

A PILOT STUDY ON CHEMISTRY ACHIEVEMENT TEST

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Abstract

Knowledge of chemistry involves abstract concepts and it should be explained in three representative levels, namely, macroscopic representative level, sub-microscopic representative level and symbolic representative level (Johnstone, 1991). Macroscopic level involves changes that are visible to the naked eye and noticeable by the senses of touch, smell and sight. Whereas, symbolic level focuses on the use of formulas, symbols and graphics. Sub-microscopic representative level, on the other hand, is the level of representation that involves particles that are not visible to the naked eye, namely, atoms, molecules and ions. The success of students in mastering the concepts of chemistry is closely related to their ability to create relationships among the three levels of representation. To understand chemistry in a meaningful way, students need to be exposed to the three levels of representation in chemistry. Therefore, this study described the development and pilot test of the chemistry achievement test. This achievement test consisted of 4 different items, developed based on the multiple representations of the topics of Acids and Bases within Malaysian context. In this study, the validity of the test was established through content and linguistic validity, while the reliability of the achievement test was established through the test-retest procedure. The test was administrated by the researchers at two different times, involving a total 27 Form 4 Science stream students. The value for the test-retest reliability coefficient was .828. The description of the test items, and the scoring procedure were also discussed in this paper.

Keywords: *chemistry triplet, acid and base, achievement test.*

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Introduction

Chemistry is a knowledge of Science that is designed to enable students to understand the chemistry in greater depth in terms of theory, concept and its application in everyday life; in addition to developing their abilities to identify and resolve related problems. Acquisition and mastery of Chemistry related knowledge and skills are crucial as part of their preparation to deal with change and to contribute towards their self and environmental management responsibly, for the benefit of mankind at large. Chemistry involves the study of matter, interactions between the material and the production and use of materials and it is closely related to human life. The contribution of Chemistry in everyday life is very substantial; the explorations of the seabed, the Earth and the outer space. In short, the production and use of chemicals in our everyday life have much impacts either directly or indirectly on the community and the environment. In the Malaysian context, the Chemistry curriculum has been designed with its aim to produce students with the knowledge and skills in Chemistry, while also providing them with the necessary preparation to further their study in Chemistry at the tertiary level, and finally to apply the knowledge and expertise gained for the development of the country. However, many previous researches showed that, there were a high number of students who had difficulty studying Chemistry and treating it as a difficult subject. According to a study by Sirhan (2007), the knowledge of Chemistry is closely associated with abstract concepts, causing difficulties for students to learn and understand it. Mastering the concepts of Chemistry requires the students to know more than just what happens in a reaction, but also the reason and the way the reaction takes place.

Chemical knowledge is represented at three levels, namely, macroscopic, sub-microscopic and symbolic levels (Ozmen, Ayas & Costu, 2002). The first concrete and actual level is the macroscopic level which contains visible and tangible concepts or processes; the second level is about the actual phenomenon which explains the sub-microscopic level depicting entities which are too small to be seen under an optical microscope and, the bonding within and between them (Bucat & Mocerino, 2009; Gilbert, 2010); and the third level is symbolic, which involves figures, signs, symbols, letters, equations, mathematical representations and formulae (Treagust, Chittleborough, & Mamiala, 2003; Wu & Shah, 2004; Gilbert, 2010). (Devetak, Hajzeri, Glažar, & Vogrinc, 2010). All of these three representational levels are interrelated with each other in the *Chemistry Triangle* (Johnstone, 1991). The success of students in mastering the concepts of Chemistry is closely related to their ability to create relationships among the three levels of representation. All of these three levels should overlap significantly during the learning process, so that, within the long-term, the students' memories develop appropriate mental models that reflect adequate levels of chemical literacy (Devetak & Glažar 2007; Devetak et al, 2010). From observations of the macroscopic changes, students have to explain these changes at the particulate level, which in turn is represented by symbols and formulas. As a result of having to deal with these three levels of representation simultaneously and the acquisition of knowledge by students without a clear understanding, confusion arose among the students who generally experienced difficulty in explaining chemical concept (Gabel, 1998).

