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Development of Diagnostic Test Instruments as Placement Tests to Determine Students' Cognitive Learning Levels on Acid-Base Material

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Abstract

This study aims to determine the validity and discriminatory power of diagnostic test instruments as placement tests on acid-base material and to determine the level of students' cognitive learning. This diagnostic test instrument development research refers to the Research & Development (R&D) development method. Data collection in this study used tests, interviews, and questionnaires. The research stage begins with potential problems, data collection, product design stage, development of diagnostic test instruments and validation by experts, validity tests, difficulty level tests, and discriminatory power tests on small-scale tests and interpretation of students' cognitive levels on large-scale trials. The results of the assessment by expert validators showed that the criteria for the developed instrument were valid. The results of the analysis of the validity of the test items obtained 25 valid question items. The results of the test of the level of difficulty of the questions obtained 11 easy criteria questions and 14 medium criteria questions. The results of the discriminatory power test obtained 25 question items with very good discriminatory power. The results of the large-scale trial showed that the average interpretation of the results of the diagnostic test instrument was 78.81%. The percentage of students who passed the test was 70.3% while the percentage of students who failed was 30%. This shows that the diagnostic test instrument is effective in that it can improve students' understanding of acid-base chemistry material.

Keywords: acid-base; cognitive learning; diagnostic test instruments; placement test

Abstrak

Penelitian ini bertujuan untuk menentukan validitas dan daya diskriminatif instrumen tes diagnostik sebagai tes penempatan materi asam-basa dan untuk menentukan tingkat pembelajaran kognitif siswa. Penelitian pengembangan instrumen tes diagnostik ini mengacu pada metode pengembangan Penelitian & Pengembangan (R&D). Pengumpulan data dalam penelitian ini menggunakan tes, wawancara, dan kuesioner. Tahap penelitian dimulai dengan potensi masalah, pengumpulan data, tahap desain produk, pengembangan instrumen tes diagnostik dan validasi oleh ahli, uji validitas, uji tingkat kesulitan, dan uji daya diskriminatif pada tes skala kecil dan interpretasi tingkat kognitif siswa pada uji skala besar. Hasil penilaian oleh validator ahli menunjukkan bahwa kriteria instrumen yang dikembangkan valid. Hasil analisis validitas butir soal memperoleh 25 butir soal yang valid. Hasil uji tingkat kesulitan soal memperoleh 11 butir soal dengan kriteria mudah dan 14 butir soal dengan kriteria sedang. Hasil uji daya diskriminatif memperoleh 25 butir soal dengan daya diskriminatif sangat baik. Hasil uji coba skala besar menunjukkan bahwa rata-rata interpretasi hasil instrumen tes diagnostik adalah 78,81%. Persentase siswa yang lulus tes adalah 70,3% sedangkan persentase siswa yang gagal adalah 30%. Hal ini menunjukkan bahwa instrumen tes diagnostik efektif karena dapat meningkatkan pemahaman siswa terhadap materi kimia asam-basa.

Keywords: asam-basa; instrumen tes diagnostik; pembelajaran kognitif; tes penempatan

Introduction

Education plays a very vital role and becomes a key factor in living in society. Therefore, education is a basic need that must be met by every individual throughout life. Without education, a group of people will find it very difficult to grow and develop according to their hopes or goals, in achieving progress, prosperity, and happiness with their outlook on life. The curriculum is an educational plan designed to shape the younger generation so that they can play a role and become useful members of society after undergoing formal education at school. The curriculum functions as a guideline and basis for the learning process in an educational institution. At this time, educators are implementing the Independent Curriculum.

The Independent Curriculum is a curriculum innovation that emphasizes freedom, creativity, and students' adaptability (Gumilar, 2023). This curriculum aims to form independent, resilient, and innovative students through an open and inclusive approach. The Independent Curriculum is a real effort by the government to improve the quality of education in order to meet the challenges of society in the 5.0 era (Manalu, Sitohang, & Henrika, 2022). Therefore, the Independent Curriculum is very important for the success of education and must be developed by the government to keep up with the times. Learning is a combination of a structured series of humans, materials, facilities, tools, and methods that interact with each other to achieve learning goals (Marlina et al., 2025).

The purpose of learning is to create a teaching and learning process that supports students in achieving optimal learning outcomes (Hamalik, 2010). Effective learning requires students to develop according to their potential. However, not all students can experience maximum or good progress in the learning process. The Independent Curriculum assesses students' cognitive abilities to determine their knowledge abilities during the learning process.

