Vol 12(3), 2023, 116-126 DOI: 10.23960/jppk.v12.i3.2023.10
Jurnal Pendidikan dan Pembelajaran Kimia
e-ISSN: 2714-9595| p-ISSN 2302-1772
http://jurnal.fkip.unila.ac.id/index.php/JPK/index

Development of Four-tier Diagnostic Test Instrument to Identify Students' Mental Models on Salt Hydrolysis Materials

Cindy Vikem Maulidiana[1], and Fajriah Azra[1*]

1 Chemistry Education Study Program, Faculty of Mathematics and Science, Universitas Negeri Padang, Padang-25131, Indonesia

*Corresponding e-mail: bunda_syasfa@yahoo.com

Received: November 11th, 2023 Accepted: December 9th, 2023 Online Published: December 28th, 2023

Abstract: Development of Four-tier Diagnostic Test Instrument to Identify Students' Mental Models on Salt Hydrolysis Materials. Mental models are concepts of thought that represent ideas used to describe and explain a phenomenon. Mental models are important to know so that teachers can find out the level of understanding, difficulties and misconceptions experienced by students. Diagnostic test instrument is one of the instruments that can be used to determine the mental model of students. Therefore, this study aims to develop a four-tier diagnostic test instrument to determine the mental model of students on salt hydrolysis material. This type of research is Research and Development (R&D) research using the Treagust development model. Based on the results of logical validity analysis obtained that the average value of Aiken's V is 0.87 valid category. Based on the results of the question trial, it was found that the results of the empirical validity analysis in the first-tier and third-tier there were several questions classified as valid with a total of 18 questions and 16 questions respectively. The reliability value in the first-tier and third-tier is 0.78 and 0.75 respectively with a high category.

Keywords: Diagnostic Test, Mental Model's, Four- Tier Multiple Choice, Hydrolysis of Salts

Abstrak: Pengembangan Instrumen Tes Diagnostik Four-Tier Untuk Mengidentifikasi Model Mental Peserta Didik pada Materi Hidrolisis Garam. Model mental merupakan konsep pemikiran yang mewakili ide-ide digunakan untuk menggambarkan dan menjelaskan suatu fenomena. Model mental penting untuk diketahui agar guru dapat mengetahui tingkat pemahaman, kesulitan dan miskonsepsi yang dialami oleh peserta didik. Instrumen tes diagnostik merupakan salah satu instrumen yang dapat digunakan untuk mengetahui model mental peserta didik. Oleh sebab itu, penelitian ini bertujuan untuk mengembangkan instrumen tes diagnostik *four-tier* untuk mengetahui model mental peserta didik pada materi hidrolisis garam. Jenis penelitian ini adalah penelitian *Research and Development* (R&D) dengan menggunakan model pengembangan Treagust. Berdasarkan hasil analisis validitas logis diperoleh bahwa nilai rata-rata Aiken's V sebesar 0.87 kategori valid. Berdasarkan hasil uji coba soal diperoleh bahwa hasil analisis validitas empiris pada *first-tier* dan *third-tier* terdapat beberapa soal tergolong valid dengan jumlah 18 soal dan 16 soal berturut-turut. Nilai reliabilitas pada *first-tier* dan *third-tier* sebesar 0,78 dan 0,75 berturut-turut dengan kategori tinggi.

Kata kunci: Diagnostic Test, Mental Model's, Four- Tier Multiple Choice, Hydrolysis of Salts

▪ INTRODUCTION

Chemistry is the study of matter, its properties, and changes in matter and energy associated with these changes (Silberbeg, 2010). The concepts in chemistry are mostly abstract (Dolok Putra, 2021). One of the abstract chemical materials is salt hydrolysis material. Abstract chemical concepts will be easier to understand by involving three levels of chemical representations, namely macroscopic, submicroscopic and symbolic representations (Sagita et al., 2018), (Yani et al., 2019), (Rachmawati et al., 2021), (Utari & Azra, 2022), (Adawiyah & Azra, 2022). Learning by applying chemical multirepresentations provides facilities for meaningful or in-depth learning to occur (Sagita et al., 2017), and is able to improve understanding of chemical concepts and chemical problem solving (Sari & Helsy, 2018). When students are able to connect the three levels of chemical representation, it will encourage the formation of students' mental models so that their understanding becomes intact (Sunyono, 2015)

Mental models are concepts contained in the minds of learners that represent ideas and are used to describe and explain a phenomenon (Jansoon et al., 2009). Learners' understanding of the three levels of chemical representation is reflected as a mental model owned by the learners. The relationship between the three levels of chemical representation can be well understood using visualization methods such as diagrams, pictures and models that illustrate chemical concepts. If students are trained to be able to understand the three levels of chemical representation, then students will often transfer knowledge through the three levels of chemical representation so that they can store knowledge into long-term memory. The connection can be seen in Figure 1 below.

