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Development of Computer Based Test Instrument for Higher Order Thinking Skills (CBT-HOTS) on Chemical Bonding Materials

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Abstract

This study aimed to produce a computer-based test instrument for higher-order thinking skills (CBT-HOTS) on the chemical bonding materials and to determine the higher-order thinking skills of students in Class X MIA at MAN Binjai Academic Year 2021/2022. This research employed the ADDIE model of Research and Development (R&D). The test instrument was created in the form of multiple-choice consisting of 30 questions measuring the cognitive domains of analyzing (C4), evaluating (C5), and creating (C6). Based on the findings, the developed instrument was declared feasible for use, considering that it had met the required content validity by expert assessments using the Aiken's V index in the range of 0.97 to 1.00 and the reliability value of 0.93. The students' higher-order thinking skills on chemical bonding materials were included in the "high" category. It was shown from the percentages of answers to the HOTS questions in each involved domain; analyzing (C4) by 28%, evaluating (C5) by 44%, and creating (C6) by 28%. Additionally, the average score was 74.64, indicating that students' higher-order thinking skills were high.

Keywords: research and development; test instrument; computer-based; chemical bonding

Abstrak

Penelitian ini bertujuan untuk menghasilkan instrumen tes kemampuan berpikir tingkat tinggi(TBK-HOTS) berbasis komputer pada materi ikatan kimia dan untuk mengetahui kemampuan berpikir tingkat tinggi siswa kelas X MIA MAN Binjai T.A 2021/2022. Penelitian ini menggunakan model pengembangan *Research and Development* (R&D) tipe ADDIE. Berdasarkan hasil penelitian, instrumen tes yang dikembangkan berupa tes pilihan ganda sebanyak 30 soal dengan masing-masing soal mengukur ranah kognitif menganalisis (C4), mengevaluasi (C5) dan mencipta (C6) menyatakan bahwa HOTS instrumen tes berbasis yang dikembangkan dinyatakan layak digunakan dengan kriteria telah memenuhi syarat validitas isi yang diperoleh dari penilaian ahli dengan indeks Aiken V pada kisaran 0,97 sampai dengan 1,00 dalam kategori valid dan memenuhi syarat reliabilitas dengan reliabilitas 0,93 yang masuk dalam kategori valid. kategori tinggi. Kemampuan berpikir tingkat tinggi siswa pada materi ikatan kimia kelas X MIA termasuk dalam kategori tinggi. Hal ini terlihat dari persentase jawaban soal HOTS yang meliputi indikator menganalisis (C4) sebesar 28%, mengevaluasi (C5) sebesar 44% dan mencipta (C6) sebesar 28%. Secara keseluruhan, keterampilan berpikir tingkat tinggi siswa memiliki skor rata-rata 74,64. Sehingga dapat disimpulkan bahwa kemampuan berpikir tingkat tinggi siswa tergolong tinggi.

Kata kunci: research and development; alat uji; berbasis computer; ikatan kimia

Introduction

Students' ability in Indonesia, especially in Chemistry, is still considered very low compared to other countries. It was evident by the international study of the PISA (Programme for International Student Assessment) organized by the OECD (Organization for Economic Co-operation and Development). The 2018 PISA results showed that Indonesia was ranked 69th out of 76 countries (OECD, 2019). Thus, it depicted that Indonesia was still very far behind several other countries, implying that the students could not answer the questions measuring higher-order thinking skills despite the ability to solve the problems classified in the low category (Hanifah, 2019).

One of the government's efforts to address this issue was by establishing the 2013 Curriculum to improve students' abilities in the 21st century, as formulated in the 4 Cs, namely (1) Critical thinking, making students able to use critical and rational logic to solve problems or contextual issues; (2) Creativity, encouraging students to be creative in finding solutions, designing new strategies, and discovering new methods; (3) Collaboration, enhancing students' abilities in working with teams, tolerance, understanding differences to achieve goals, and (4) Communication, enabling students to communicate and gain broad abilities to capture ideas, interpret information, and argue in broad essence (Kemendikbud, 2019).

