JPPS (Jurnal Penelitian Pendidikan Sains)
Homepage : https://journal.unesa.ac.id/index.php/jpps
Email : jpps@unesa.ac.id

p-ISSN : 2089-1776 **; e-ISSN :** 2549-1597
JPPS, Vol. 12, No. 2, May 2023 : 108-121

(Jurnal Penelitian Pendidikan Sains)

Practicality of Web-Based Four-Tier Test to Identify Student's Misconceptions in Chemical Bonding Materials

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DOI : *https://doi.org/10.26740/jpps.v12n2.p108-121*

Sections Info

Article history:
Submitted: January 31, 2023
Final Revised: May 2, 2023
Accepted: May 4, 2023
Published: May 23, 2023

Keywords:
Chemical bonds
Education
Four tier test
Misconceptions
Website

ABSTRACT

Misconceptions can be identified using a four-level test format diagnostic test. However, this test is less effective because it still uses paper/print and requires a long time at the correction stage. Therefore, it is necessary to develop a web-based four-level test. ***Objective:*** *The purpose of this research is to find out the practicality of a web-based four-level test.* ***Methods:*** *This type of research is descriptive quantitative with data sources from class X MIPA MAN 1 Hulu Sungai Tengah. The data collection technique uses a questionnaire to test practicality.* ***Results:*** *The results of the practicality test obtained an average percentage of 82.5% in the very practical category in aspects of web appearance, image clarity, material suitability, language, paperless, and helping to determine students' abilities and weaknesses in chemical bonding material. Based on this assessment, a web-based four-level practice test product was used to identify misconceptions in class X MIPA MAN 1 Hulu Sungai Tengah. While the results of students' misconceptions on Lewis structure indicators in chemical compounds were 49.21%, ionic bond formation indicators were 39.68%, covalent bond formation indicators were 47.09%, polar covalent compound indicators were 38.89%, metallic bond indicators were 39.42%, and indicators of the physical properties of compounds based on their bonds of 46.03%. All percentages on these indicators include medium criteria.* ***Novelty:*** *Previous researchers have never done this research, which measured students' misconceptions with web-based four-tier test in chemistry concept.*

INTRODUCTION

Chemistry is one lessons that have characteristic abstract (Anggi Priliyanti et al., 2021; Ristiyani & Bahriah, 2016). Another charachters is atiered concept and is related to calculation (Santi & Rahayu, 2022). Subjects considered difficult for understood student is lesson chemical (Tutiana et al., 2022; Yakina et al., 2017). Student required understand concepts in chemical in a manner intact to avoid from difficulty in learn knowledge chemical (Murniningsih et al., 2020; Safitri et al., 2018). Difficulty understand draft possible student experience error concept. Every student own draft the initial (preconception) brought as knowledge early, if draft beginning no corresponding with draft scientific so will happen misconception or error draft (Rahman et al., 2014). Misconception is one understanding of the concept that is not in accordance with the experts (Fantiani et al., 2023; Karim et al., 2022; Yolviansyah et al., 2022).

Error concept in students can caused by previous experiences experienced as student in the learning process difficulty or wrong hook draft new with concept (Halim et al., 2017). Misconceptions can also occur due to students' initial knowledge that is not appropriate (Murniningsih et al., 2020; Rahmiati et al., 2022; Sofianto et al., 2020). There is misconceptions in lessons chemical could fatal because concepts chemical generally

taught in a manner coherent from easy concept to difficult, of such a simple concept to complex. If the concept is easy and simple student already experience misconception, then next student will the more difficulty in understand concepts difficult and complex chemistry (Halim et al., 2017).

One of the subject matter in chemistry lessons that can experience misconceptions is the material of chemical bonds. The concept of chemical bonds underlies most of the concepts in advanced sciences in chemistry such as inorganic chemistry, organic chemistry, and physical chemistry (Islami et al., 2018). Misconceptions students on the material bond chemical reinforced research by Setiawan et al., (2017a), et al which stated analysis misconceptions on the topic bond identified chemical of 54.48%. This was also reinforced by the interviews conducted to chemistry teacher and deployment questionnaire to 32 students class X MIPA MAN 1 Hulu Sungai Tengah, got researcher identification that student experience difficulty in understand Theory bond chemical because characteristic material abstract. Based on results task ever done student, student indicated experience misconception.

