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An analysis of students conceptual understanding of submicroscopic level in solubility and solubility product constant (Ksp) using three-tier multiple choice test

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Abstract. This research aims to know the student's conceptual understanding of the submicroscopic level using a three-tier multiple choice test with the help of multiple representation's teaching material. This research used mix method with sequential explanatory strategies, and the research subject was students of Islamic senior high school (MA) Riyadlotut Thalabah, Rembang, Central Java, Indonesia which consists of the class of XI IPA 1, XI IPA 2, and XI IPA 3. The data collection technique used three-tier multiple choice test that most questions focus on the submicroscopic level. The result shows that the percentage of students' Conceptual Understanding of Particulate Level on Solubility and Solubility Product Constant (Ksp) material was 15,14% for Scientific Knowledge(understand)category, misconception type 1 was 7,99%, misconception type 2 was 0,97%, misconception type 3 was 21,55%, lack of knowledge type 1 was 5,06 %, lack of knowledge type 2 was 0,36%, lack of knowledge type 3 was 46,03%, and for lucky guess was 2,86%.

1. Introduction

Chemistry is part of science that includes chemical knowledge in the form of facts, theories, principles and laws based on scientific findings and scientific work. There are 3 characteristics in chemistry they are, (i) abstract in most of its concepts, (ii) chemical concepts in general are a simplification of the actual situation, and (iii) chemical concepts are sequential and tiered [1]. Concepts are essential when studying chemistry. The deep concept will allow students to have various ways to find solutions to problems.

The Complexity and abstract of concepts in chemistry make students assume that chemistry is a difficult lesson [2]. Particulate or submicroscopic levels are the most abstract parts in studying chemical concepts [3]. This causes students to have difficulty understanding the submicroscopic level and building knowledge from one context to another [4]. At this level, students often have difficulty understanding the concept of chemistry so that there is the potential for misconceptions.

The interrelated between the three levels of chemical representation have been widely examined with the conclusion that students do not have a complete understanding of chemical phenomena and



between each level of chemical representation [4-6]. This is also following the results of interviews with chemistry teachers and some students on early observations. The results of early observations indicate that students have difficulty when working on problems related to the effect of pH on solubility, the effect of the same ions on solubility and the concept of sedimentation reactions. Students still have difficulty representing at particulate level, that is when the process of ionizing a salt. Students are still often wrong and still confused when asked to write ionization reaction from the salt in the solubility and solubility product constant (K_{sp}) material. Previous research conducted by Ulfah et al. (2016) also shows the difficulty of understanding concepts experienced by students in solubility material and the 95% solubility results include all concepts tested [7].

Understanding a chemical concept intact it must know the concept both from the macroscopic, submicroscopic, and symbolic levels. The three levels of chemical representation must be proportionally integrated into learning because aspects of macroscopic, submicroscopic, and symbolic representation contain information on concepts that cannot be separated [8-12].

Understanding the concept of students can be known by diagnostic tests. Diagnostic tests are one way to find out the early knowledge and misconceptions that occur in students [9-13]. The diagnostic test model used in this research was a three-tier multiple choice test. Three-tier multiple choice test consists of three levels of questions. At the first level contains multiple choice questions with answer choices. The second level contains questions about the reasons, and the third level contains questions about students' beliefs in answering first and second level questions. A three-tier multiple choice is considered to be more accurate in raising students' misunderstandings because this test can detect a lack of percentage of knowledge utilizing the level of trust [9,14].

Based on the description, the researcher intends to analyze the concept understanding on the level of particulates with a three-tier multiple choice test instrument on solubility and solubility product constant (K_{sp}) with the help of multiple representation-based teaching materials.

2. Methods

The research design used is a mixed method with sequential explanatory strategy design. Subjects in this research were students of class XI MIA Madrasah Aliyah Riyadlotut Thalabah in 2017/2018 academic year, and they were class XI MIA 1, XI MIA 2, XI MIA 3 where each class consisted of 39 students.