The HOTS questions were used to assess higher-order thinking skills, namely the ability to think, not just recall, restate, or refer without processing (recite) (Azmi et al., 2021). In the context of an assessment, they could measure the ability to transfer one concept to another, process and apply information, find connections among different kinds of information, use the information to solve problems, and examine ideas and information obtained more critically (Wadana, 2017).

Chemical bonding is one of the primary materials studied in class X (the tenth grade) of senior high school in odd semesters and is considered necessary in Chemistry (Iskandar, 2015). It is perceived as one abstract chemical concept that is difficult for students to understand, leading to their misconceptions about it. The chemical bond is characterized by conceptual understanding and application. Hence, it is regarded appropriate to engage HOTS questions that require skills in analyzing (C4), evaluating (C5), and creating (C6) (Arikunto, 2013).

In the Computer Based Test (CBT), students can take tests or examinations from different places on the internet and an intranet network (Chaiyo, 2017; Chaiyo & Nokham, 2017). It can be used as an alternative in learning evaluation. Some schools evaluate learning by manually conducting daily tests and school exams using paper and pencils. This method is considered inefficient and impractical due to the costs of providing question materials and examinations (Muchlis & Andromeda, 2020).

A learning evaluation model utilizing technology makes it more effective and efficient to evaluate, measure, and assess quickly, precisely, and practically (Arifin, 2013). Therefore, the obstacles encountered in the manual method can be minimized or even eliminated (Mulianah & Hidayat, 2013).

Research on the development of HOTS test instruments was carried out by Netri et al. (2018) showed that the developed test instrument was valid based on the material, construction, and language aspects. Based on the description above, the researchers were interested in conducting a research entitled development of computer based test instrument for higher order thinking skills (CBT-HOTS) on chemical bonding materials.

Research Method

The present study employed a model of Research and Development, namely a systematic study of the design, development, and evaluation of programs, processes, and learning products that must meet the criteria of validity, practicality, and effectiveness. (Rayanto & Sugianti, 2020). The product developed was a test instrument based on

HOTS (Higher-Order Thinking Skills) on chemical bonding materials in senior high school.

This research was conducted in class X MIA at MAN Binjai, Binjai City, North Sumatra Province. The researchers referred to the ADDIE model of development. The techniques and instruments administered in this study included interviews, validation sheets, and tests. The test instrument was structured to obtain data on students' higher-order thinking skills according to the HOTS indicators covering C4, C5, and C6 (Sarah et al., 2021).

The research data were analyzed in stages to determine the feasibility (validity) and the level of students' higher-order thinking skills. The data validation results were analyzed by considering validators' input, comments, and suggestions (Saputro, 2021). The analysis results were used as guidelines for revising the developed instruments. The instrument validity can be seen on the validation sheet utilized during the validation process. The level of students' higher-order thinking skills can be seen in their test results.

Results and Discussion

The research data were obtained from students' answers to the HOTS-based test instrument on the Chemical Bonding materials at MAN Binjai. Three expert validators revised and validated the instrument before being used to determine students' higher-order thinking skills. It consisted of 30 multiple-choice questions, distributed into 6 C4 questions, 14 C5 questions, and 10 C6 questions. Afterward, based on the test conducted on students through small classes to determine the instrument's validity, 25 questions were declared valid.

This study was conducted incorporating the ADDIE development model, namely: (1) Analysis; (2) Design; (3) Development; (4) Implementation; and (5) Evaluation.

1. Analysis

In the analysis stage, researchers analyzed the need for developing a computer-based test instrument to assess student learning outcomes. This stage included three elements: needs analysis, curriculum analysis, and student characteristics analysis.

2. Design

In this stage, researchers initially designed the HOTS-based test instrument on chemical bonding materials for the tenth-grade students of senior high school. It consisted of determining the instrument's form, compiling the grid and creating the design, and inputting questions into the Quizizz platform.

3. Development

This stage comprised expert and practitioner assessments involving two Chemistry lecturers at the State University of Medan and a teacher at MAN Binjai.