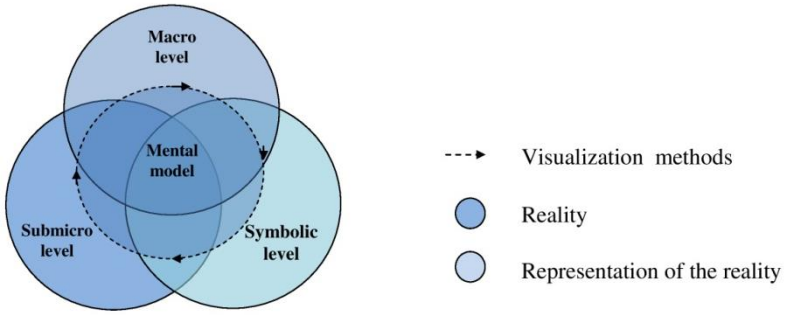


Figure 1. The Connection of The Three Chemical Representations with Mental Models (Devetak et al., 2009)

It is important for teachers to know the mental models of students because it can provide information about the concepts that students already have (Murni et al., 2019), knowing the level of understanding and difficulties experienced by students so that teachers can choose the right strategies, methods and media to use in the learning process (Darmiyanti et al., 2017), (Devi & Azra, 2023). The mental model of students can be known one of them by using diagnostic tests. One type of diagnostic test that can be used is a multiple-choice diagnostic test, either one-tier, two-tier, three-tier, or four-tier (Kania et al., 2020)

The one-tier multiple choice diagnostic test is the simplest multiple choice test, which consists of several answer choices without reasons. However, this test has limitations, namely the teacher cannot know the reason students choose the answer, whether because they already understand or just guess and happen to guess right (Rusilowati, 2015). According to Fitriani & Putra (2021) a two-tier multiple choice diagnostic test consists of answer choices at the first level and there are several choices

of reasons at the second level. Although in this test the teacher already knows the reason students choose the answer, the teacher cannot yet know the students' confidence in the answer choices and reasons given by the students. If learners choose the answers and reasons correctly, but their beliefs are not known then the teacher cannot describe the level of understanding of the learners well (whether the learners really understand, misconceptions or do not understand at all). The four-tier diagnostic test is a diagnostic test that has the addition of the level of confidence of students in choosing answers and reasons for each, making it easier for teachers to identify the level of students' understanding of chemical concepts. When knowing the reason for the correct answer and being confident that the answer choices and reasons given are correct, it means that the learner has fully understood (has a scientific-model mental model). Based on this, Kania et al., (2020) have developed a four-tier diagnostic test to identify students' mental models, but at this time the four-tier diagnostic test based on chemical multirepresentation by applying the independent curriculum on salt hydrolysis material is still very limited.

It is also emphasized based on the results of interviews that have been conducted with several high school chemistry teachers in Padang City, stating that the evaluation questions used by teachers still use one-tier multiple choice questions and apply little chemical multirepresentation, especially in salt hydrolysis material, based on the description above, it is worth to develop a four-tier diagnostic test to identify students' mental models on salt hydrolysis material.

▪ METHOD

This type of research is a development research or Research and Development (R&D) using the development model that has been developed by Treagust (1988)This development model involves three stages, namely as follows

Determine the Content

At this stage there are four steps carried out, namely a) defining propositional knowledge statements carried out by analyzing learning outcomes and learning objectives adapted to the independent curriculum on salt hydrolysis material; b) developing concept maps; c) linking propositional statements with concept maps; d) conducting content validation of propositional statements and concept maps by experts.

