction rate factor	Graphs the relationship between reaction rate and time
12	Reaction rate factor	Analysing the gas produced based on experimental data
13	Reaction rate factor	Analyse the reaction rate factor
14	Reaction rate factor	Assess conditions based on data from curves
15	Reaction rate factor	Make an experimental step

Content Validation Results

The developed assessment test was validated by three validators. Fourteen items fell into the very good category, and only one item fell in the good category (item number 2). The average percentage of score was 93.33%. Therefore, the developed HOTS-based assessment test instrument was categorized as a very good instrument for measuring HOTS-based assessment test of concept understanding on chemical reaction rate.

Validity of HOTS-Based Assessment Test Question Items

The assessment instrument was used to assess student HOTS-based concept knowledge. The scores were analyzed and they fell to valid criteria. The r-value from the statistical calculation (r_{count}) was compared to r_{table} value. All of the items had r_{count} greater than r_{table} (0.207). The results of empirical validity is listed in Table 5.

Table 5. Table 5. Empirical Validation Results

No. Item	r_{count}	r_{table}	Information
1	0.666	0.207	Valid
2	0.589	0.207	Valid
3	0.720	0.207	Valid
4	0.737	0.207	Valid
5	0.611	0.207	Valid
6	0.248	0.207	Valid
7	0.250	0.207	Valid
8	0.225	0.207	Valid
9	0.325	0.207	Valid
10	0.653	0.207	Valid
11	0.294	0.207	Valid
12	0.603	0.207	Valid
13	0.657	0.207	Valid
14	0.725	0.207	Valid
15	0.358	0.207	Valid

Reliability of HOTS-Based Assessment Tests

The validated assessment instrument test was then tested for reliability with the Cronbach's Alpha test using SPSS 25.0 for Windows. The calculation results show the Cronbach's Alpha value of 0.805.

Difficulty Level of Problem Items and Effectiveness of HOTS-Based Assessment Test Distractors

The level of difficulty of the items was determined based on the difficulty index formula and then categorized according to the predetermined item difficulty index criteria. All 15 items have been analyzed, 10 items are classified as moderate, 1 item is classified as easy, and 4 items are classified as difficult. The percentage of the results of empirical validation is shown in Figure 2 and the distractor effectiveness is shown in Table 6.

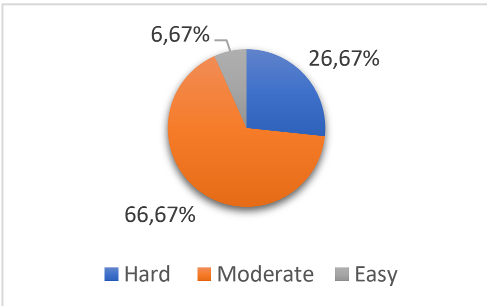

Figure 2.Figure 2. Percentage of Empirical Validation Results

Table 6. Table 6. Results of Distractor Effectiveness Analysis

No. Item	Index Distractor				
	A	B	C	D	E
1	0.06	0.1	0.26	0.26	0.3
2	0.04	0.07	0.22	0.30	0.35
3	0.12	0.06	0.27	0.21	0.32
4	0.10	0.14	0.22	0.44	0.08
5	0.13	0.08	0.23	0.50	0.04
6	0.06	0.74	0.05	0.05	0.07
7	0.15	0.14	0.50	0.10	0.07
8	0.07	0.06	0.06	0.72	0.06
9	0.62	0.11	0.05	0.12	0.08
10	0.15	0.11	0.08	0.57	0.06
11	0.21	0.05	0.31	0.36	0.05
12	0.02	0.66	0.15	0.10	0.04
13	0.06	0.24	0.06	0.54	0.07
14	0.10	0.14	0.35	0.12	0.27
15	0.23	0.11	0.13	0.27	0.24

Discussion

Stages of Making HOTS-Based Assessment Test

This research was carried out following the first three stages of ADDIE model development research procedure, and the following research results were obtained:

1. *Analysis*

The analysis stage was carried out as an observation stage to identify and obtain information before the research was carried out. Based on the observations, it was found that the teacher had never tried to apply HOTS-based assessment test for evaluation on chemical reaction rate and the given evaluation questions were limited to C1 to C3. Furthermore, the results of the evaluation questions consisted of C1 to C3 also did not reach the target, because students still had difficulty solving the given problems. The difficulties experienced by students are caused by the lack of practice on HOTS-based problems. Students had difficulty when they were given questions that were different from the questions during problem-solving practices. Student handbooks for learning provisions were only textbooks borrowed from schools and the practice questions in the textbook mostly were also the practice questions in the form of LOTS-based questions.

2. *Design*

The second stage was the design stage. At this stage, it included the activity of designing a question grid and compiling research instruments by assessing the basic competencies of the reaction rate. The grid that had been created was validated and consulted with the supervisor which will then was developed into a HOTS-based assessment test.