According to cognitive theory, learning is a process involving active mental activity, where students not only store information but students can also process and change it (Gage & Berliner, 1984). This idea emphasizes that children have an active, constructive nature, and the ability to seek and find the truth, conduct analysis, interpret and draw conclusions. Cognitive abilities can improve students' overall qualifications (Vidayanti, 2017). There is a theory that writes about the main ability to think, namely Benjamin Samuel Bloom's theory, where in high-quality education can be achieved and apply all levels of cognition in the learning process (Huda, 2013). The cognitive domain includes behavior that emphasizes all intellectual aspects, namely knowledge and thinking skills, from basic thinking skills such as remembering to high-level thinking skills such as analyzing and drawing (Derman et al., 2024; Permatasari et al., 2024)).

The United States Office of Education (USOE), namely stating that learning difficulties are disorders experienced by individuals in the early psychological process of understanding and applying lessons or writing. To overcome this problem, a diagnostic approach is used to determine the location of students' learning difficulties (Saifatun & Rinaningsih, 2025). Diagnosis of student misunderstandings can be done by testing. Diagnostic tests are designed to address students' weaknesses and strengths in learning (Ebel, 1979). The main purpose of diagnostic tests is to identify problems faced by students and plan appropriate problem-solving efforts. This test supports teacher assessment in improving students' understanding of certain topics (Rusell & O'dwyer, 2009).

Difficulties are seen in their conceptual abilities and thinking skills in solving problems. Difficulties in understanding chemistry are characterized by complex and abstract concepts and chemicals that cannot be seen (Taboy et al., 2022). One of the chemistry lessons that is difficult to understand is the material on acids and bases. Acids and bases are materials found in various aspects of everyday life. This material is important because it is closely related to everyday life

because its properties can be proven through observation and problem-solving processes.

Based on the results of the interview observations conducted, it is known that students think that in chemistry lessons the acid-base material is difficult. This is because the difficulty in acids and bases is in calculating pH where students still take a long time to calculate pH and also students have difficulty during practicums using pH indicators, universal indicators, and natural indicators. So that students experience a lack of understanding of the concept of acids and bases, which is one of the reasons for the low learning outcomes of students. Based on the description above, it is necessary to analyze students' problem-solving abilities using diagnostic test instruments on acid-base material by grouping classes.

Grouping classes for students with different abilities requires a varied learning approach (Kim et al., 2024). This is based on the assumption that high-achieving students learn faster than students with low abilities. Combining students with different abilities can create a gap in understanding, where students who learn quickly have to wait for their friends to understand the material (. The purpose of this grouping is to increase the effectiveness and efficiency of learning and to facilitate guidance according to the abilities of each student (Rahmadani & Azra, 2025).

Diagnostic tests act as important placement tests in the implementation of the sorogan-bandongan model. Student placement determines the group leader and its heterogeneous members. This approach is different from other learning models, where the group leader functions as an assistant and must be completed before classical learning begins. The group leader is the best student seen from the top-bottom cross ranking. Grouping by class often uses the Islamic boarding school model such as sorogan and bandongan.

The sorogan bandongan model is taken from Islamic boarding schools in Indonesia. This model helps students understand and learn concepts individually, namely in sorogan where students study the material independently, while bandongan establishes group discussions for those who do not understand. Sorogan and bandongan are variants of learning models which are structured process frameworks in teaching and learning to achieve learning goals (Rinaningsih, 2014).

Method

This research is a type of research with a Research and Development (R&D) approach. The development model used is the model according to (Sugiyono, 2019) with the following stages: 1) Potential and Problems 2) Data Collection 3) Product Design 4) Product Validation 5) Design Revision 6) Product Trial 6) Product Revision 7) Usage Trial 8) Product Revision 9) Final Product. This research is adjusted to the research needs. This study was conducted in May 2025 at a public high school in Surabaya. The sample in this study was 30 students of class XI of high school.

Data Collection Techinue

The data collection techniques used in this study consisted of a diagnostic test consisting of 20 question items, a questionnaire consisting of an expert validation questionnaire and a student response questionnaire and interviews. The diagnostic test instrument was used to determine the validity value of the question items, the level of difficulty, the discriminatory power, and the interpretation of the results of the diagnostic test instrument. The expert validation questionnaire was used to determine the feasibility of the questions before being tested on students while the student response questionnaire was used to see students' responses to the level of readability and the time used in working on the questions. Interviews were conducted to find out how teachers responded to chemistry learning and the diagnostic test instrument as a placement test.

