Senior high school students’ need analysis of Three-Tier Multiple Choice (3TMC) diagnostic test about acid-base and solubility equilibrium

Ardiansah1*, M Masykuri2 and S B Rahardjo3

1Science Education Student in Sebelas Maret University of Surakarta, Indonesia
2Science Education Department in Sebelas Maret University of Surakarta, Indonesia
3Chemistry Department in Sebelas Maret University of Surakarta, Indonesia

*Corresponding email: ardiansah@student.uns.ac.id

Abstract. Students’ conceptual understanding is the most important comprehension to obtain related comprehension. However, they held their own conception. With this need analysis, we will elicit student need of 3TMC diagnostic test to measure students’ conception about acid-base and solubility equilibrium. The research done by a mixed method using questionnaire analysis based on descriptive of quantitative and qualitative. The research subject was 96 students from 4 senior high schools and 4 chemistry teachers chosen by random sampling technique. Data gathering used a questionnaire with 10 questions for student and 28 questions for teachers. The results showed that 97% of students stated that the development this instrument is needed. In addition, there were several problems obtained in this questionnaire include learning activity, teacher’s test and guessing. In conclusion, this is necessary to develop the 3TMC instrument that can diagnose and measure the student’s conception in acid-base and solubility equilibrium.

1. Introduction

Student conceptual understanding is the major prerequisite knowledge that must be obtained by the student after learning chemistry. However, a student sometimes doesn’t achieve this goal completely [1–3]. A student can hold his/her misunderstandings either in high school or campus. They might difficult to understand and use scientific model. This difficulty of conceptual comprehension can cause misconception in students.

The misconception a concept that different from science conception accepted by science society [4] while the concept is a set of specific objects, symbols, or events which are grouped together on the basis of shared characteristics and which can be referenced by a particular name or symbol. The misconception definition included the conception which is not complete. It means that conception with missing pieces would direct to misunderstanding in full scientific concept. It also caused by incomplete understanding or interpretation by students in the complex subject [5–7].

Acid-base was one of the subjects that have higher complexity level. It contained a sub-microscopic, macroscopic, and symbolic level of chemistry [8,9]. Based on Johnstone theory, sub-microscopic level in this subject include reaction mechanism in acid and base, the collision of acid and base molecules, the interaction of hydronium ion with indicator ion, etc. The macroscopic level of Johnstone’s theory observed by our eye. For instance, the changing colour of an indicator when
titrating process between hydrochloric acid and sodium hydroxide. The last level, symbolic level includes the symbol of a molecule, the equation counting of hydronium ion concentration, etc.

Chemistry researchers generally agree that acid-base and solubility are the complex subjects in chemistry. Several types of research about acid-base and solubility equilibrium (ABSE) concept already done. For instance, about acid-base [10–20] that include of acid and base concept [21,22], titration concept [23], salt hydrolysis concept [24], buffer concept[25]. Solubility equilibrium researchers were conducted in stirring and temperature effect [26,27], solution of chemistry [28,29] and solubility concept [30].

Measurement of acid-base complexity can be developed using various instruments [31,32]. There were used interviews (53%), open-ended tests (34%), multiple-choice tests (32%) and multiple tier tests (13%) to diagnose misconception [33]. Multiple tier test includes of two-, three-, and four-tier[34–36]. The three-tier multiple choice constructed from original multiple-choice. The first tier was original multiple-choice; the second tier was a reason for the first answer, and the third tier was a scale of certainty. With this instrument, we can determine the conceptual comprehension. It includes science knowledge, false positives, false negatives, lack of knowledge, lucky guess, and misconception. The consideration of this result easy to calculate although use common processing data like Microsoft Excel and open office Calc. With this instrument, the teachers’ also can determine student certainty with a confidence level [37]. Further, only two research related to chemistry done by 2014 that used three tier multiple choice test.

The instrument, 3TMC, was chosen because of a number of strengths[33]. These instrument strengths were: (1) time efficient in administering, (2) immediately scored, (3) objectively scored, (4) validity evidence is strong, (5) applied to a large number of subjects, (6) gives an opportunity to decide the proportions of false positives and false negative, and (7) determines the answers given to the first two tiers are due to misconception or a mistake due to lack of knowledge. However, there was two weakness of this instrument that underestimates the proportions of lack of knowledge since cannot decide whether the responder is sure for his/her answer in the first tier, in the second tier or in both tiers, and overestimates students’ scores [34,35,38].

