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Construction of a Chemical Literacy Test for Engineering Students

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ABSTRACT

The objective of this study was to construct an assessment instrument to assess chemical literacy among undergraduate engineering students at a university in Thailand. The subjects were 400 undergraduate engineering students who were enrolled in a basic chemistry course in 2012 from the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces. The instruments consisted of 1) a table of test specifications, and 2) assessment forms to check congruence of agreement between experts. The assessment tool was entitled "Chemical Literacy Test (CLT)". The CLT had two assessment formats: 1) Multiple-choice CLT, and 2) Written CLT. The results showed that the K-R 20 of the multiple-choice test was 0.720. The Cronbach's alpha reliabilities of the Written CLT for knowledge and understanding of the relationship between chemistry, technology and society, application of analytical thinking, application of reasoning, and moral awareness and a sense of responsibility were 0.66, 0.61, 0.82, and 0.77, respectively. The result showed that the CLT was a quality assessment tool for assessing chemical literacy of engineering students studying chemistry.

Keywords: Chemical Literacy; Chemical Literacy Test; Construction, Engineering; Undergraduate Students.

INTRODUCTION

A changing world has resulted in the need for human society to be involved in the production of scientific knowledge and understanding of technology. The influence of science and technology on modern society has been so extensive that the print and electronic media often announce the latest advancements in science and technology in the fields of genetic engineering (e.g., human genome project, gene transplant, and cloning) and artificial intelligence as well as about space stations (Yrez & Cakir, 2006). Moreover, the impact of science on a nation and her citizens could be seen from the production of basic human needs for social, political, educational, technological and economic advancement (Oludipe & Awokoy, 2010). Thus, understanding scientific information and the relationship between

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science, technology, and society are extremely useful. We need to prepare people to have enough knowledge and ability when encountering changes with competence to solve real-world problems. This calls for the need to have scientific literacy (Bond, 1989). Scientific literacy is a target in major reforms in the teaching of science today and is conceptualized as the main goal of science education (American Association for the Advancement of Science (AAAS), 1993; DeBore, 2000; Institute of the Promotion Science and Technology (IPST), 2003; National Research Council (NRC), 1996). Scientific understanding is a goal for a scientifically literate society. Scientific understanding deals with the ability to use the conceptual knowledge of science and the ability to differentiate between scientific data and data from other disciplines (Barlia, 2016). Scientific literacy, which is the gateway to achieve scientific and technological advancement and economic survival, is achievable through science education (Oludipe & Awokoy, 2010). Scientific literacy is for everyone because it enlightens and enables each individual to make informed choices and to make rational decisions where issues of science and technology are concerned. Therefore, all of us need to develop scientific literacy with the ability to understand how science works, to make informed decisions, to apply knowledge rationally, creatively and ethically and to use our science related skills to improve ourselves and to develop the country.

In addition, science involves life-long learning because scientific knowledge is about the natural world which has changed over time, so everyone must learn to apply science learning in our everyday lives and careers. Science enables us to develop our process skills in logical, creative, analytical, and critical thinking. It also enables us to obtain essential investigative skills for seeking knowledge and allows the ability for systematic problem-solving, and for verifiable decision-making based on diverse data and evidences. When students learn science that arouses excitement, enthusiasm, and challenges problem situations facing them, they corporately think and act together in order to understand and to see a connection between science and other issues in life so that they will be able to describe, explain, predict, and forecast things rationally (IPST, 2003).

At present, scientific literacy is an important issue affecting human decisions. It is evident at the international level in various perspectives of science education. Coll and Taylor (2009) conducted a survey of the perspectives of scientific literacy at the international level and found that scientific literacy played an important role in science education worldwide. The view of scientific literacy has spread in education at all levels from children to the general population. Scientific literacy can be developed from children to adults and scientific literacy is an indication that individuals have participated in the life-long sciences (Liu, 2009). Science scholars have suggested that the definition of scientific literacy should consist of components of knowledge of science, understanding and application of science, higher-order cognitive skills, the ability to use scientific knowledge to solve problems, understanding the nature of science, ethics that guide the work of scientists, and its relation to culture, society, and technology. Scientifically literate individuals will also be able to use science concepts, processes, and terms accurately and appropriately (Chin, 2005; Duschl, Schweingruber, & Shouse, 2007; Holbrook & Rannikmae, 2009; Norris & Philip, 2003; NRC, 1996; Preczewski, Mittler, & Tillotson, 2009; Rutherford & Ahlgren, 1990).