The study began with an early observation. The early observations were made through interviews with teachers and some students related to the learning carried out at the school. Known problems then followed up with the preparation of appropriate learning designs equipped with instruments that support chemistry teaching materials on solubility and solubility product constant (K_{sp}) based on multiple representations that are used as tools for the introduction of representation levels, lesson plan, syllabus, and questions three-tier multiple choice diagnostic test. The instruments that have been compiled are then validated. Validity testing consists of two stages, namely the content validity and the validity of each item. The content validity testing was carried out by three lecturers of the Postgraduate Program Universitas Negeri Semarang and 1 Chemistry teacher of Madrasah Aliyah Riyadlotut Thalabah.

Research data sources are quantitative and qualitative data. The test method was carried out to obtain quantitative data through test trials of questions and diagnostic tests on three-tier multiple choice questions. The test was conducted in class XII MIA 1 with a total of 38 students, and they were students who had received solubility material and solubility results. The results of the trial questions were then analyzed and the results of the questions that fulfilled the valid criteria, the level of difficulty, different power of questions, and reliability were used for diagnostic tests in the 117 subjects of the study consisting of class XI MIA 1, XI MIA 2, and XI MIA 3. Qualitative data in the form of in-depth interview results to determine students' concept understanding, implementation of three-tier multiple choice test, type of concept misconception experienced by students on solubility and solubility (K_{sp}) results.

3. Result and Discussion

The results of the study consisted of teaching materials based on multiple representation, three-tier multiple choice diagnostic test instruments, and the results of an analysis of the understanding of the concept of particulate level through a three-tier diagnostic test. Characteristics of teaching materials based on multiple representations produced in this research using animated image media, photos, and videos related to solubility and solubility product constant (Ksp), and thinking skills-based questions. three-tier multiple choice test characteristics used in the research are (1) Each item is mostly focused on particulate level or submicroscopic level, (2) Each item consists of three levels (Tier). The first level is in the form of multiple choice questions with one correct answer key and four deceptive items, the second level is the column provided for students to write down reasons, and the third level is a column of confidence that contains choices "sure" and "not sure", (3) Guidelines interpretation of student test results to classify categories of understanding, misconception, lack of understanding, and guessing based on Arslan et al. (2012) [15] shown in Table 1.

Table 1. Interpretation of based answer combinations [15]

First Tier	Second Tier	Third Tier	Category
Correct	Correct	Certain	Scientific Knowledge
Correct	Incorrect	Certain	Misconception (false positive) type 1
Incorrect	Correct	Certain	Misconception (false negative) type 2
Incorrect	Incorrect	Certain	Misconception
Correct	Incorrect	Uncertain	Lack of knowledge Type 1
Incorrect	Correct	Uncertain	Lack of knowledge Type 2
Incorrect	Incorrect	Uncertain	Lack of knowledge Type 3
Correct	Correct	Uncertain	Lucky guess

The recapitulation of the results of the research instrument validation consisting of teaching materials, syllabus, lesson plans, and diagnostic test questions are found in Table 2.

Table 2. Recapitulation of results of validation of research instruments

No	Instruments that validated	Validator Score				Total	Validation Score	Criteria
		1	2	3	4			
1	Teaching material: Material assessment	144	159	167	140	610	0,75	Valid
2	Teaching material: Legibility	40	37	35	32	144	0,76	Valid
3	Syllabus	33	37	-	-	70	0,83	Valid
4	Lesson plan	48	45	44	43	180	0,82	Valid
5	Diagnostic test question	18	18	17	-	53	0,84	Valid

Based on the results listed in Table 2, it can be concluded that all research instruments have valid criteria. Validation of instruments was done by validator with scoring guidelines ranging from 1 to 4. If the validator gave a score 4 on each point, the maximum score of teaching materials for material assessment and readability was 188 and 44, the maximum score of the syllabus was 40, the maximum score of lesson plan was 52, and the maximum score of the diagnostic test questions was 20. The score obtained from the validator was calculated using the Aiken V formula, which was by calculating the score from the validator minus the lowest guideline score then divided by the number of validators multiplied by the highest score guidelines minus 1. The calculation results show more than 0.75 for each instrument, and it meant each instrument belongs to a valid category. All instruments also fulfill the category worthy of use because the average score of each validator was 3. All research instruments can be used in trials after some improvements were made by the notes given by the validator.