Three-tier multiple choice diagnostic test is the potential test to disseminate in Indonesia. Review article conducted by Gurel, Eryilmaz, McDermott [33] stated that no similar research done by Indonesia’s researchers’. It gives the chance for our further research about this scope. Although there was an acid-base based three-tier multiple choice conducted before [39], the misconception Indonesia is needed by students’ and teachers’ need analysis. This research will enhance teacher reference to obtain their students’ concept and concept comprehension of ABSE subject. Author’s research elicits student’s concept mapping in ABSE subject. Using 3TMC, the conceptual comprehension from student might find during the Treagustten steps of research [40,41].

2. Method
This is a mixed method of research which include of descriptive quantitative. This research aims to explore students’ need about three-tier multiple choice diagnostic test. The instrument developed to determine their misconception and concept comprehension about acid-base and solubility equilibrium. The subject in this instrument includes acid and base concept, titration concept, salt hydrolysis concept, buffer concept, and solubility equilibrium.

2.1. Participants
Participants used in this research were students who learned acid-base and equilibrium solubility chapter in chemistry subject. They come from four schools located in Bengkayang Residence, West Kalimantan, Indonesia. The subjects of research were chosen using purposive sampling. There were 96 students involved in this study that already learned about ABSE subject in their classes. Furthermore, we collected four chemistry teachers taught in representative school to make sure the data valid.

2.2. Data Collection
Data were collected from the questionnaire given to the students and the teachers. Validity used in the Aiken’s formula which value \(0.92 - 1.00\) and average \(0.97\) that can interpret as valid for six validators from four Likert relevance scales [42]. The students’ questionnaire consisted of 10 questions which three questions were open ended question and other provided 2 to 6 options each. The sixth question has a large number of choices because we need to cover as many as possibilities for students’ response about the type of test used by the teacher in class. Also, we gave possibilities the students to choose their choice more than one. Question number 1 to 4 about students’ problem in learning chemistry generally that is learning manner in chemistry (1st question), reason used that manner (2nd question), the problem in learning chemistry and settle it. Question number 5 asked students’ opinion about concept content in acid-base and solubility equilibrium. In line with this need analysis, we ask the student about the test in teachers’ daily evaluation which is found in 6th to 8th question. Furthermore, to obtain information about student guessing when answering the question, we made the 9th question. At the end of the questionnaire, 10th question, we asking about the need for a diagnostic test to obtain their conception.

The other questionnaire gave to teachers. This questionnaire consists of 28 questions. The indicator used are teaching and learning process, subject book and substance, evaluation instrument, and student need of a diagnostic instrument. There were 18 questions in open ended question and the others were close ended question.

2.3. Data Analysis

Descriptive analysis on investigating students’ need analysis was carried out using descriptive manner. Each option described student need and their manner without a correct and incorrect decision. Further, students’ analysis of need was determined when we analyse all of the questions in the questionnaire. The complementary data, international journal, collected using the relevant scope of this research. The journal analyses related to this research. The data collected using some journal search engine such as: Scopus, Science direct, ERIC, EBSCO, and google scholar. Keywords used in this searching were student’s misconception, ABSE, 3TM C, need analysis, and misconception in Indonesia

3. Result and Discussion

3.1. Student Questionnaire Result

Based on this questionnaire result, several data were obtained. Every question was interpreted to show students’ need analysis about this instrument. There were seven aspects that we got with this research. The aspects were:

1) learning method when studying at home,
2) acid-base and solubility equilibrium was the conceptual subject,
3) test question format used by the teacher,
4) type of question that student prefer to,
5) most of the test type used by the teacher to evaluate student concept comprehension,
6) student action when cannot answering the question, and
7) students’ need of the misconception instrument.

Each aspect contained one question so that there were seven questions made. Other three aspects, students’ problem in learning chemistry, located in #2 until #4 question.