3. *Development*

This stage was carried out after the design stage was completed. Development was done based on the previously prepared grid. The development stage was the core stage for developing a HOTS-based assessment test. A total of 15 items were successfully developed according to indicators in Table 4.

The developed assessment test was validated by two lecturers of the Department of Chemistry, State University of Malang and one chemistry teacher at SMA Negeri 2 Malang. Some revisions were done following validator suggestions. Trial for empirical validation was subjected to third-semester of chemistry students at Chemistry Department Universitas Negeri Malang and high school students with science majors. The test results were analyzed for the validity of the items, reliability, difficulty level, and distractor effectiveness.

Validation of HOTS-Based Assessment Test

The validation results showed the lowest percentage of validity was question number 2 with a percentage of 66.70% categorized as good. Questions number 5, 6, 8, and 9 showed percentages of 83.30% with very good criteria. Items 1, 3, 4, 7, 10, 11, 12, 13, 14, and 15 showed a percentage of 100% with very good criteria. Suggestions and input from the validator were used to improve the items before small-scale trials are carried out to obtain a suitable instrument for use.

HOTS-Based Assessment Test Trial Phase

The results based on the results of data analysis are as follows.

1. The validity of The Question Items

Before item analysis, the score for each item was collected. Each answer was given a score of 1 and 0 for correct and incorrect answers, respectively. The scores were then tabulated for data entry. The data was analyzed using the aforementioned technique in the methodology section. All items were valid with r_{count} value between 0.225 and 0.737 (r_{table}= 0.207).

2. Reliability of HOTS-Based Assessment Test

Reliability is the consistency level of a test. According to Sugiyono (2005) reliability is a measurement using a measuring instrument that is carried out repeatedly and giving consistent results. An instrument is reliable if the instrument is used repeatedly and gives consistent results (Creswell, 2012). Reliability test using method *Cronbach's Alpha* is reliable when the score of *Cronbach's Alpha is* more than 0.60. Based on the calculation of the trial test it gave *Cronbach's Alpha* score of 0.805, which indicated that the HOTS-based assessment test was is reliable.

3. Difficulty Level of Problem Items and Distractor Effectiveness

The difficulty level of the items is a number that indicates whether the item is categorized as difficult or easy that is expressed as a difficulty index in Table 3 (Arikunto, 2013). Good quality of assessment test is characterized by three important criteria, validity, and reliability, and difficulty level. Applying the difficulty index formula (Equation 2) for all items yielding 10 items were classified, 1 item classified as easy, and 4 items were classified as difficult. Figure 3, showed 26.67% were classified as difficult, 66.67% were classified as moderate, and 6.67% were classified as easy.

The effectiveness of the distractor is how well the wrong choice can trick test-takers who do not know the correct answer. According to Sudjiono (2007), a distractor is good if at least 5% of the test participants chose the distractor. The more test takers choose the distractor, the better it functions as a distractor. Table 6 shows the distractor index in all items. The distractor indexes less than 0.05 (shadowed values) indicated that the distractors were ineffective. There were only 3 distractors that had an ineffective distracting effect, those were distractors in 2, 5, and 12 items. Ineffective distractors were repaired or replaced with new distractors.

In a learning activity, an assessment test is an important component (Lestari, 2019; Sukardiyono & Rosana, 2017). According to Widiyawati et al. (2019) the current assessment instruments in learning, both tests and non-tests, mostly measure the LOTS. The ability of teachers to develop HOTS-based assessment test instruments is needed to be able to measure student achievement in HOTS (Heru & Suparno, 2019; Retnawati et al., 2018). HOTS assessment test in chemistry learning is still limited. Netri & Holiwarni, (2018) had developed a HOTS-based assessment test on chemical equilibrium. Afriyani et al. (2018) has developed a HOTS-based assessment test electrolyte and non-electrolyte solution. Our work focused on the development of the HOTS-based assessment test on reaction rate which had been validated. However further works need to be done to apply the instrument and measure the effectivity for border subjects to know its effectiveness.

CONCLUSION

Based on the research objectives and results, it can be concluded that the developed HOTS-based assessment test had met the valid criteria for both content and empirical. The assessment test was reliable and had various levels of difficulty. However, this development also had limitations. The development is an initial process based on the ADDIE development model which only performed three stages which need to do two more stages, implementation and evaluation.

Although not all ADDIE stages were yet completed, the work provided an instrument to be tried in high school to measure the HOTS ability of the students for reaction rate knowledge. It was rather difficult to find trial subjects especially high school students who meet the prerequisite condition. The key prerequisite condition was the learning environment that had been constructed for developing student’s HOTS. Nevertheless, our work provides a valid and reliable instrument that can be implemented and evaluated by n teachers or other researchers who have an interest in improving students’ HOTS related to reaction rate.

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