The results of the combination of the students' answers from the diagnostic test questions included in the particulate level category are as many as 14 questions which can be seen in Table 3, and they were the question grouping table based on the representation level of the 20 diagnostic test questions. The percentage of students' answers to particulate level questions is presented in Figure 1.

There were 14 questions that met the criteria of the particulate level in the diagnostic test questions of the 20 questions used, namely at numbers 2, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20. The 14 particulate questions were then analyzed by the students' answers to find out their understanding of the concept of solubility and solubility (K_{sp}).

Table 3. Grouping questions based on representation level

Number	Level of Representation	Number	Level of Representation
1	Macroscopic & Symbolic	11	Macroscopic& Sub-microscopic
2	Macroscopic & Sub-microscopic	12	Symbolic & Sub-microscopic
3	Macroscopic	13	Symbolic&Sub-microscopic
4	Macroscopic&Symbolic	14	Macroscopic&Sub-microscopic
5	Symbolic&Sub-microscopic	15	Symbolic&Sub-microscopic
6	Symbolic	16	Symbolic&Sub-microscopic
7	Macroscopic& Simbolik	17	Symbolic&Sub-microscopic
8	Symbolic	18	Macroscopic&Sub-microscopic
9	Sub-microscopic	19	Symbolic&Sub-microscopic
10	Symbolic&Sub-microscopic	20	Symbolic&Sub-microscopic

The percentage of students' answers to particulate level questions is presented in Figure 1.

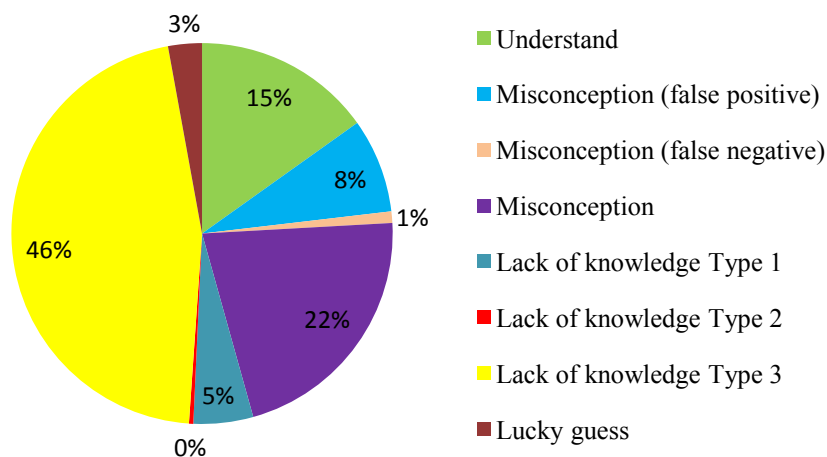


Figure 1. Percentage of results of combined answers to the problem of particulate levels

Details on the percentage profile of understanding the concept of particulate level on solubility and solubility product constant (K_{sp}) was 15% of students understood the concept, meaning that out of 117 research subjects, only 26 students answered the multiple choice questions correctly, gave reasons correctly, and believed in answering and giving reasons. The percentage of students' misconception type 1 was 8%, it means only 7 students who had misconception type 1 of 117 students. The students were had misconception type 1 when students answer multiple choice questions correctly and feel confident, even though the reasons written are wrong. As many as 1% of students had misconception type 2. This means that only 2 research subjects did not have misconception type 2. Students are categorized as having misconception type 2 when students answer incorrectly on multiple choice questions, while the reasons are written correctly and feel confident answering them. This type of

answer is almost the same as lack of knowledge type 2, which distinguishes only the level of confidence. If the misconception type 2, the participant feels confident about the answer, while in the lack of knowledge type 2, students feel uncertain about the answer. These two categories are very rare for students because the answers to the multiple choice questions affect students to determine the reasons. This is according to the research conducted by Rositasari et al. (2014) that the probability of answering correctly was more in the first tier compared to the second tier. If the first tier students have answered wrongly, it was very unlikely to answer the reason (second tier) [16].