Identification misconception is important thing conducted in the learning process chemical (Rizki & Setyarsih, 2022). Wrong one method for know identify level understanding as well as misconceptions about the material certain ie with use device test given diagnostics to student after learning (Astuti et al., 2021) . Test diagnostic could used for find weakness in understand a number of part from Theory learning and discovering reason weaknesses and strengths student in tree discussion the (Elvia et al., 2021). One of type diagnostic test ie *four-tier test* (Wilantika et al., 2018).

The four-tier diagnostic test is an update or development of the three-tier diagnostic test (Saputri et al., 2021). In addition, the advantage of the four-tier is that it can obtain data that will be able to distinguish the abilities of students who understand concepts, do not understand concepts, misconceptions and errors (Kaltakci-Gurel et al., 2017; Triastutik et al., 2021). In general, the developed four-tier test diagnostic test instrument is still in the form of a paper-based test which is considered impractical in its use. The test instrument which consists of many questions requires a lot of paper which can cause errors when correcting manually and is not environmentally friendly because it does not support the go green program (Septiyana, 2019).

One alternative to minimize correction errors is to utilize technology (Chen et al., 2020), such as technology that uses a computer or internet-based website or web. The system on the web can identify student misconceptions quickly and can immediately categorize students based on understanding concepts and descriptions of student misconceptions quickly and precisely (Maison et al., 2020; Peprizal & Syah, 2020). By using a web-based four tier test, it can make it easier to identify wrong concepts in these students. Therefore, a website-based four-tier test has been developed to identify students' misconceptions about chemical bonds.

The development of a website-based four tier test has reached the expert validation and empirical validation stages. The results of the material expert validation on the four tier test instrument showed that the instrument was classified as valid with a

percentage of 92%. While the results of media expert validation show that the instrument is very valid in terms of appearance, language and application usage. For the empirical validation test, it shows that of the 18 questions developed, 16 questions were declared valid. Thus, the website-based four-tier test instrument was deemed feasible to be tested on students.

The website-based four tier test trial phase must be carried out on students to find out the practicality of the instrument. This practicality test serves to determine the quality of the product being developed and the extent to which the product is practical to identify student misconceptions (Annisa et al., 2020). In addition, with practicality testing it can help instrument developers to revise parts that need to be repaired. If the practicality test has been carried out, then the instrument is ready to be used to identify students' misconceptions about chemical bonds. Therefore, it is necessary to conduct a practical test of the website-based four-tier test instrument. which will be conducted in this research with the objective to identify students' misconceptions about chemical bonding material.

RESEARCH METHOD

This research is a descriptive research with a quantitative descriptive approach to explain the research results. The technique of collecting data through tests is using diagnostic instruments in the form of four-tier tests and practicality questionnaires for students who have taken the web-based four-tier test. The samples in this study came from 63 students of class X MIPA 1 and X MIPA 2 at MAN 1 Hulu Sungai Tengah who had received chemical bonding materials. Class X MIPA 3 is not used because the teachers hold different chemistry subjects, and the indicators used are also different.

The test in this study was in the form of a multiple-choice test with a four-tier web-based format consisting of 18 questions tested for empirical validation on students of class X MIPA 1 and X MIPA 2 MAN 2 Hulu Sungai Tengah. After the empirical validation test was carried out, 16 valid questions were obtained. The 16 valid questions are used as questions used for the application of web-based four-tier test questions. The web-based four-tier test was carried out to test the practicality of 5 students as a sample. Students were asked to fill out a questionnaire to assess the practicality of the product. The assessment is given using a Likert scale. The data analysis technique uses the assessment interpretation criteria table shown in Table 1. (Milala et al., 2022).