According to Davidowitz & Chittleborough (2009), teachers should assist students to make a link between the three levels. However, findings by many researchers have found that, many

high school teachers do not integrate the three representations in their teaching. Rather, they move between representational levels without highlighting their inter-connectedness (Gabel, 1999). They always explain the chemical process at an abstract and symbolic level only (Devetak, Vogrinc, & Glažar, (2009). As a result, students are often unable to see the linkages between the three levels of representation although they may know Chemistry at all the three levels. They often find these representations difficult to grasp and use. Thus, it is important to help students see the connections between the three levels of representation so that they will be able to generate comprehensible explanations (Treagust et al, 2003) and generate relational understanding (Mulford & Robinson, 2002). Although, the most difficult challenges faced by Chemistry teachers in teaching the subject is conveying students with the three chemical representations when explaining the concepts of Chemistry (Abdoolatiff & Narod, 2009), opportunities and exposure should be provided to the students to the three levels of representations, in order for them to master the concepts of Chemistry better. Therefore, this study was an initiative to provide achievement test which implements the three levels of representation for students taking chemistry subject in the context of Malaysian education. This achievement test, based on the multiple representations of the topics of Acids and Bases comprised 4 different items, developed to suit the Malaysian context. In this study, the validity of the test was established through content and linguistic validation, while the reliability of the test was established through the test-retest procedure.

Methodology

The purpose of this study was to test the validity and reliability of the Chemistry Achievement Test (CAT). According to Creswell (2014), validity refers to the ability of an instrument to measure a concept or construct matches for its proposed use, while reliability refers to the stability of the score of the instrument. In this study, validity referred to content validity and linguistic validity. The content validity gave more focus on the suitability of the contents of the Chemistry curriculum of Malaysia, while the linguistic validity focused on the format and the linguistic requirements. The reliability of the CAT was established through the test-retest procedure.

In this study, the draft of CAT was referred to the experts for validation. The first step taken was the linguistic validation, focusing on the spelling, the instruction, the clarity of the meaning of each item and the learning objectives. After improvements were made, the draft was prepared for the content validity. The draft of CAT was referred to the content experts to make sure that the content of this test was in line with the Form Four Chemistry Syllabus. Upon completion of the validity test, the improvised draft of CAT was analyzed for its reliability. For this study, the reliability values were established through test-retest procedure, administered by the researcher at two different times on all of the students at a sufficient time interval. In this test-retest procedure, all the respondents completed the CAT twice. The validity and reliability processes are as shown in Figure 1.

