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Development Of An Integrated Instrument About Critical Thinking Skills And Chemical Literacy In Hydrolysis

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This research study aimed to analyse the characteristics of integrated assessment instruments to measure critical thinking and chemical literacy skills in salt hydrolysis material by meeting the criteria of validity, reliability, and level of difficulty. This research utilised the 4-D approach, i.e. define, design, develop, and disseminate. An experimental test was conducted on 175 students. Data analysis was done by analysing the results of item validation, assumption test analysis with Rasch modelling and analysis of an instrument test result. The results of this study showed that there were 30 multiple choice items in the instrument that had been vetted by two experts and four practitioners of education and which yielded 28 valid questions. Based on the result of Rasch modelling assumption, it was found that from 28 items, i.e. 14 questions of code A and 14 questions of code B, only 9 items from code A and 11 items from code B were found to be fit with Partial Credit Model 1-Parameter Logistic (PCM 1-PL). The cronbach alpha reliability coefficients were also computed and were found to be high. . The difficulty level of the items included in code A and code B were also established.

KEYWORDS: Integrated Instrument, Critical Thinking Skills, Chemical Literacy, HOTS, Salt Hydrolysis

Introduction

The development of science and technology is very fast and produces a wide range of influential products in social life. Understanding the facts or topics of

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science and connecting them with science, technology, and society is very important for students. An understanding of the knowledge of science and having the ability to apply it in terms of problem solving in daily life is known as science literacy (Celik, 2014). The main goal of science education, especially chemistry, is to help students develop thinking skills to solve the problems in daily life and to encourage students to develop high-level thinking skills, such as critical thinking, reasoning, reflective, and science skills (Saido, 2015; Aktamis & Yenice, 2010). Higher Order Thinking Skills (HOTS) is a concept based on the cognitive level of learning or known as Bloom's Taxonomy, which emphasizes the degree of analysis, evaluation, and synthesis. The learning process integrated with HOTS requires different teaching and learning methods than simply learning facts and concepts. In other words, the concept of HOTS concentrates more on understanding students in their own learning process and is able to train students to think creatively, critically and innovatively (Ping, Ahmad, Adnan & Hua, 2016).

Critical thinking is a key component in many subjects at secondary school level. Critical thinking in the area of chemistry requires students to not just think about concepts and principles, but also requires students to apply it in other areas. Critical thinking can relate information to the nature of a certain function. In chemistry, critical thinking can help students to relate information about specific nature of a certain theory, function, formula or equation. In chemical experiment, collecting data and drawing a conclusion is the basic process. Collecting data and drawing a conclusion are essential in critical thinking as it involves logic, depth, clarity, and accuracy (Gluck, Gilmore & Dilihunt, 2015). Critical thinking as per the definition based on consensus of 46 critical thinking experts across disciplines, describes it to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, contextual considerations upon which that judgment is based (Facione, 1990). Critical thinking refers to use of cognitive skills or strategies involved in solving problems, formulating inferences, calculating probabilities, and making decisions (Halpern, 1999). Critical thinking skills are often referred as high order thinking skills. High order thinking skills are relatively complex that require judgment, analysis, synthesis, and are not applied in a rote or mechanical manner. In real life, critical thinking skills are needed whenever people grapple with complex issues and messy, ill-defined problems (Halpern, 1998). Critical thinking is concerned with analysis, inference, evaluation, interpretation, explanation and self-regulation as part of the cognitive abilities. Critical thinking includes truth-seeking, openness, analytical, regular, systematic and curious skills, interpersonal skills, and the ability to access information (Stephenson & Mcknight, 2015).