Table 1. Practicality Score Interpretation

No	Value Ratings	Category
1	81% - 100%	Very Practical
2	61% - 80%	Practical
3	41% - 60%	Currently
4	21% - 41%	Less Practical
5	0% - 20%	Not Practical

The results of misconceptions were identified using the developed web-based four-tier test product. On the web, the percentages generated will be categorized into understanding concepts, not understanding concepts, and misconceptions with the following formula (1) (Zayyinah et al., 2018):

$$P = \frac{S}{Js} x\ 100\% \ldots\ldots\ldots (1)$$

Description :

P : Percentage total students understand concept, no understand concepts, and misconceptions

S : Amount students understand concept, no understand concepts, and misconceptions

Js : Amount whole student test

The results of calculations based on the percentage of misconceptions are then grouped according to Table 2 (Sheftyawan et al., 2018).

Table 2. Misconception Criteria Based on the Percentage

Criteria	Percentage
Tall	61% - 100%
Currently	31% - 60%
Low	0 - 30%

RESULTS AND DISCUSSION

Results

After students have finished working on the questions on the website, students can find out the percentage of test results by clicking see percentage, categories and percentages of test results will appear. The percentage of test results on this website can be seen in Figure 1.

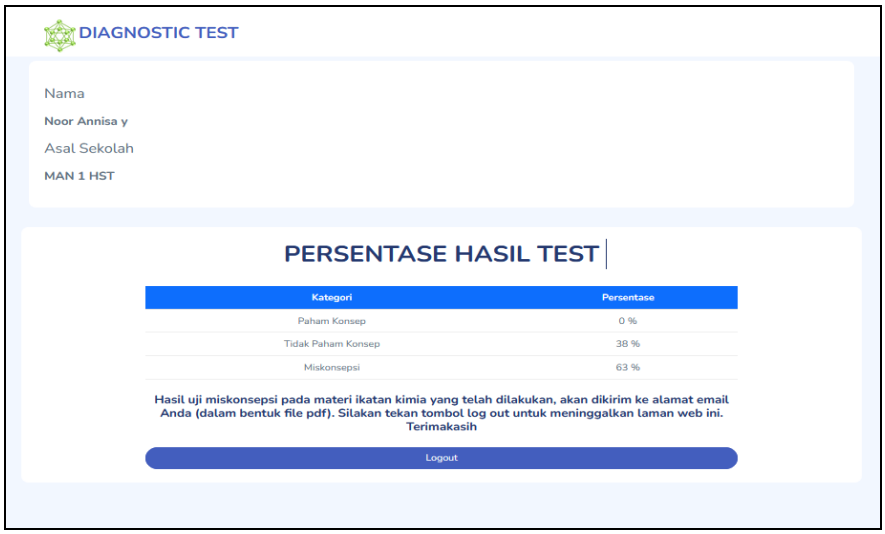

Figure 1. Percentage of Test Results page on the web

This practicality test is carried out after students complete the web-based four-tier test or after an empirical validation test is carried out. The practicality test was carried out by distributing questionnaires to 5 students. The practicality results based on an assessment with a Likert scale are shown in Table 3.

Table 3. Practicality Test Results

Student	Percentage
A	85%
B	85%
C	82.5%
D	82.5%
E	77.5%
Percentage average	82.5%

After the web is declared practical, then proceed to the web-based four-tier product test stage. The number of questions on the web is 16 questions. This test was conducted on 63 students of MAN 1 Hulu Sungai Tengah, namely students in class X MIPA 1 and X MIPA 2 on Wednesday, 25 May 2022 via the link https://diagnostic-testt.herokuapp.com This web-based four-tier test format diagnostic test shows that there is an update due to the use of the web which can make corrections easier, has higher accuracy, is flexible in time and place, and other advantages. Through this website you can also find out about concepts, not concepts and misconceptions experienced by each student. The results of applying the four-tier test product can be seen in Table 4.