Students were asked about (question #1) learning method when studying at home. The result showed that almost a half of student chosen to understand as his/her learning method when studying chemistry at home. It indicated that chemistry still becomes memorising subject for the student. In addition, this result showed that teacher meaningful learning application tends to the memorising system. However, this problem becomes a general problem in Indonesia’s student [43]. Further, he stated that teachers tend to have the students memorise contents of the textbooks and teach them techniques about how to answer multiple choice questions by giving them drills. These students do not learn and understand mathematics and science, but merely memorise mathematical and scientific formulas for the examinations.
Question number two until four especially used for student problem in learning chemistry generally. These questions were open ended question. So that, the student can write his/her problem, his/her settle for providing his/her problem. Student’s problems obtained in this question are:

1) the teacher only explains about formula,
2) student memorise the formula given by his/her teacher without knowing the usage of formula,
3) student memorise the conceptual subject but did not understand the concept,

In line with this question, we give a student to asking their conceptual comprehension to decide the acid-base subject whether it conceptual or algorithmic subject. This question was written in question #5. With this question, the student gives his/her opinion about this subject. Although most of them give the conceptual as their reason, there was about 36% student do not realise that this subject was conceptual. In this question, can be concluded that student assumes that algorithmic comprehension is emphasised in students’ mind.

A sixth question asking about test question format used by his/her teacher. This question is an open question that student can choose more than one question as for their choice. In this question, there was five options given that is generally used by a teacher that is: yes-no question, short answering, multiple choice, essay, and multiple-tier. The essay was the most test format used by a teacher with 63%. In addition, the student chose about 23% in multiple choice student. The teacher is not prefered to the yes-no question, short answering and multiple-tier format of the test.

The seventh and eighth question requires the student to give an opinion about the popular type of teacher test whether it algorithmic or conceptual. This question almost same as the previous question. However, the surprising result was obtained that related each other. In #7 question, most of the student (about 60%) chosen conceptual test as his/her type of question prefer to. It seems described the next question that teachers were used the algorithmic test to evaluate student conceptual comprehension. There were 93% students chosen algorithmic test.

The ninth question required student opinion about his/her action when cannot answer the question in multiple choice question. Two third of students were chosen to guess as their choice. It proved that student uses the weakness of guessing possibility as their answer. In high school level, there were five choices of multiple choice that means students’ correct possibility to answer about 20%. With this possibility, the teacher must provide the effective distractors to increase students’ guessing. Only 3% student chose left blank as his/her choice while 29% of student chose other activities such as cheating and counting another choice. With 3TMC instrument, the guessing probability decrease from 13% (using 8 option) until 4% (using 25%). This instrument can cover student guessing cultures when answering the question.

The last question, we obtained that most of the student (97%) need this instrument about the three-tier multiple-choice diagnostic test in acid-base and solubility equilibrium subject to measure and describe their misconception and concept comprehension. This means that student needs this instrument. There only 3% of student need not this misconception instrument.

This table show student needs questionnaire result.

| Table 1. Questionnaire Result of 3TMC Instrument Need |
|------------------------------------------------------|
| **Aspect**                                             | **Question** | **Percentage** |
| Learning method when studying at home                  | Memorising   | 23            |
|                                                      | Understanding| 43            |
|                                                      | Both of them | 34            |
| Acid-base and solubility equilibrium were the conceptual subjects | Yes | 64 |
|                                                      | No           | 36            |
|                                                      | Yes-no question | 4 |
|                                                      | Short answering | 7 |
|                                                      | Multiple choice | 23 |
|                                                      | Essay        | 63            |
|                                                      | Multiple-tier | 4 |

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### 3.2. Teachers’ questionnaire result

The result of teachers’ questionnaire was obtained several results. Every aspect interpreted to show students’ need analysis about this instrument from teachers. The indicator used are teaching and learning process, subject book and substance, evaluation instrument, and student need of a diagnostic instrument.

The first aspect, we asked the teacher about teaching and learning process. This aspect located in question number one until eight. Question number one until four asking about the approach used by the teacher in teaching and learning process while the number five until eight about teachers’ strategy. We obtained that direct approach was the most approach used by the teacher. Another approach to science, technology, and society approach, constructivist approach, contextual approach, and problem-based approach seldom used by teacher caused by the complexity of this approach. However, they used the scientific approach as their standard that must be applied in 2013 curriculum of Indonesia’s education system.