Obtaining Information about Students' Mental Models

At this stage there are two steps taken, namely a) conducting interviews with teachers regarding the mental models of students; b) conducting a literature study review regarding the mental models of students on salt hydrolysis material

Developing Diagnostic Test Instruments

In this stage there are three steps carried out, namely a) developing a four-tier diagnostic test instrument; b) designing a specific grid of diagnostic test instruments; c) further refinement stage where qualitative analysis is carried out to see the logical validation of the instrument that has been developed while quantitative analysis by conducting a small-scale trial conducted on 34 students at SMAN 7 Padang to see empirical validity, test reliability, difficulty index, question differentiation and distractor function.

The subjects of this research are students who have studied salt hydrolysis material, chemistry teachers, and chemistry lecturers FMIPA UNP while the object of

this research is a four-tier diagnostic test instrument to identify students' mental models on salt hydrolysis material

▪ RESULT AND DISCUSSION

This research uses a development model that has been developed by Treagust (1988), using three stages found in the figure 2 below

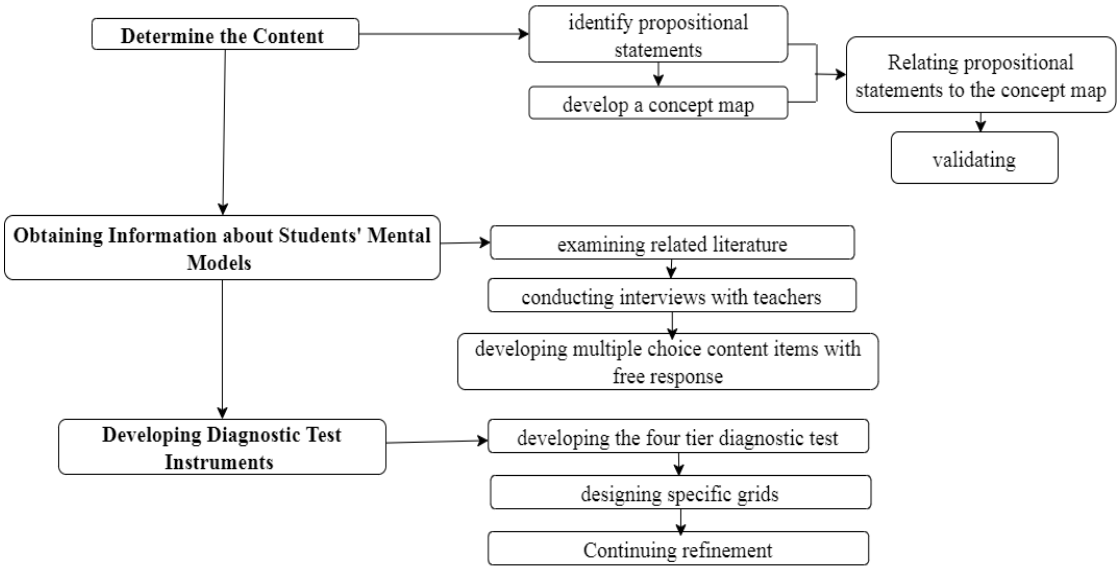


Figure 2. Treagust Development Model (1988)

Determine the Content

Based on the analysis that has been carried out on learning outcomes and learning objectives adjusted to the independent curriculum, there are several prerequisite materials on salt hydrolysis material, namely chemical reactions, the concept of moles, chemical equilibrium and acids and bases. The results of the concept analysis and concept definition of salt hydrolysis along with the prerequisite material are loaded into a table of propositional statements. Propositional statements and concept maps will be connected to ensure that the concept map already contains the concepts contained in the propositional statement so that the diagnostic test instrument that has been developed is consistent and in accordance with the independent curriculum.

Furthermore, the propositional statements and concept maps that have been designed are validated by three chemistry lecturers FMIPA UNP and two high school chemistry teachers. Validation was carried out by filling out a validation questionnaire. This questionnaire has nine questions that have a relationship to the suitability of CP and TP, the suitability of facts/concepts/principles based on chemical science, and can help students in completing mental model diagnostic tests. The validation data were analyzed using Aiken's formula. and obtained an average value of Aiken's V index of 0.83, which indicates that the propositional statements and concept maps developed have been valid which is in accordance with Aiken's opinion (1985) which states that an instrument is considered valid when validated by five validators with a rating scale of five then the validity value is ≥ 0.8.