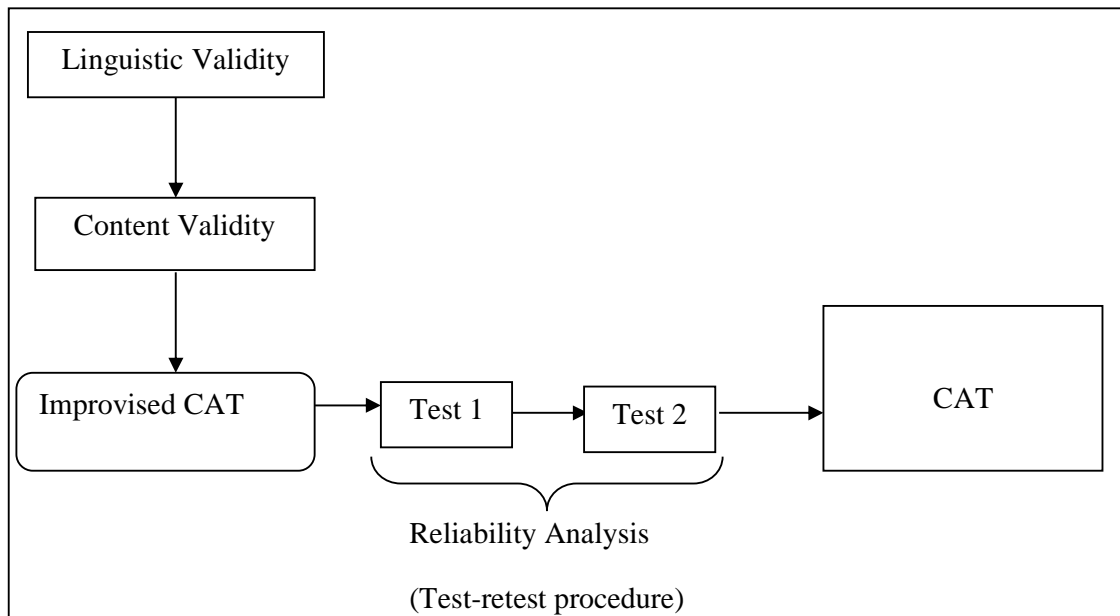


Figure 1: The process of pilot study for CAT

Respondent

This study involved experts and students. The experts comprised a total of three lecturers and two teachers with 5-25 years of experience. The experts were assigned to evaluate the content and linguistic validity. The students, comprising Form Four Science stream students, were assigned to evaluate reliability through test-retest procedure. The details of the number of respondents for each analysis are as shown in Table 1.

Table 1 Respondents involved in the pilot study for CAT

Type of Analysis	No of respondents	Role of the respondents
Linguistic Validity	3	To validate the instrument in terms of meanings of items, language, instruction and etc.
Content Validity	3	To validate the instrument in terms of suitability with the research objectives, respondents' cognitive level and etc.
Reliability	27	To evaluate the reliability of the test through test-retest procedure

Description of the CAT

Chemistry involves abstract concepts and this causes difficulties for students to understand the topics mainly Acid and Base (Norasekin, 2008; Ozmen, 2004). The study by Chiu (2005) found that among the weaknesses of students in this topics are the students failed to clearly explain the neutralization process. Furthermore students will be considered the strength of an acid is higher if there are a high number of hydrogen atoms. By taking account on that findings, therefore, this CAT will covers topic Acid and Base and it was developed based on chemical concept at three different levels, which are macroscopic, sub-microscopic and symbolic level (Johnstone, 1991). Table 1 shows the distributions of item in CAT based on subtopic and representation. Next is the further description of the 4 items consists in the CAT.

Table 2 Distribution of items in CAT based on subtopic and representation level

Item (Subtopic)/ Representation level	1 (Chemical properties of acid)	2 (Strength of an acid)	3 (Concentration of an acid)	4 (Neutralization)
Macroscopic	1a	2a	3a	4a
Sub- microscopic	1b	2b	3b	4b
Symbolic	1c	2c	3c	4c

Item 1

The first item was about chemical properties of an acid. At the macroscopic level, students' needs to make an observation on reaction of ethanoic acid and magnesium. While at the sub-microscopic level, the students' needs to draw the particles during the reaction occurred. At the symbolic level, the students have to write a balance chemical equations for that particular reaction.

Item 2

The second item was more focus on ionization of an acid which are under the subtopic of the strength of an acid. At the macroscopic level, students' needs to make an observation on ionization of ethanoic acid. While at the sub-microscopic level, the students' needs to draw the particles of ethanoic acid before and after the ionization process. At the symbolic level, the students have to write an ionization equations for ethanoic acid.

Item 3

The third item was about the concentration of an acid. At the macroscopic level, students' needs to make an observation involving two set of beaker both consisting hydrochloric acid with different concentration. The students' needs to choose which beaker will give the lower pH value. While at the sub-microscopic level, the students' needs to draw the particles of

hydrochloric acid in both beakers. At the symbolic level, the students have to write the chemical formula of hydrochloric acid.

Item 4

The fourth item was about the neutralization process. At the macroscopic level, students' needs to make an observation when the end point for the neutralization between hydrochloric acid and potassium hydroxide was reached. While at the sub-microscopic level, the students' needs to draw the particles in the conical flask during the neutralization occurred. At the symbolic level, the students have to write a balance chemical equations for that particular neutralization reaction.

Scoring Procedure

The total marks for the CAT is 20 marks. Table 3 shows the total marks for each item in the CAT in each multiple representation level.

Table 3 Distribution of marks according to item and representation level

Item / Representation level	1	2	3	4	Total Marks
Macroscopic	1 mark	1 mark	1 mark	1 mark	4
Sub-microscopic	2 marks	2 marks	2 marks	2 marks	8
Symbolic	2 marks	2 marks	2 marks	2 marks	8
Total Marks	5 marks	5 marks	5 marks	5 marks	20

While the details of the marks given to the students answers are summarized in Table 4 below.