Table 4. Test Results Four-Tier Test based web

Indicator	Number About	Percentage	Criteria
Lewis structure of compounds chemical	1, 2, 3, 4	49.21%	Currently
Formation ionic bond	5, 6, 7	39.68%	Currently
Formation bond covalent	8, 9, 10	47.09%	Currently
Compound polar covalent	11, 12	38.89%	Currently
Bond metal	13, 14	39.42%	Currently
Physical properties compound based on the bond	15, 16	46.03%	Currently
Average		43.39%	Currently

Based on Table 4, there are 6 sub-concepts of chemical bonding material that experience misconceptions in the results of applying the web-based four-tier test. Analysis of the results of the research on the misconceptions that occur in each sub-concept are as follows:

Lewis Structures in Chemical Compounds

The misconception that occurs in the Lewis structure sub-concept of chemical compounds is 49.21%. This sub-concept is represented by questions number 1, 2, 3, and 4. In this indicator, the highest percentage of misconceptions is number 1 of 52.03% and item number 4 of 71.42%. Meanwhile, questions 2 and 3 have lower percentages, namely 34.92% and 38.09%. The following is a discussion of questions number 1 and 4 because they have a misconception percentage of more than 50%:

Question number 1

Conceptually, the Lewis symbol is the symbol for an element with the dots representing the valence electrons of the atom. Element O has an atomic number of 8, with a valence electron of 6. So that in the Lewis symbol of element O, the number of electrons depicted with dots around the atom is 6. The Lewis symbol of element O can be seen in Figure 2.

Figure 2. Lewis symbol of element O

However, the students misrepresented the Lewis symbol of the O atom. This could be seen from the number of students who answered C in the choice of answers and answered B in the choice of reasons. According to students around the O atom there are 8 electrons with the reason that the Lewis symbol is indicated by the atomic number. Student answer choices at point C can be seen in Figure 3.

Figure 3. Choice of student answers at point C

This shows that students have misconceptions, because conceptually the Lewis symbol is shown by valence electrons.

Question number 4

In question number 4, questions related to Lewis structures in covalent compounds are presented. Conceptually, a covalent bond consists of a single covalent bond, a double covalent bond, and a triple covalent bond. If there is only one pair of bonding electrons between two atoms in a molecule, the bond is called a single covalent bond. The questions presented are asking the Lewis structure of the HCl compound which is a covalent compound. The HCl compound is a single covalent bond, because H and Cl

atoms share an electron pair. In general, students have answered correctly in the answer choices, but students are wrong in determining the lone pair found in the reason choices. This can be seen from the student's choice of reasons which stated that HCl has 1 pair of lone electrons. This shows that students have a misconception that HCl should have 3 pairs of lone electrons.

Formation of Ionic Bonds

The misconception that occurs in the sub-concept of forming ionic bonds is 39.68%. This sub-concept is represented by questions number 5, 6, and 7. In this indicator, the highest percentage of misconceptions is in question number 5 of 52.38%. While questions 6 and 7 have lower percentages, namely 28.57% and 38.09%. Therefore, the discussion of questions on this indicator is represented by question number 5. This problem contains questions related to the formation of ionic bonds which are known from each atomic number. Conceptually in forming ions, an atom will lose or gain electrons. The elements in a period from left to right have greater ionization energies.

Atoms with low ionization energies tend to lose electrons, while atoms with high ionization energies tend to gain electrons. Ionic bonds occur because the positive ions and negative ions that are formed will attract each other with electrostatic forces to form neutral compounds. In general, students have answered correctly, but students are still not precise in making choices because the elements X and Y are intertwined together. Ionic bonds should occur because element X as a negative ion and element Y as a positive ion attract each other with electrostatic forces to form a neutral compound.

Formation of Covalent Bonds

The misconception that occurs in the sub-concept of covalent bond formation is 47.09%. This sub-concept is represented by questions number 8, 9 and 10. The misconception that occurs in the sub-concept of covalent bond formation is 47.09%. This sub-concept is represented by questions number 8, 9 and 10. In this sub-concept, the highest percentage of misconceptions is number 8 and 10, which both have a misconception percentage of 57.14%. While question number 9 has a lower percentage, namely 29.68%. Therefore, the discussion of questions on this indicator is represented by questions numbers 8 and 10. The following is a discussion of questions numbers 8 and 10:ghest percentage of misconceptions is number 8 and 10, which both have a misconception percentage of 57.14%. While question number 9 has a lower percentage, namely 29.68%. Therefore, the discussion of questions on this indicator is represented by questions numbers 8 and 10. The following is a discussion of questions numbers 8 and 10:

Question number 8

In question number 8, the Lewis structure of the SO_3 compound is presented to determine the bonds. Conceptually, the bond shown in number 1 is a coordinate covalent bond, because the electron pair used comes from one of the bonding atoms, namely S atom donates an electron pair to O atom. Of the 63 students, 36 students

experienced misconceptions. In general, there are 2 patterns of students' answers that experience misconceptions. The pattern of the first answer is that students choose A in the answer choices, namely ionic bonds, on the grounds that electrons in metal and non-metal elements are shared. Conceptually, S and O atoms are non-metallic elements. The ionic bond itself is formed because positive ions and negative ions attract each other with electrostatic forces to form neutral compounds.