Chemical literacy is a part of science literacy that has several components, namely knowledge that can understand the science and application, the ability to think scientifically, the ability to use scientific knowledge in problem solving, and knowledge related to the risks and benefits of studying science (Holbrook & Rannikmae, 2009). The literacy of science can be realized through scientific ideas, concepts, and practices that emphasize the science of technology, social, and ethics (Cigdemoglu & Geban, 2015). Shwartz, Zvi, & Hofstein (2006) describe chemical literacy in 4 aspects, which are as follows:

a) Chemical Literacy in the Content Aspect

Chemical literacy in the content aspect aims to enable students to understand general scientific ideas, chemistry as experimental disciplines, chemistry as the science used to explain phenomena. Students that can master chemical literacy can make a scientific investigation, generalize, and make a theory to explain the universe.

b) Chemical Literacy in the Context Aspect

The chemical literacy in the context aspect aims to enable students to recognize the importance of chemical science in explaining the daily phenomena, to apply the knowledge of chemistry, and to understand the relationship between chemical innovation and sociological processes. Students can develop an understanding of chemistry in various fields, as consumers of the latest products and technologies, in decision making, and participating in social debates that are related to chemistry.

c) Chemical Literacy in the Skill Aspect

Chemical literacy in the skills aspect aims to enable students to improve their ability to ask questions, seek information, and connect various kinds of information about chemistry. Students can analyse the advantages and disadvantages about chemistry in a discussion.

d) Chemical Literacy in the Attitude Aspect

The chemical literature in attitude aspect aims to make students look at chemistry in a neutral, realistic, and impartial manner. Students are also expected to have an interest and interest in related issues in chemistry.

RESEARCH METHODOLOGY OF THE STUDY

A four step process was used in the development of an integrated instrument. These are define, design, develop, and disseminate the instrument as explained below:

a) Define

A review of literature of an integrated instrument about critical thinking skills and chemical literacy is part of the define process. Study of literature aims to fetch the related information that can be used to arrange items of the instrument. Chemistry teachers have been interviewed regarding the hydrolysis material. Questionnaires have been distributed to students to know the response related to salt hydrolysis that has been taught by chemistry teacher.

b) Design

The process of designing the product has been done on the basis on data of the definition process that has been collected. The results of the design process are used as reference or framework for developing integrated instrument products. They are phases of the implementation of the development research, determining the basic competence about salt hydrolysis material, establish indicators of achievement of competencies, and develop indicators of integrated assessment instrument.

c) Develop

The process of development is the preparation of a research product based on the data of the design process. The developed product is an integrated test instrument and assessment guide that can be used to measure students' critical thinking and chemical literacy in salt hydrolysis material. The test instrument consists of 30 multiple-choice questions based on the results of the analysis of competency achievement indicators and indicators of integrated assessment instrument. Instrument preparation has passed through a series of testing processes to obtain a valid and reliable assessment instrument so that it can be used to measure students' critical thinking and chemical literacy in salt hydrolysis. Experiments conducted include expert judgment tests, limited field tests, and the most recent field tests. Data analysis based on the data obtained from the experiment was then revised to produce an accurate final product. Then Aiken's V analysis and Rasch modelling assumption analysis were done on limited field test data.

d) Disseminate

The process of dissemination is the process used to disseminate information about the test items that have been developed. Dissemination activities involve various parties to test instrument. Dissemination process can be done through publication activities, such as compiling scientific journals, presenting research papers in national or international seminars, and compilation of test items as assessment books.

This integrated assessment instrument is the final product of a valid and reliable development result, so that it can be used to measure critical thinking skills and chemical literacy of high school students of class XI in salt hydrolysis material. This integrated instrument consisted of multiple-choice questions.

DATA ANALYSIS

a) Expert Judgment of Test Results

The result of the validation of an item has been analysed based on the data from the validation sheet of the item. The validation sheet is based on expert judgment viz. one content expert, one learning evaluation expert, and four chemistry teachers. Analysis of the validation aims to find the empirical validation. Instrument is said to be valid if it is able to measure the ability of the test participants appropriately. The content validity can be calculated using the formula V Aiken. This instrument is said to be valid as it has a value of V that is more than 0.92 (Aiken, 1985).