Obtaining Information about Students' Mental Models

According to the results of the literature review, it was found that students had difficulty in salt hydrolysis material, namely difficulty identifying changes in the color of red litmus and blue litmus indicators in several salt solutions by 46.72%, understanding the explanation of ion equilibrium in salt solutions by 45.83%, concluding the acid-base properties of a salt solution, 37.83% and determining the pH of a salt solution, each of which was 49.67%, this is because students do not understand the submicroscopic representation that is pressed in the problem so that students are less able to distinguish the properties and types of salt solutions (Isnaini et al., 2022). Based on the results of interviews with several high school chemistry teachers, students still have difficulty in distinguishing strong acids, weak acids, strong bases and weak bases. Students also have difficulty in problems related to calculations and applying stoichiometry in determining the pH of salt hydrolysis solutions.

Obtaining Information about Students' Mental Models

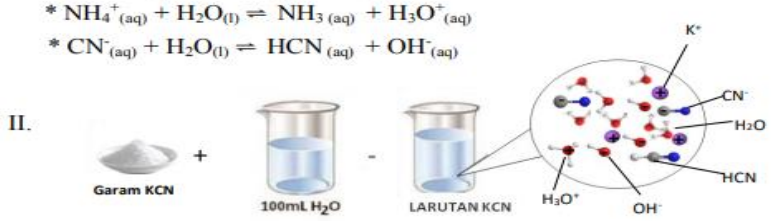
The four-tier diagnostic test instrument is a type of test instrument developed in this study. Where this instrument has been developed based on a grid of questions that have been designed and already contain multirepresentation of chemistry. The questions developed consisted of 25 items of 4-level multiple choice questions. The first level contains questions with five answer choices, the second level contains confidence in the answer choices, the third level contains reasons for the answer choices, while the fourth level contains confidence in the choice of reasons. One of the questions designed can be seen in Figure 3 below

Gambar dibawah ini merupakan beberapa pelarutan garam dalam air beserta reaksinya

Reaksi : * $NH_4CN_{(aq)} \rightarrow NH_4^+{}_{(aq)} + CN^-{}_{(aq)}$

* $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3\,(aq)} + H_3O^+{}_{(aq)}$

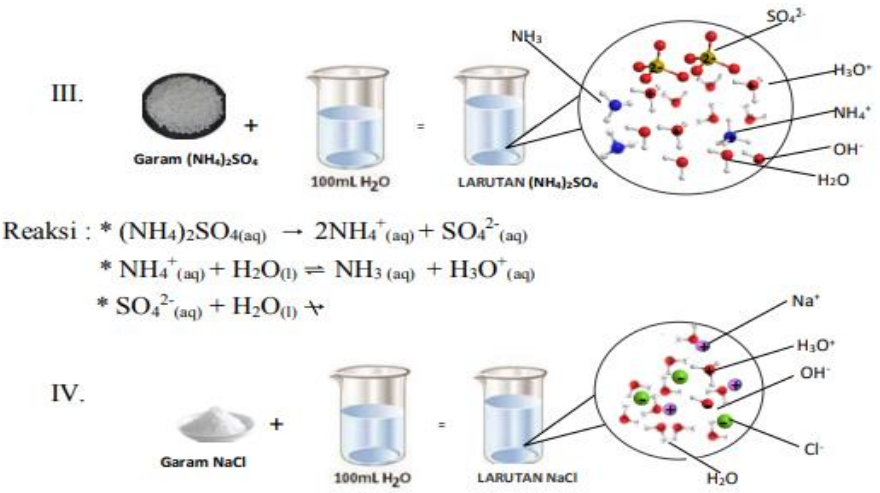
* $CN^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HCN_{\,(aq)} + OH^-{}_{(aq)}$



Reaksi : * $KCN_{(aq)} \rightarrow K^+{}_{(aq)} + CN^-{}_{(aq)}$

* $K^+{}_{(aq)} + H_2O_{(l)} \not\rightarrow$

* $CN^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HCN_{\,(aq)} + OH^-{}_{(aq)}$



Reaksi : * $(NH_4)_2SO_{4(aq)} \rightarrow 2NH_4^+{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

* $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3\,(aq)} + H_3O^+{}_{(aq)}$

* $SO_4^{2-}{}_{(aq)} + H_2O_{(l)} \not\rightarrow$

Reaksi :* $NaCl_{(aq)} \rightarrow Na^+{}_{(aq)} + Cl^-{}_{(aq)}$

* $Na^+{}_{(aq)} + H_2O_{(l)} \not\rightarrow$

* $Cl^-{}_{(aq)} + H_2O_{(l)} \not\rightarrow$

Dari gambar diatas, garam manakah yang tidak mengalami peristiwa hidrolisis …

A. I
B. III
C. IV
D. I dan II
E. II dan III

Apakah anda yakin dengan jawaban yang anda berikan?