There were four aspects in the validation sheet for the developed instrument: material, construction, language, and HOTS. The validity of questions was declared based on the obtained Aiken's V index for each item. Subsequently, the invalid items must be revised while the valid ones could be used for the test. According to Suharsimi Arikunto, the expert validity results shown in the index table could be used to indicate that all developed items passed the content validity test.

The Aiken's V index was classified as high (0.60-0.80) and very high (0.80-1.00). Accordingly, the analysis results showed that the developed question items obtained the index between 0.97-1.00. The items with an index of 1.00 were numbers 2, 3, 4, 5, 6, 7, 8, 14, 17, and 24. The items with an index of 0.98 were numbers 1, 9, 10, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23, 26, 27, 28, 29, and 30. And the last, the items with an index of 0.97 were numbers 11 and 25.

Based on the obtained Aiken's V index and the table of validation levels provided by Suharsimi Arikunto, researchers concluded that the developed test instrument was valid and feasible to measure students' higher-order thinking skills on chemical bonding materials.

4. Implementation

The implementation was carried out in a small trial class, Class X MIA 1 at MAN

Binjai, involving 20 students who were asked to answer the questions within 90 minutes. This stage was conducted to determine the test instrument's validity, reliability, difficulty level, and discriminating power. The item analysis results were as follows:

a. Validity

The validity testing aims to examine the test instrument in terms of technical, content, and editorial aspects (Silitonga, 2011). Validity is the accuracy of an instrument in measuring particular items. Expert validators carried out the validity testing in terms of content quality and cognitive accuracy. However, the test instrument still needed to be tested on students who had studied the relevant materials contained in the question items. In this regard, the testing was done on 20 students of class X MIA 1. It was completed by testing the product-moment validity using Ms. Excel. The criteria used in this validity test, with r_{table} for N = 20 and at = 0.05 is r_{table} = 0.3783. Then the questions that were declared valid were 25 of the 30 questions tested, namely questions number 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17 , 18, 21, 22, 23, 25, 26, 27, 29, 30.

b. Instrument Reliability

Tests Test reliability tests are used to see how far the measuring instrument is reliable and trustworthy, so that the test instrument can be accounted for in disclosing research data. The reliability of the test in this study used the Kuder Richardson-20 (KR-20). From the table of product moment values, it is known that the value of r_{table} for N = 20 and at = 0.05 is r_{table} of 0.44 while the price of r_{11} = 0.93. By comparing the price of r_{11} with r_{table}, it can be determined the reliability of the test items with the criteria of $r_{11} > r_{table}$ or 0.93 > 0.44, it can be concluded that the 30 questions as a whole have a high level of reliability, so this test is declared reliable.

c. Difficulty Level

In essence, a good test item should be neither too easy nor too difficult (Silitonga, 2011). The HOTS-based test instrument in Bloom's taxonomy has a difficulty level of C4 (Analyzing), C5 (Evaluating), and C6 (Creating). Hence, many students consider it more difficult than the common type of test. The results of the difficulty level testing revealed that the 30 question items being developed were classified into easy, medium, and hard. The "hard" item was number 19. The "medium" items were numbers 1, 2, 3, 5, 6, 7, 8, 9, 11, 12, 14, 16, 17, 18, 22, 23, 24, 26, 27, 28, and 29. Meanwhile, the "easy" items were numbers 4, 10, 13, 15, 20, 21, 25, and 30.

d. Discriminating Power

The discriminating power intends to distinguish between high-ability and low-ability students. Based on the calculation results, the discriminating power in the question items was declared qualified, with most of them being in the "very good" category.

5. Evaluation

At this stage, researchers made the final revision of the developed HOTS-based test instrument based on the validation results carried out by experts and practitioners and the small trial class analysis. Furthermore, the evaluation was intended to determine whether the instrument was truly appropriate and could be used to measure the students' higher-order thinking skills. Therefore, of the 30 questions, only 25 items were feasible for use.

a. Higher Order Thinking Skill

The revised HOTS-based test instrument was tested in large trial classes, Class X MIA 1 and Class X MIA 3 at MAN Binjai. The total number of respondents was 50 students, and the items being tested were 25 questions. This large class trial aimed to determine the students' higher-order thinking skills on chemical bonding materials. The data obtained are presented in Table 1 below.