Students who had misconceptions type 3 was 22%. Students are categorized as having type 3 of misconception when students answer incorrectly on multiple choice questions and reasons, while students feel confident about the answer. There were 16 students from 117 who had type 3 of misconceptions. The percentage of students in lack of knowledge type 1 was 5%. This means that 6 students still did not understand the material provided. Students are categorized as lack of knowledge type 1, when students answer correctly on multiple choice questions, while the reasons are incorrect and feel uncertain about answering them. The percentage of students with lack of knowledge type 2 approaching 0%. It can be interpreted that almost all research subjects did not have lack of knowledge type 2. Students were categorized as lack of knowledge type 2 when students answered incorrectly on multiple choice questions, while the reasons were correctly written and felt unsure about answering them. The percentage of students with type 3 of lack of knowledge as 46%. This is the highest percentage of 8 types of student answers. Students are categorized as lack of knowledge type 3, that was when students answer incorrectly on multiple choice questions, the reasons written are also wrong, and they are not sure about answering them, and there were 38 students who had the lack of knowledge type 3. The lack of understanding of students can be caused due to lack of maturity of planning and also be caused by the material of bankruptcy and the results of solubility (K_{sp}) is material that most of the concepts are abstract and most of the diagnostic test questions given are particulate level which is a study of abstract concepts [3] so that students still have difficulty understanding it. The last category is guessing, and the percentage of students who answer with the guessing category is 3%. Students are categorized as guessing when students answer correctly in multiple choice questions and reasons, while students feel uncertain about the answers. The results of the analysis of both the answers of the 20 diagnostic test questions given and the 14 questions about the particulate level in the guess category have a small percentage of 3%. This is one of the advantages of reasoned multiple choice test questions that is to reduce students' answers to the guessing category [16].

Based on the percentage of the results of the analysis of the understanding of the concept of the particulate level of students in the solubility material and the results of solubility times (K_{sp}) can be explained the results of understanding the concepts that are grouped into 5 subtopics. The analysis decomposition is also supported based on the results of interviews of 9 students selected from each class of 3 people with consideration of students who have high understanding scores, high misconceptions, and high scores. They were interviewed as confirmation of the answers they wrote.

Based on the results of in-depth interviews for solubility material, it shows that most students understand the concept of solubility at the particulate level. The most common mistakes in the sub-material results of solubility (K_{sp}) are that students are still experiencing confusion when the ionization process of soluble difficult electrolyte compounds is presented in the problem to determine the solubility formula of the compound. For example, during the ionization process of lead azide compound, which has the formula $Pb(N_3)_2$, some students experience confusion during the ionization process. $Pb(N_3)_2$ which should be ionized to Pb^{2+} and $2N_3^-$ ions, ionize it to Pb^{3+} and $3N^-$, some even become Pb^{6+} and $6N^-$. The difficulty in the sub-material of the influence of namesake ions is that students still experience difficulties and confusion in using the concentration (molarity) used in the calculation. The difficulties experienced by students in the K_{sp} sub-material and the sedimentation reaction are at the time of the solubility calculation process to estimate deposits. The ionization process is very important in determining the solubility formula. When the ionization process is not

correct, it can lead to the inappropriate formula solubility of the compound, which affects the solubility value.

4. Conclusion

Solubility and solubility product constant (Ksp) chemistry teaching materials based on multiple representations arranged as a tool for recognition of representation levels in multiple representations included in the valid category by obtaining validity values of 0.75 for content and 0.76 for legibility, The instrument of three choice tier multiple choice diagnostic test was arranged to analyze the understanding of the concept of particulate level of students in the valid category with a value of 0.84 by the validator, and understanding the concept of particulate level of students on solubility and solubility (Ksp) was 15,14% for Scientific Knowledge (understand) category, misconception type 1 was 7.99%, misconception type 2 was 0.97%, misconception type 3 was 21.55%, lack of knowledge type 1 was 5.06 %, lack of knowledge type 2 was 0,36%, lack of knowledge type 3 was 46.03%, and for Lucky guess was 2.86%.

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