A. Yakin
B. Tidak yakin

Alasan berikut yang mendukung jawaban yang anda berikan ?

A. NH_4^+ berasal dari asam kuat dan CN^- dari asam kuat tidak dapat bereaksi dengan air
B. NH_4^+ berasal dari asam lemah dan SO_4^{2-}dari asam kuat tidak dapat bereaksi dengan air
C. Na^+ berasal dari asam lemah dan Cl^- dari asam kuat tidak dapat bereaksi dengan air
D. Na^+ berasal dari basa kuat dan Cl^- dari asam kuat tidak dapat bereaksi dengan air
E. K^+ berasal dari basa kuat dan CN^- dari asam kuat tidak dapat bereaksi dengan air

Apakah anda yakin dengan alasan yang anda berikan?

A. Yakin
B. Tidak yakin

Figure 3. Sample Questions of Four-Tier Diagnostic Test Instrument on Salt Hydrolysis Material

Furthermore, continuing refinement is carried out where the questions that have been designed are logical validation by experts and trial is carried out on student to see the empirical validation, reliability value, difficulty index, discriminating power, and distractor function.

a. Validity and Reliability

The validity carried out consists of two types of validity, namely logical validity and empirical validity. Logical validity can be achieved if the instrument is designed following existing theories and provisions. There are two kinds of logical validity, namely content validity and construct validity. The content validity of a test instrument describes a condition of an instrument designed based on existing content, while construct validity describes the condition of an instrument designed in accordance with the constructs on devices that form cognitive aspects such as knowledge and

understanding (Arikunto, 2016). Logical validity was obtained through validation results with five validators consisting of three lecturers and two high school chemistry teachers. The three aspects assessed include content suitability, presentation (construct), and language. To determine the logical validity, the analysis was carried out using Aiken's V formula:

$$V = \frac{\sum s}{[n(c-1)]} \quad s = r - l_o$$

Information :

V :validity index
s : r – lo
lo : the lowest score in the scoring category
r : score given by rater
n : many raters (validators)
c : number of categories in the assessment

The criteria for logical validity research using Aiken's V scale are grouped in table 1 below.

Table 1. Validity Category

Aiken's V Scale	Validity
V ≥ 0.80	Valid
V < 0.80	Invalid

(Aiken, 1985)

This logical validation was carried out twice, because there were several invalid items with validity values <0.8. This is due to the absence of macroscopic and submicroscopic images on the question of calculating the pH of salt hydrolysis solution, the existence of illogical reasoning choices with answer choices and the question of macroscopic representation that does not match the symbolic representation. After making improvements according to the suggestions given by the validator, the second validation was carried out. After the second validation of all the items that have been developed and then data processing is carried out on the results of the logical validation, the average Aiken's V value is 0.87 after revision which can be seen in Figure 4 below.