Table 1 showed that the highest score of students in solving HOTS questions on chemical bonds was 88, while the lowest was 48. The average score was 74.64, with a standard deviation of 10.21. It indicated that the students' higher-order thinking skills were good overall. Table 2 below presents the percentage of students' higher-order thinking skills in answering HOTS questions on chemical bonding materials.

Table 1
Data on Students' Higher Order Thinking Skills in Solving HOTS Questions on Chemical Bonding Materials

Aspect	Score
Maximum score	88
Minimum score	48
Average score	74.64
Standard deviation	10.21

Table 2
Percentage of Students' Higher Order Thinking Skills

Score Range	Category	Absolute Frequency	Percentage
81-100	Very Good	14	28%
61-80	Good	30	60%
41-60	Average	6	12%
21-40	Low	0	0%
0-20	Very Low	0	0%
Total		50	100%

Table 2 depicts that 30 students obtained the highest frequency in the range of 61-80, included in the "Good" category, up to 60%. In the "Very Good" category, with a range of 81-100, there were 14 students (28%). In the "Average" category, with a range of 41-60, there were 6 students (12%). Meanwhile, no student was included in the "Low" and "Very Low" categories, indicating that there were no learners with low and very low levels of higher-order thinking skills.

Furthermore, the percentage of students' abilities to solve HOTS questions based on each indicator is presented in Table 3.

Table 3
Percentage of HOTS Questions based on Indicators

Indicator	Percentage
Analyzing (C4)	28%
Evaluating (C5)	44%
Creating (C6)	28%
Total	100%

Based on Table 3, the largest percentage was obtained in the indicator of analyzing (C4) at 28%, followed by evaluating (C5) at 44% and creating (C6) at 28%.

b. Students' Higher Order Thinking Skills According to Indicators on Chemical Bonding Materials

1) Analyzing

Regarding the indicator of "Analyzing", 28% of students could answer the questions well. It indicated that they

could analyze the test items, covering the process of formation of ionic and covalent bonds and the types of the existing bonds. It was in line with research by Widihastuti & Suyata (2014), which found that students could reason logically, systematically, and analytically. Additionally, the results of this study were supported by interviews conducted with the Chemistry teachers at MAN Binjai, confirming that the students were willing to solve the questions.

2) Evaluating

In the "Evaluating" indicator, 44% of students could answer the questions well. In addition, this indicator obtained the highest percentage. It revealed that the students could assess and examine whether the existing things were relevant or not, such as predicting the compounds formed into the ionic or covalent. This result was in line with Redhana (2019), revealing that students having a good level in "Evaluating" could solve problems correctly and quickly and make the right decisions.

3) Creating

Considering the indicator of "Creating", 28% of students could respond to the questions well. Thus, they were considered able to plan a procedure for solving a problem or creating a new product. Regarding the chemical bonds, the learners could conclude the difference between ionic and covalent bonds in terms of physical and chemical properties. It was in line with Fanani (2018), in which the higher-order thinking could be in the form of curiosity, open thinking, and skills such as analyzing, drawing conclusions, creating, and producing a new product by organizing several elements into different shapes or patterns.

Conclusion

The development of the computer-based test instrument for higher-order thinking skills on Chemical Bonding materials in the present study employed the ADDIE model of the Research and Development (R&D). The developed test instrument was a multiple choice test consisting of 30 questions measuring the cognitive domains of analyzing (C4), evaluating (C5), and creating (C6). The constructed test instrument was declared feasible for use because it met the content validity requirements incorporating the Aiken's V index, in the range of 0.97 to 1.00. In addition, it also attained the reliability requirements, up to 0.93. Therefore, the levels of higher-order thinking skills on Chemical Bonding materials in Class X MIA at MAN Binjai in the academic year of 2021/2022 were included in the "High" category. Likewise, students' overall higher-order thinking skills had an average score of 74.64, which was classified as "High".

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