Table 4 Details of marks given to students answers in the CAT

Representation level	Scoring Criteria	Score awarded
Macroscopic	The observation is aligned with the question	1 mark
	Did not answer or the given statement is difficult to understand	0 mark
Sub-microscopic	Answers given were aligned with the scientific concept	2 marks

	Answer given were partially aligned with scientific concept	1 mark
	Did not answer or the given statement is difficult to understand	0 mark
Symbolic	Answers given were aligned with the scientific concept	2 marks
	Answer given were partially aligned with scientific concept	1 mark
	Did not answer or the given statement is difficult to understand	0 mark

The scores obtained by the students were recorded and analyzed.

Result and Discussion

To determine the validity and reliability of CAT, the comment and suggestion from the experts and the result from the test-retest were utilized and the following results were revealed:

Validity

Impara (2010) stated that, each type of the instrument has a different type of validity which depends on the purpose of the particular instrument. In this study, the validation of the CAT was more focused on the content and linguistic validity. Table 5 below shows the views from the experts regarding the language used in the CAT. All of the experts agreed that there was no spelling error, that the font used was suitable and that, the language used was easy to be understood. However, there were a few comments on the instruction given by the experts, especially on how the instructions were written. The experts suggested that, each of the items would be better understood if written in the contextual form. Other than that it is also suggested for a new line to be provided for each task in the item. All of these comments were taken into account during the correction and improvement of the CAT.

Table 5 Views of linguistic experts

No	Item	Percentage Given by Experts (n=3)		Comments
		Yes (%)	No (%)	
1	The format of the study is suitable and interesting	100		Satisfactory
2	The meaning of each item is clear	67	33	Satisfactory
3	The language used is easy to be understood	100		Satisfactory

4	The size of the fonts is suitable	100		Satisfactory
5	The instructions given are clear	33	67	Each of the task must be written in a new line
6	The font spacing is suitable	100		Satisfactory
7	The indicators for measurement scale are clear	67	33	Diagrams should be labelled uniformly
8	There are no spelling errors	100		Satisfactory
9	The objectives stated are clear	100		Satisfactory

Table 6 below shows the views from the content experts. All of the experts gave a positive response about the content of the CAT. In addition, for the content validity, the two teachers were also asked to evaluate whether the content of the CAT suited the Form Four Chemistry Syllabus endorsed by the Minister of Education of Malaysia, 2012. The results showed that, the content of the CAT suited the suggested curriculum and was suitable to be used for Form Four science stream students.

Table 6 Views of content experts

No	Item	Percentage Given by Experts (n=3)		Comments
		Suitable (%)	Not suitable (%)	
1	Suitability with the research objectives	100		Satisfactory
2	Suitability of the language used	67	33	There is some confusion on instruction, need to be revised
3	Suitability with the cognitive level of the respondents	100		Satisfactory
4	The accuracy of construct and dimension used	67	33	Check the item number four
5	The clarity of the meaning of each item	100		Satisfactory
6	Alignment of the construct	100		Satisfactory

In overall, all of the experts commented that the CAT are easy to understand and can be used in the study. In addition, the experts also stated that the question in CAT is appropriate and in line with the research objective.

Reliability

For the reliability analysis, the CAT was administrated by the researcher at two different times, involving a total of 27 Form Four Science stream students. The value for the test-retest reliability coefficient, determined by using *Statistical Package for Social Sciences* software was .828. Table 7 below shows the results of the reliability analysis.

Table 7 The test-retest reliability coefficient for CAT

		Test 1	Test 2
Test 1	Pearson Correlation	1	.828**
	Sig. (2-tailed)		.000
	N	27	27
Test 2	Pearson Correlation	.828**	1
	Sig. (2-tailed)	.000	
	N	27	27

**Correlation is significant at the 0.01 level (2-tailed).

The Pearson correlation test results above showed that, for this group of subjects (n=27), the test-retest correlation value for the CAT was .828. This means that, the CAT was suitable for obtaining reliable data from other subjects with the same characteristics, namely, Form Four Science stream students.

Conclusion

This study reported an analysis of validity and reliability of CAT for Form Four Science students, especially those taking Chemistry subject. The CAT demonstrated a high degree of content and linguistic validity. The study also showed that, the CAT had high reliability values and was suitable to be used among Form Four science students especially in Malaysia context. This research can be considered as one of the initiatives to provide more instruments on multiple representation, specifically in the Malaysian context.

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