As for the second misconception pattern, students choose C in the answer choices, namely covalent bonds and choose E in the choice of reasons. Even though in the picture presented, the covalent bond is formed in the bond shown in number 2, namely the double covalent bond 2. While the number 1 in the picture in the question is a coordination covalent bond, this is because the bond is formed because the electrons only come from one one atom is shared. This is not in accordance with the concept, thus showing students experiencing misconceptions.

Question number 10

In question number 10, the atomic number of the F atom is presented. Students are asked to determine the correct covalent formation of F_2. Conceptually, a covalent bond is formed when a pair of electrons is shared by two atoms. In the formation of an F_2 covalent bond, each bonded atom contributes one electron in the formation of a covalent bond. The F atom has 7 electrons so it requires one electron from the other F atom to bond together. As many as 36 out of 63 students chose the correct answer, namely at point C, but the students were wrong in choosing the reason for the answer. According to students, the formation of an F_2 covalent bond is formed because it has 5 electrons belonging to an F atom so it requires 1 electron from another F atom to bond together. This shows students experience misconceptions.

Polar Covalent Compounds

The misconception that occurs in the sub-concept of polar covalent compounds is 38.89%. This sub-concept is represented by questions number 11 and 12. On this indicator, the percentage of misconceptions number 11 is higher than number 12. Question number 11 is 42.85% and question number 12 is 34.92%. Therefore, the discussion of questions on this sub-concept is represented by question number 11 which has a higher percentage. In problem number 11, students are asked to determine which molecule has the highest polarity. Conceptually, a polar covalent bond occurs when the two atoms bonded are different atoms. The electron pair in a polar covalent bond is attracted more strongly to the atom with the greater electronegativity. As many as 27 out of 63 students have chosen the correct answer choice, namely answer option D, namely H_2O. However, students are wrong in choosing the reason choices. Some students chose the reason for point A, according to students the H_2O bond occurs because the 2 atoms are the same. Other students chose D in their choice of reasons, according to students the H_2O bond was formed due to the bonding of non-metallic and non-metallic atoms. This shows students experience misconceptions.

Metallic Bonds

The misconception that occurred in the metal bond sub-concept was 34.92%. This sub-concept is represented by questions number 13 and 14. On this indicator, the percentage of misconceptions about number 13 is higher than number 14. Question number 13 is 52.38% and question number 14 is 17.46%. Question number 13 is a question regarding the correct order of the strength of metallic bonds between Si, Al, Mg, and Na metals. Si metal has a lower metallic bond strength than Al. Conceptually, a metallic bond is defined as the attractive force between metal cations and the negatively charged electron cloud formed by the valence electrons of metal atoms. The strength of the metallic bond depends on the bond between the cation nuclei and the electron cloud. The distance between the ion core and the electron cloud in Si < Al < Mg < Na metals results in the strength of the metallic bond in Si > Al > Mg > Na metals. However, in the answer choices students chose answer E, namely Na > Si on the grounds that the atomic number of Na is smaller than the atom of Si so that the bond strength of Na is greater. Conceptually, the greater the atomic number, the greater the strength of the metallic bond.

Physical Properties of Compounds Based on Bonds

The misconception that occurs in the sub-concept of the physical properties of compounds based on their bonds is 46.03%. This sub-concept is represented by questions number 15 and 16. In this sub-concept, the percentage of misconceptions about number 16 is higher than number 15. Question number 15 is 41.26% and question number 16 is 50.79%. This indicator is represented by the discussion in question number 16 because it has a percentage of more than 50%. In problem number 16, students are asked to relate the melting point to the electrical conductivity of a substance from ionic compounds.