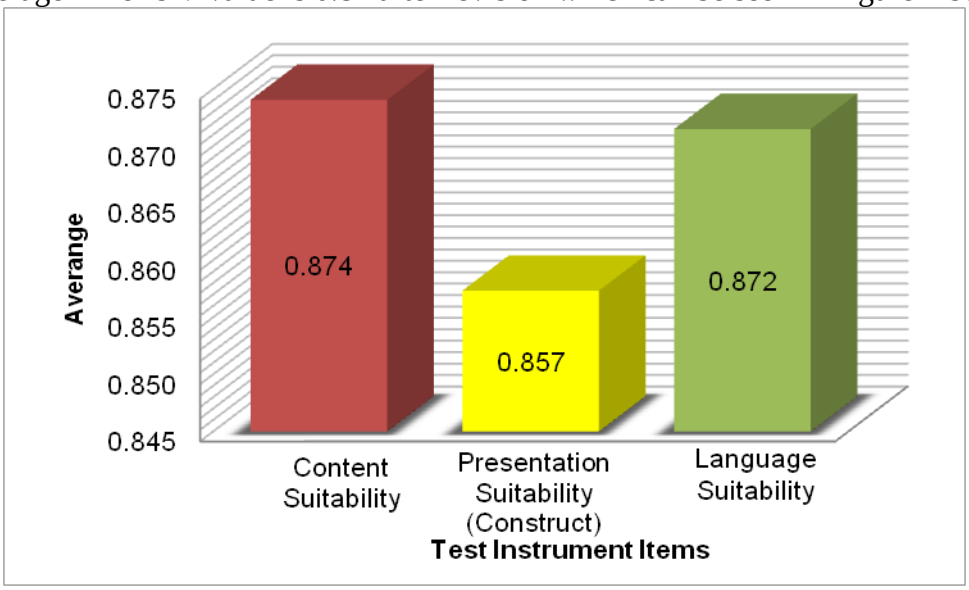


Figure 4. Graph of Average Logical Validity After Revision

The next stage, empirical validity was obtained by conducting a four-tier diagnostic test instrument trial on 34 students of SMAN 7 Padang who had studied salt hydrolysis material. Empirical validity was analyzed using the biserial correlation validity test. Based on the results of data processing, it was found that in the first-tier 18 questions with valid categories and 7 questions with invalid categories while in the third-tier 16 questions with valid categories and 9 questions with invalid categories. Question number 8 is one of the questions in the first-tier and third-tier including the valid category with a validity value of 0.42 and 0.79 respectively. This shows that the information obtained from a test represents the actual understanding of students (Habiddin & Page, 2019). The following is a recap of empirical validity in the first-tier in table 2 and third-tier in table 3.

Table 2. Empirical Validity of the First-tier

Question Number	Category
1, 2, 3, 5, 6, 7, 8, 9, 11,12, 14, 15, 17, 18, 21, 22, 23, 25	Valid
4, 10, 13, 16, 19, 20, 24	Invalid

Table 3. Empirical Validity of the Third-tier

Question Number	Category
1, 3, 5, 7, 8, 9, 11, 14, 15, 17, 18, 19, 21, 22, 23, 25	Valid
2, 4, 6, 10, 12, 13, 16, 20, 24	Invalid

The reliability test was carried out using the KR-20 technique, the reliability value of the four-tier diagnostic test instrument was 0.78 with a high category in the first-tier while in the third-tier it was 0.75 with a high category. A test is declared reliable if repeated data collection on the same subject will produce consistent data (Arikunto, 2016).

b. Index of Difficulty, Discriminating Power, and Distractor Function

To find out the level of difficulty of the question, the question difficulty index test is the existence of a question item whether it is considered difficult, moderate or easy to work on (Sundayana, 2018). Based on the results of the analysis of the difficulty index in the first-tier, it was found that 13 questions in the medium category and 12 questions in the difficult category, one of which was with the lowest difficulty index of 0.09 found in question number 10, this is evidenced that only three students were able to answer the question correctly but the three students were not able to answer with the correct reasoning which means that students are only able to use content reasoning, but have not been able to use conceptual reasoning properly (Habiddin & Page, 2019). while in the third-tier it was found that 12 questions were in the medium category and 13 questions in the difficult category. The following is a recap of the difficulty index in the first-tier in table 4 and the third-tier in table 5.

Table 4. Difficulty Index of the First-Tier

Question Number	Category
1, 5, 8, 11, 12, 15, 16, 20, 21, 22, 23, 24, 25	Medium

2, 3, 4, 6, 7, 9, 10, 13, 14, 17, 18, 19	Difficult

Table 5. Difficulty Index of the Third-Tier

Question Number	Category
1, 2, 4, 5, 8, 9, 12, 14, 15, 18, 21, 23	Medium
3, 6, 7, 10, 11, 13, 16, 17, 19, 20, 22, 24, 25	Difficult

Discriminating power is the ability of a question to be able to distinguish between students with high abilities and those with low abilities (Sundayana, 2018). The differentiating power of questions is categorized into four categories, namely poor, medium, good, very good. Based on the results of the analysis of the discriminating power, one of the questions that is included in the good category in the first-tier is question number 1, while the question that is included in the good category in their-tier is question number 5. This states that the question is able to distinguish between high-ability and low-ability students. Unlike the case with question numbers whose distinguishing power is negative in the first-tier and third-tier, it shows that the question has not been able to distinguish between students with high abilities and those with low abilities. The following is a recap of the discriminating power in the first-tier in table 6 and the third-tier in table 7.