Data Analysis Techiques

The initial stage in data analysis is testing the feasibility or validity of the diagnostic test instrument that has been

developed. After the diagnostic test instrument is considered feasible by the expert validator and meets the criteria for instrument feasibility, then the test instrument is tested on students to determine the cognitive level of students in the acid-base material. A score of 1 is given if the answer is correct. While a score of 0 is given if the answer is wrong. The data analysis techniques used include validity, level of difficulty, discriminatory power and interpretation of diagnostic test results.

The validity of the test items is to determine whether the test items from the diagnostic test instrument that has been given meet the valid or invalid criteria. The validity of the items for multiple choice questions can use the point biserial formula in. (Silitonga, 2014)

$$r_{pbis} = \frac{Mp - Mt}{St}\sqrt{\frac{p}{q}}$$

Where :

r_{pbis} = Point biserial correlation coefficient
Mp = Average score of subjects who answered correctly
Mt = Average total score (average score of all test participants)
St = Standard deviation of total score
P = Proportion of subjects who answered correctly
q = Proportion of subjects who answered incorrectly (1-p)

The validity coefficient obtained (r_{pbis}) is compared with the r_{table} product moment values at $\propto = 0{,}05$. If $r_{pbis} > r_{table}$ then the test item is said to be valid.

The level of difficulty is done to find out the level of difficulty of the questions. The level of difficulty can be known through the formula below with the criteria for the level of difficulty in Table 1 (Arikunto, 2012).

$$P = \frac{B}{JS}$$

Where:

P = Difficulty index
B = Number of students who answered the question correctly
JS = Total number of students

Table 1.
Difficulty Level Criteria

Difficulty Level Index	Interpretation
0.00 – 0.30	Difficult
0.31 – 0.70	Currently
0.71 – 1.00	Easy

(Rusilowati, 2014)

The discriminatory power can be determined using the formula below with the discriminatory power criteria as in Table 2 (Arikunto, 2012).

$$D = \frac{Ba}{Ja} - \frac{Bb}{Jb} = Pa - Pb$$

Information :

J = Number of students
Ja = Number of students in the upper group
Jb = Number of students in the lower group
Ba = Number of students in the upper group who answered the question correctly
Bb = Number of students in the lower and upper groups who answered correctly
Pa = Proportion of participants in the upper group who answered correctly
Pb = Proportion of lower group participants who answered correctly

The Student Response Questionnaire can be known through the formula below with the response questionnaire criteria as in Table 3.

$$P = \frac{S}{N}\ x\ 100\%$$

Information:

P = Percentage response value
S = Total scores obtained
N = Maximum number of scores obtained

Table 2.
Distinguishing Power Criteria

Item Discrimination Index	Interpretation of the Discriminating Power of Questions
D ≥ 0.40	Very good
0.30 ≤ D ≤ 0.40	Good
0.20 ≤ D ≤ 0.30	Enough
D < 0.20	Bad

Table 3.
Percentage of Student Response Scoring Criteria

Percentage	Criteria
82% < score ≤ 100%	Very good
64% < score ≤ 82%	Good
score ≤ 64	Not good

Interpretation of Diagnostic Test Results

The analysis of the interpretation of the results uses binary assessment, with the interpretation of of correct results being worth 1 and incorrect being worth 0. Determine the degree of understanding by using the percentage of student assessment using a formula as in the equation below.

$$P = \frac{F}{N} \; x \; 100\%$$

Information:
P = Percentage value of the group
F = Number of students in each group
N = Number of students

The results of this percentage calculation are then grouped into frequency distributions and percentages as in Table 4.

Table 4.
Criteria for Student Learning Outcome Scores

No	Mark	Category
1.	85-100	Very high
2.	65-84	Tall
3,	55-64	Currently
4.	35-54	Low
5.	0-34	Very low

Result and Discussion

The development of this test instrument is based on the need for a measuring instrument that not only evaluates the final results of learning, but is also able to describe the initial conditions and thinking processes of students. In chemistry learning, especially regarding acid-base material, students often face difficulties in understanding abstract concepts such as acidity levels, pH, ionization reactions, and acid-base theories (Arrhenius, Bronsted-Lowry, and Lewis), therefore, the existence of this diagnostic test instrument is very important to help teachers place students according to their level of cognitive ability, as well as a foundation in formulating appropriate learning strategies.