As many as 32 out of 63 students have chosen D, namely compound IV in the answer choices which is the correct answer. However, the students were wrong in choosing the reason, the students chose point D, namely in the molten state, the ions began to stretch and the ions could move, although not too freely, so they could not conduct electricity. Meanwhile, in the solution state, the ions decompose in the solution state so that they can conduct electricity. Conceptually, ionic compounds have high boiling points, and in melts and solutions can conduct electricity. This is because in the molten state, ionic compounds begin to stretch and move freely so that they can conduct electricity. Meanwhile, in the solution state, the ions decompose in the solution state so that they can conduct electricity.

Discussion

Based on Table 3 regarding the practicality test, it shows a practicality percentage of 82.5% which is classified as very practical based on web appearance, image clarity, ease of language, suitability of material, saving paper because it is paperless, and helps identify abilities and weaknesses in mastering chemical bonding material. The use of

this web-based four-tier test has several advantages, namely being able to correct the results of working on questions automatically so that test results can be known more quickly and minimize correction errors (Suyoso & Subroto, 2017).

This is in line with previous research that has been carried out explaining that the web system can identify student misconceptions more quickly and can directly categorize students based on understanding concepts and descriptions of student misconceptions quickly and precisely (Hanum et al., 2021). In addition, the four-tier test questions developed in paperless form are a step in the digital era to reduce paper use. Another advantage is that it is flexible with respect to time and place because students only need to use a cell phone or computer to do a misconception test (Saputri et al., 2021). In addition to obtaining a practicality test, there were also suggestions from several students for product based *four-tier test web*, namely that logging into the web could be done more than once using the same e-mail. However, because this product is used to carry out a misconception test, the product is specifically designed for one-time access. The negative impact if it can be accessed many times will cause students to know the questions earlier because the email used can be logged in again. Therefore, the web-based four-tier test product was not repaired based on the suggestion and maintained a product that could only log in to the same email once.

In using this web it can also be seen that the misconceptions experienced by students X MIPA 1 and X MIPA 2 at MAN 1 Hulu Sungai Tengah based on Table 4 of 6 sub-concepts, the average percentage is 43.39% with the criteria of "Moderate" and the highest misconception found in the Lewis Structure sub-concept of chemical compounds with a percentage of 49.21% with moderate criteria. Students experience misconceptions in writing Lewis structures in chemical compounds. This is in accordance with the statement Warsito et al., (2021) that there are still 47% of students in describing Lewis structures in chemical compounds bonds correctly. For example on MgCl2; students describe the Lewis structure of MgCl2 along with the charges on Mg and Cl. The highest misconception in this sub-concept is in question number 4 with a percentage of 71.42%. This question tests students' understanding of covalent bonds. Most covalent compounds involve lone pairs of electrons. Covalent compounds in HCl have 3 lone pairs of electrons (Effendy, 2016). Most students do not understand lone electron pairs, this is in line with research by (Yakubi et al., 2017) that students do not understand how to determine the electrons used from two bonded atoms to fulfill the octet rule.

CONCLUSION

Fundamental finding: The research that has been carried out has resulted in the conclusion that the results of the practicality test obtained in the very practical category based on web appearance, image clarity, ease of language, suitability of material, saving paper because it is paperless. In addition, it can also help determine the abilities and weaknesses in mastering chemical bonding material. The students' misconceptions about Lewis structure indicators for chemical compounds were included moderate

criteria, indicators for the formation of ionic bonds were included moderate criteria, indicators for the formation of covalent bonds were included moderate criteria, indicators for polar covalent compounds were included moderate criteria, metal bond indicator were included moderate criteria, and indicators of physical properties of compounds based on their bonds amounted were included moderate criteria. **Implication:** The existence of a web-based four-tier test format diagnostic test is expected to be an effort to remediate misconceptions about chemical bonds that occur in students, as well as assist teachers in overcoming misconceptions so that they can create better learning in the future. **Limited:** This research only focuses on chemical bonding materials. **Future research:** So it is hoped that further research on other chemical materials and even better web development.

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