b) Assumption Test Results: Rasch Modelling

Kaiser-Mayer-Olkin Test for Sampling Adequacy (KMO-MSA) has been used to determine the feasibility of the sample and Bartlett test to determine the correlation between variables used. From the result of Bartlett's test, it can be concluded that research variables can be predicted and analysed further and there is a very significant correlation between variables. The result of the analysis of the KMO-MSA test shows that the sample taken is sufficient ($p>0.5$). The results of factor analysis indicate that the value of anti-image ranged value from 0 to 1. If the value of anti-image is equal to one, then the variable can be predicted without error. If the value of anti-image is greater than 0.5 then the variable is still predictable and can be analysed further. If the anti-image value is less than 0.5 and / or close to 0, then the variable cannot be analysed further or must be removed from other variables.

c) Instrument Test Results

Instrument test results begin by describing the characteristics of an integrated assessment instrument using item response theory. The analysis is based on the approach that uses fit analysis with the model. Interpretation of MNSQ Infit and Outfit values in the measurement has a matching assessment criterion and the value of Mean Square Outfit (MNSQ) is $0.5 < MNSQ < 1.5$, the accepted Z-Standard Outfit (ZSTD) value is $2.0 < ZSTD < +2.0$. and the value of Point Measure Correlation (Pt Mean Corr) value is $0.4 <$ Pt Mean Corr < 0.85.

The level of difficulty aims to determine whether questions are easy, moderate, or difficult. A good question is not too easy and also not too difficult. The level of difficulty of an item has been given in Table 1.

Table 1

Category of the Level of Difficulty.

Value Measure	Category
$x \geq 1$	Very difficult
$0.5 \leq x < 1$	Difficult
$-0.5 \leq x < 0.5$	Moderate
$-1 \leq x < -0.5$	Easy
$-1 < x$	Very Easy

FINDINGS OF THE STUDY

a. Expert Judgment Test Results

This instrument consisted of 30 items of multiple choice that have been tested by two experts, one was material salt hydrolysis expert and the other was evaluation expert. The test items were also tested by four chemistry teachers and practitioners (See Table 2).

Table 2

Substance Validation Results by Expert Judgment and Practitioners.

Number of Question	Aiken's V Value	Number of Question	Aiken's V Value
1	1.00	16	1.00
2	1.00	17	1.00
3	1.00	18	1.00
4	1.00	19	0.92
5	1.00	20	0.92
6	1.00	21	1.00
7	1.00	22	1.00
8	1.00	23	0.92
9	1.00	24	0.92
10	0.92	25	0.92
11	1.00	26	0.92
12	1.00	27	0.92
13	1.00	28	0.92
14	0.67	29	0.92
15	0.67	30	0.92

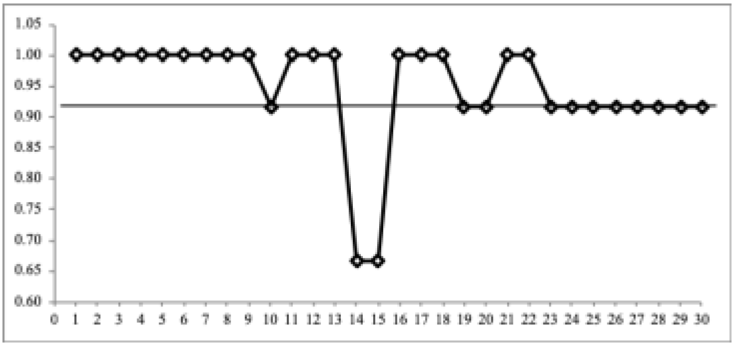

Figure 1. Substantial Validation Results by Expert Judgment and Practitioners.

Experimental expert test results and practitioners analysis have been used to determine the validity of the substance of the integrated assessment instrument. Aiken (1985) explains that if V = 0.92, the item can be said to be valid. From Table 2 and Figure 1, it can be seen that item number 14 and 15 obtained Aiken's V value of 0.67, so that the two questions can be said to be invalid or void. This shows that out of 30 multiple choice questions, only 28 questions can be used to determine the construct validity of the integrated instrument.

b. Assumption Test Results : Rasch Modelling

The unidimensional test analysis has been done by factor analysis for construct or empirical validity. Conditions to be met in performing factor analysis is a Kaiser-Mayer-Oliver Measure of Sampling Adequacy (KMO-MSA) test that has been used to measure sample feasibility and correlation between variables which has been found using Bartlett's test (Table 3 and 4).