Experts in the field validated the diagnostic test instrument that was designed to produce good content validity questions. The results of the validation of the diagnostic test instrument showed that there were a number of questions that had to be improved first so that they were in accordance with the indicators that were to be achieved (Rinta & Fitriza, 2022). Product improvements were made by looking at input or suggestions. validator and those who have theoretically valid various aspects of material, construction aspects, language aspects, and other aspects that help the appearance of the product.

Validation data obtained by the validator showed that 25 questions were considered valid. Of these, 14 questions were included in the very good criteria, meaning they were used without improvement with a score between 14 and 19 questions. 10 questions were included in the good category, meaning they still needed a little improvement with a score between 9 and 14. Furthermore, the diagnostic test instrument that had been validated would go through small-scale and large-scale trials to detect students' knowledge levels. The trial use was carried out in class XI of high school, with a working time of 90 minutes.

The validity test of the test items is used to determine the validity of the questions in the diagnostic test instrument. The test items are said to meet the valid criteria if $r_{count} > r_{table}$. Based on the validity test conducted on 30 students using SPSS version 16.0 and the r table value of 0.3809, all 25 test items were declared valid.

The difficulty level test was conducted to identify the level of difficulty of the questions. Whether the questions are easy, medium , or difficult. Based on the data from the test results of the level of difficulty of the questions, it can be concluded that every 11 questions are included in the easy criteria, while 14 items are included in the medium criteria .

The discriminatory power test aims to assess the ability of questions to differentiate between students with high and low abilities. Based on the analysis using SPSS version 16.0, all 25 questions have very good discriminatory power so they are suitable for use.

The response questionnaire aims to measure students' responses to the diagnostic test instruments provided. The questionnaire contains questions about the readability of the questions and responses to the instrument as a placement tool in measuring the cognitive level of student learning. The average percentage of questionnaire results reached 73.42%, which is included in the good category.

The results of the interpretation of the diagnostic test instrument stated that out of a total of 30 students as research subjects, 27 students took and completed the test, while 3 students did not take the test. The analysis showed that 19 students obtained a percentage of 70.3% successfully getting a score above the KKM, which was 75 and were declared to have passed or completed. Meanwhile, 8 students obtained 30% still below the limit or completion or below the KKM and were declared not yet completed, as can be seen in Table 5.

Table 5.
Percentage of Completion of Chemistry Learning Outcomes of Grade XI High School Students

No	Category	Frequency	Percentage (%)
1.	Not finished	8	29.63
2.	Completed	19	70.37
Amount		27	100

student scores states that the highest score reaches 100 and the lowest score is 12. Based on the grouping of scores, it was obtained that 11 students produced 41% with a score of 85-100 having a very high score, 12 students produced a percentage of 44.4% with a score of 55-64 having a high category, 2 students produced a percentage of 7.4 with a score of 0-34 having a medium category, while 2 students produced a percentage of 7.4 with a score of 0-34 having a very low category as can be seen in Table 6.

Table 6.
Frequency Distribution and Percentage of Learning Outcome Scores of Class XI Students

No	Mark	Category	Frequency	Percentage (%)
1.	85-100	Very high	11	41
2.	65-84	Tall	12	44.4
3,	55-64	Currently	2	7.4

No	Mark	Category	Frequency	Percentage (%)
4.	35-54	Low	-	-
5.	0-34	Very low	2	7,4

The average value of the chemistry test results of students who have used the diagnostic test instrument via the quiziz web is 78.81%, which shows that in general the cognitive level of students is at a high level in understanding acid-base material. The majority of students are in the middle to upper range, which indicates that most have mastered the basic competencies of the material, but there are still groups of students who need more attention to achieve completeness.

Conclusion

The conclusion of the research on the development of diagnostic test instruments as placement tests to determine the level of cognitive learning of students in acid-base material is explained as follows the validity of the developed test instrument 25 questions are included in the good category from the validation results by instrument experts. The validity of the diagnostic test questions shows that 25 questions are valid. The level of difficulty results in every 11 questions being included in the easy category and 14 questions being included in the moderate category. The response questionnaire shows that the percentage has 73.42% with a good category. Based on the results of the discriminatory power for diagnostic test questions as placement tests, there are 25 questions that have very good discriminatory power. So this diagnostic test instrument is suitable for use.

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