Teachers’ strategy in teaching student varied. Most of the teacher used direct instruction strategy when teaching their students. They assume that their subject can be transferred fast through this strategy. Another strategy that is a discussion, cooperative and project are not preferred by teachers. Those strategies consume much time due to lack of limited estimation time. Also, students are not familiar with those strategies.

The second aspect obtained teachers’ book used in teaching and learning process and references. This aspect included in question number #9 until #13. The result showed that teacher chosen their book or reference developed by his/herself and from authorised publisher. Teachers generally used two or three books as their references when teaching chemistry. Furthermore, they used until four books when teaching in class. It enhanced teacher and student knowledge about the subject in chemistry class.

The most important aspect in this questionnaire is the third aspect. It described teachers’ evaluation instrument. It showed in question #14 until #25. This aspect can strengthen the student aspect of evaluation done by his/her teacher. Also, this aspect can describe reality in teachers’ evaluation. This aspect includes four sub-aspects that are emphasising of concept in teaching, student difficulties in chemistry, teacher settle this problem and part of evaluation measured by the teacher.

In first sub-aspect, teacher emphasising conceptual aspect. However, the algorithmic aspect gets a little part. They clarified that student can count by his/herself using the formulae given. This statement in line with student opinion that acid-base and solubility equilibrium concept were the conceptual subjects. Teacher measure student conceptual comprehension by asking some of them randomly due to lack of time. Thus, this is an efficient decision for limited available time for teaching and learning process.

The second sub-aspect, teacher stated that 30%-50% of students were having difficulty in conceptual comprehension. This statement also in line with student learning method at home. This difficulty was caused by the complexity of chemistry terminology, student learning method, and lack of understanding the basic concept or prerequisite concept. In student open ended question, they
usually memorise the molecule’s name, formula, and the name of the element. It becomes a difficulty if they forgot what they’re memorised.

The third sub-aspect require teacher attention to settle the problem. The students’ problem also become teacher problem. The teachers settle the problem using two ways. First, they repeat and remedial the subject that did not pass the standard. It can be done using improve the method and teaching strategy. Further, the teacher gave the coaching question for under criteria indicator. The second, they relate the subject with other previous or prerequisite subject. It can increase student comprehension with relating other subjects.

The last sub-aspect, evaluation measurement system used by the teacher. Teachers measure cognitive domain more than another aspect those are affective and psychomotor. In cognitive domain, a teacher using multiple choice and open-ended question to assess student comprehension. A teacher using 21% of remembering aspect, 45% of understanding aspect, 16% applicating and 18% of higher order thinking skill as their test aspect. This result can be concluded that teacher using in lower order thinking the skill of Bloom taxonomy Anderson revision.

In other two domains, a teacher using standard measurement. In affective domain measurement, the teacher used questionnaire and observation sheet. This measurement is measured only in specified time. In the other word, the affective domain used only several times in a semester. This term also did by the teacher to measure psychomotor domain. They only measure this domain at lab activity or lab practice.

The last aspect is student need of a diagnostic instrument. We obtained two results about this aspect. First, cognitive measurement tools used by the teacher do not tend to a diagnostic test. This problem caused teacher need a diagnostic instrument to describe and measure students’ conceptual comprehension and misconception. Second, all of teacher certain this instrument can measure and map the student misconception.

4. Conclusion
This instrument is needed by the student. With some strength of this instrument, we assume that students want to map their conceptual comprehension include: know concept, false positive, false negative, lucky-guess, misconception, and don’t know concept. This instrument also can be used by the teacher to assess their students’ weakness in concept comprehension. The 3TMC instrument can become a diagnostic tool.

This instrument used only focused on student’s and teacher’s need about 3TMC diagnostic test in ABSE chapter. The result of misconception and concept comprehension are not described. The instrument result might be varied depends on the subject. However, the tendency of misconception sometimes can be predicted. Furthermore, these two questionnaires cannot represent other instrument needs such as formative and summative.

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