Table 3

KMO-MSA Test Results and Bartlett Test for Code A.

Suitability of Kaiser-Mayer-Olkin Sample Size (KMO-MSA)		0.673
Uji Sphericity Bartlett	Chi-Square	418.723
	df	91
	Sig.	0.000

Table 4

KMO-MSA Test Results and Bartlett Test for Code B.

Suitability of Kaiser-Mayer-Olkin Sample Size (KMO-MSA)		0.763
Uji *Sphericity Bartlett*	Chi-Square	427.113
	df	91
	Sig.	0.000

Empirical data generated in this study amounted to 28 items that are divided into 2 parts / code viz. code A and code B. There are 14 items in code A and 14 items in code B. Empirical data in this study needed to be done using initial analysis called assumption modelling Rasch test. The Rasch test has been performed by performing factor analysis that serves as construct or empirical validity. The factor analysis has been done using KMO-MSA test and Bartlett's test (Tables 3, 4, 5 and 6). The value of KMO-MSA test result should be greater than 0.5 and significance value on Bartlett test should be less than 0.05. The obtained KMO-MSA values for the A and B codes are 0.673 and 0.763 respectively, while the significance values for the Bartlett test for code A and code B are 0.000 and 0.000 respectively. Based on these values, it can be seen that the research sample has met the criteria of feasibility that sample size in this research is enough.

Table 5

Factor Analysis Results for Code A.

Number of Question	*Anti-image Correlation Value*
1	0.594
2	0.398
3	0.607
4	0.776
5	0.724
6	0.669
7	0.375
8	0.617
9	0.873
10	0.763
11	0.647
12	0.677
13	0.500
14	0.887

Table 6

Factor Analysis Results for Code A.

Number of Question	*Anti-imageCorrelation Value*
1	0.645
2	0.515
3	0.362
4	0.444
5	0.768
6	0.717
7	0.739
8	0.763
9	0.740
10	0.853
11	0.848
12	0.878
13	0.743
14	0.895

c. Item Fit Instrument Test

Table 7

Item Fit Analysis with Quest Program in Instrument Code A.

Number of Question	*Infit MNSQ*
1	1.30
2	1.16
3	1.04
4	0.68
5	0.82
6	1.38
7	0.85
8	1.18
9	1.02
10	0.90
11	0.96

Table 8

Item Fit Analysis with Quest Program in Instrument Code B.

Number of Question	*Infit MNSQ*
1	1.30
2	1.30
3	1.02
4	1.20
5	1.16
6	0.79
7	0.68
8	0.85
9	0.83
10	1.00
11	1.10
12	0.78

Based on the unidimensional test, it can be seen that there are 23 valid questions, consisting of 11 questions of code A and 12 questions of code B, afterwards item fit test analysis has been done. The result of item fit analysis instrument of code A (Table 7) shows that there are 2 items (items number 4 and 6) that are outside the range of 0.77 to 1.3. The results of item fit analysis instrument of code B (Table 8) indicate that there is 1 item (item number 7) that is located outside the range of 0.77 to 1.3. So, it can be seen that a valid A code of 9 points, while the question of code B is 11 points. Item fit is an indicator that describes the item can function optimally and can be used as a good measurement tool.

d. Instrument Test Results

Table 9

Item Fit Analysis in Instrument Code A.

Number of Question	Outfit		PT-Measure Corr.	Information
	MNSQ	ZSTD		
1	1.06	0.3	0.55	Fit
2	0.98	0.0	0.58	Fit
3	0.70	-1.4	0.68	Fit
4	1.26	1.2	0.53	Fit
5	0.74	-1.2	0.67	Fit
6	1.16	0.7	0.53	Fit
7	0.86	-0.5	0.63	Fit
8	0.69	-1.5	0.68	Fit
9	0.87	-0.5	0.64	Fit

Table 10

Item Fit Analysis in Instrument Code B.