Table 6. Discriminating Powers in the First-tier

Question Number	Category
4, 10, 13, 16, 19, 20, 24	Poor
2, 3, 5, 6, 8, 9, 11, 12, 14, 17, 21, 23	Sufficient
1, 7, 10, 15, 18, 22, 25	Good

Table 7. Discriminating Powers in the Third-tier

Question Number	Category
2, 4, 6, 10, 13, 16, 20, 24	Poor
1, 3, 7, 12, 15, 21, 22, 25	Sufficient
5, 8, 9, 11, 14, 17, 18, 19, 23	Good

The function of the distractor on each item is so that of the many students who take the test there are those who are interested in choosing it because they think the choice is the correct answer. Distractors are said to be good if they can carry out their function well, if the distractor has good attractiveness and is chosen by at least 5% of all students who take the test (Sudiyono, 2005). Based on the results of the analysis of distractors in the first-tier and third-tier on each item, it functions well, this is because in each item more than 5% of students choose answers other than the answer key.

▪ CONCLUSION

The study's findings indicate that the four-tier diagnostic test for assessing students' mental models on salt hydrolysis material is valid, as evidenced by an average Aiken's V index value of 0.87. Based on the results of the trial of the four-tier diagnostic

test instrument questions to students, it was found that the empirical validity value in the first-tier and third-tier there were several questions classified as valid with a total of 18 questions and 16 questions respectively. The reliability value in the first-tier and third-tier is 0.78 and 0.75 respectively with a high category. Analysis of the index of difficulty in the first-tier obtained that 13 questions in the medium category and 12 questions in the difficult category, while in the third-tier obtained that 12 questions in the medium category and 13 questions in the difficult category. Analysis of the discriminating power found that in the first-tier there were 7 questions with poor categories, 12 questions with sufficient categories and 6 questions with good categories, while in the third-tier there were 8 questions with poor categories, 8 questions with sufficient categories and 9 questions with good categories. Furthermore, the distractors on all items can function properly.

▪ REFERENCES

Adawiyah, R., & Azra, F. (2022). Pengembangan Aplikasi Media Pembelajaran Berbasis Android pada Materi Larutan Elektrolit dan Nonelektrolit. *Edukimia*, *4*(1), 018–023. https://doi.org/10.24036/ekj.v4.i1.a333

Aiken, L. R. (1985). Three Coefficients for Analyzing the Reliability and Validity of Ratings. *Educational and Psychological Measurement*, *45*(1), 131–142. https://doi.org/10.1177/0013164485451012

Arikunto. (2016). *Dasar-Dasar Evaluasi Pendidikan* (2nd ed.). Bumi Aksara.

Darmiyanti, W., Rahmawati, Y., Kurniadewi, F., & Ridwan, A. (2017). Analisis Model Mental Siswa Dalam Penerapan Model Pembelajaran Learning Cycle 8e Pada Materi Hidrolisis Garam. *JRPK: Jurnal Riset Pendidikan Kimia*, *7*(1), 38–51. https://doi.org/10.21009/JRPK.071.06

Devetak, I., Drofenik Lorber, E., Juriševič, M., & Glažar, S. A. (2009). Comparing Slovenian year 8 and year 9 elementary school pupils' knowledge of electrolyte chemistry and their intrinsic motivation. *Chem. Educ. Res. Pract.*, *10*(4), 281–290. https://doi.org/10.1039/B920833J

Devi, N. A., & Azra, F. (2023). Pengembangan Instrumen Tes Diagnostik Four-Tier untuk Melihat Gambaran Model Mental Peserta Didik pada Materi Asam Basa. *Entalpi Pendidikan Kimis*, *4*(4), 16–26. https://doi.org/10.24036/epk.v4i4.353

Dolok Putra, D. P. S. (2021). Desain dan Uji Coba Media Pembelajaran Berorientasi Everyday Life Phenomena pada Materi Termokimia. *JRPK: Jurnal Riset Pendidikan Kimia*, *11*(2), 64–73. https://doi.org/10.21009/JRPK.112.02

Fitriani, L. I., & Putra, N. M. D. (2021). Pengembangan Instrumen Tes Diagnostik Pilihan Ganda Tiga Tingkat untuk Mengidentifikasi Pemahaman Konsep Siswa MAN Blora pada Materi Gelombang Bunyi. *Unnes Physics Education Journal*, *10*(1), 53–60. https://doi.org/10.15294/upej.v10i1.46650

Habiddin, H., & Page, E. M. (2019). Development and Validation of a Four-Tier Diagnostic Instrument for Chemical Kinetics (FTDICK). *Indonesian Journal of Chemistry*, *19*(3), 720. https://doi.org/10.22146/ijc.39218

Isnaini, M., Roziah, & Astuti, R. T. (2022). Analisis Kesulitan Belajar Kimia pada Materi Hidrolisis Garam Terhadap Peserta Didik di SMA Jam'iyah Islamiyah. *Prosiding Seminar Nasional Pendidikan Kimia*, *1*(1), 27–43. http://103.84.119.236/index.php/snpk/article/view/51

Jansoon, N., Coll, R. K., & Somsook, E. (2009). *Understanding Mental Models of Dilution in Thai Students*.

Kania, V. I., Samsudin, A., Aminudin, A. H., Rachmadtullah, R., Jermsittiparsert, K., & Nurtanto, M. (2020). Multitier of Greenhouse Effect (MoGE) Instrument Development to Identify Middle School Students' Mental Model in Thailand with Rasch Analysis. *International Journal of Advanced Science and Technology*, *29*(7).

Murni, H. P., Azhar, M., & Ulianas, A. (2019). *Mental Models and Understanding Student of Grade XI High School in the Reaction Rate Material*. *13*(2).

Rachmawati, T., Azhar, M., Aini, S., & Azra, F. (2021). Validity and Practicality of The Salt Hydrolysis Electronic Module Based on Structured Inquiry with Interconnection of Three Levels of Chemicals Representation. *Journal of Physics: Conference Series*, *1788*(1), 012039. https://doi.org/10.1088/1742-6596/1788/1/012039

Rusilowati, A. (2015). Pengembangan Tes Diagnostik Sebagai Alat Evaluasi Kesulitan Belajar Fisika. *Prosiding Seminar Nasional Fisika Dan Pendidikan Fisika (SNFPF)*, *6*(1), 1–10.

Sagita, R., Azra, F., & Azhar, M. (2017). Engembangan Modul Konsep Mol Berbasis Inkuiri Terstruktur Dengan Penekanan Pada Interkoneksi Tiga Level Representasi Kimia Untuk Kelas X SMA. *Jurnal Eksakta Pendidikan (JEP)*, *1*(2), 25. https://doi.org/10.24036/jep.v1i2.48

Sagita, R., Azra, F., & Azhar, M. (2018). Development of Mole Concept Module Based on Structured Inquiry with Interconection of Macro, Submicro, and Symbolic Representation for Grade X of Senior High School. *IOP Conference Series: Materials Science and Engineering*, *335*, 012104. https://doi.org/10.1088/1757-899X/335/1/012104

Sari, C. W., & Helsy, I. (2018). Analisis Kemampuan Tiga Level Representasi Siswa Pada Konsep Asam-Basa Menggunakan Kerangka DAC (Definition, Algorithmic, Conceptual). *JTK (Jurnal Tadris Kimiya)*, *3*(2), 158–170. https://doi.org/10.15575/jtk.v3i2.3660

Silberbeg, M. (2010). *Principles Of General Chemistry Second Edition* (2nd ed.). McGraw-Hill.

Sudiyono, A. (2005). *Pengantar Evaluasi Pendidikan*. Raja Grafindo Persada.

Sundayana, A. (2018). *Statistika Penelitian Pendidikan*. Alfabeta.

sunyono. (2015). *Model Pembelajaran Multipel Representasi*. media akademi.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education*, *10*(2), 159–169. https://doi.org/10.1080/0950069880100204

Utari, N., & Azra, F. (2022). *Development of Android-Based Learning Media Applications on Chemical Equilibrium Materials for Class XI SMA/MA*. *5*(1).

Yani, F. H., Mawardi, & Azra, F. (2019). Development of student worksheet with class and laboratory activity based on guided inquiry in electrolyte and nonectrolyte solution materials. *Journal of Physics: Conference Series*, *1317*(1), 012153. https://doi.org/10.1088/1742-6596/1317/1/012153

.