Number of Question	Outfit MNSQ	Outfit ZSTD	PT-Measure Corr.	Information
1	0.83	-0.7	0.65	Fit
2	0.77	-1.0	0.70	Fit
3	0.75	-1.1	0.72	Fit
4	0.77	-1.1	0.66	Fit
5	1.31	1.4	0.57	Fit
6	0.59	-2.3	0.76	Fit
7	1.04	0.8	0.62	Fit
8	0.72	-0.7	0.73	Fit
9	1.50	2.1	0.45	Fit
10	1.44	0.7	0.41	Fit
11	0.98	0.1	0.56	Fit

Based on item analysis fit about items of code A in Table 9 and items of code B in Table 10 using MNSQ outfit value, ZTSD outfit, and PT-Measure Correlation. It can be seen that the whole instrument belongs to the category of fit items, so it can be used to measure the ability of critical thinking and chemical literacy on salt hydrolysis. Item fit analysis shows it as a valid instrument containing 9 items from code A and 11 items from code B.

Table 11

Difficulty Level of Items in Instrument of Code A.

Number of Question	Measure (logit)	Category
1	-0.75	Easy
2	-0.31	Easy
3	-0.25	Easy
4	0.10	Moderate
5	0.51	Difficult
6	0.55	Difficult
7	1.21	Very Difficult
8	0.30	Moderate
9	0.37	Moderate

Table 12

Difficulty Level of Items in Instrument of Code B.

Number of Question	Measure (logit)	Category
1	-0.66	Easy
2	-0.52	Easy
3	-0.10	Moderate
4	0.53	Difficult
5	0.50	Difficult
6	-0.25	Moderate
7	0.07	Moderate
8	0.05	Moderate
9	0.15	Moderate
10	1.15	Very Difficult
11	0.35	Moderate

The level of the difficulty of an item is expressed in logit. It serves to analyse the quality of the item using the measure value of the output item entry. Based on the results of the analysis of the level of difficulty of items in instrument of code A (Table 11) and the level of difficulty of items in instrument of code B (Table 12) it can be seen that there are 5 items with easy category, 9 items with moderate category, 4 items with difficult category, and 2 items with very difficult category.

The reliability of the tool is the level of consistency that students get in working on the same question in different times or occasions. In Rasch modelling, the reliability of the question can be known through the value of person reliability, by knowing the consistency of students' answers and the value of item reliability. Reliability of the test instrument can also be known from the value of Cronbach alpha, which is the reliability of questions based on the interaction between students' answers and the quality of the items as a whole. Based on the results of reliability analysis items of code A, it can be seen that the value of person reliability obtained is 0.83 which indicates that the consistency of student answers is very good. The value of reliability items obtained is 0.88 which indicates that the quality of the item is very good. Cronbach alpha value obtained by 0.92 which shows the interaction between students' answers with the quality of the items as a whole is in a very good category. Thus, the instrument of code A consisting of 9 items of question has a very good level of consistency or reliability. Based on the results of reliability analysis instrument of code B can be seen that the value of person reliability obtained by 0.85 which indicates that the consistency of student answers is in very good category. The reliability value of the item is 0.86 which shows that the quality of the item is in very good category. Cronbach alpha value obtained is 0.96 which shows the interaction between students' answers to the quality of the items as a whole is in a very good category. Thus, the instrument of code B consisting of 11 items has a very good level of consistency or reliability.

CONCLUSIONS

Based on the results of data analysis, we can conclude that:

a. A total of 30 multiple choices questions and assessment guidelines have been tested by two experts and four practitioners, producing 28 valid questions as they have a value of V = 0.92. Based on the results of Rasch modelling assumptions test, it can be seen that from 28 items of questions consisting of 14 questions of code A and 14 questions code B, 20 valid items were obtained i.e. 9 items from code A and 11 items from code B.

b. The test instrument consisting of 9 multiple choice questions from code A and 11 multiple choice questions from code B were declared fit with Partial Credit Model 1-Parameter Logistic (PCM 1-PL). The Cronbach alpha value for code A is 0.92, while the alpha Cronbach value for code B is 0.96.

c. Based on the results of the analysis of the level of difficulty for items of code A and code B, it can be seen that there are 5 questions in the easy category, 9 questions are in moderate category, 4 questions are in difficult category, and 2 questions are in very difficult category.

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