Chemistry is one of the most important branches of science. It enables learners to understand what happens around them (Sirhan, 2007). Chemistry topics generally involve studying about matter and understanding the properties of matter that are important in many disciplines such as health sciences, geography, physics, environmental science and economics (Brown, LeMay, & Bursten, 2000). Moreover, in recent years it has been shown that the use of chemicals can play a role in our daily life as a consumer both directly and indirectly. It can also affect human decision making in areas such as health, information on dietary intake (starch, carbohydrates, fats, vitamins) and food choices that affect the metabolism of the human diet. The use of chemicals can affect social decisions, for example, about choosing a place for locating an incinerator. The public must have knowledge and understanding about pollution control, chemical absorption processes, and catalytic converters, including economic decisions about climate change caused by the use of biotechnology in industry, and decisions about genetic engineering, such as genetically modified chemicals and their risk to humans and the environment (Gilbert, de Jong, Treagust, & van Driel, 2002). Therefore, we would not deny that that it is unavoidable that we will have to use chemicals in our lives. Gräber et al. (2001) have said that the direction of teaching chemistry in classrooms should consider real-life issues in the actual practice of science, applications in technological contexts, and social relations of environmental issues related to matter that will enable students to understand life and the world of science. In future, research about teaching chemistry effectively is needed to improve skills and chemical literacy, at both the secondary and tertiary levels (Moje, 1992). Therefore, it is necessary to prepare the population to be knowledgeable about chemicals in everyday life. It makes learning chemistry to not just learning content available only in textbooks or the requirements of the curriculum. However, for the learning to be effective, learners must be able to put that knowledge into practice in everyday life, get involved in activities concerning chemical issues, and make informed decisions about their own experiences rationally.

To achieve the goal of teaching chemistry to encourage the development of students' chemical literacy effectively, assessment instruments of chemical literacy have been very important in helping instructors to assess students' chemical literacy and evaluating the effectiveness of their practice in the classroom in promoting chemical literacy. Currently it is difficult to find a suitable instrument for evaluating chemical literacy. The researchers, as instructors of basic chemistry, were interested in constructing an assessment instrument for assessing students' chemical literacy. The instrument should be useful to lecturers and researchers at any institution for assessing the chemical literacy of learners.

Objective

This study aimed to construct an assessment tool to assess chemical literacy of undergraduate engineering students in Thailand.

Definition

Chemical literacy refers to a person's ability to comprehend and apply the knowledge of chemistry in everyday life in terms of understanding of three major aspects of knowledge, awareness and the application of chemistry in daily life appropriately and effectively. This chemical literacy test was constructed based on five components consisting of the following:

a) Knowledge and understanding of chemistry contents

This involves an understanding of relevant facts, concepts, principles, laws, hypotheses, theories, and models (AAAS, 1998; BouJaoude, 2002; Chin, 2005; Duschl et al., 2007; Gräber et al., 2001; Lee, 2002; Norris & Philips, 2003; NRC, 1996; PISA, 2008).

b) Knowledge and understanding of the relationship between chemistry, technology and society

This involves an understanding of the relationship between chemistry, technology and society and an awareness of the advantages and disadvantages of chemistry, technology and society, including an awareness of various benefits of chemistry for the general public (BouJaoude, 2002; Chin, 2005; Lee, 2002).

c) Application of analytical thinking

This involves the ability to break down complex problems into small, manageable components that allows the problems to be solved quickly and effectively (Duschl et al., 2007; Holbrook and Rannikmae, 2009; Lee, 2002; Norris & Philips, 2003; NRC, 1996; Preczewski et al., 2009).

d) Application of reasoning

This involves the ability to reach rational conclusions based on evidence, as well as to evaluate the logical soundness of other peoples' conclusions (AAAS, 1998; Lee, 2002; Norris & Philips, 2003).

e) Moral awareness and a sense of responsibility

This refers to an awareness of the potential consequences, both practical and moral, of chemistry-related scientific and technological developments on the general public (Gräber et al., 2001; Holbrook & Rannikmae, 2009).

METHODOLOGY

The researchers constructed a chemical literacy test assessing chemical literacy of students studying in engineering according to the components of chemical literacy based on scientific literacy tests developed by Chang and Chiu (2005), Mateapinitkul (2005), PISA (2006), and Shwartz, Ben-Zvi, and Hofstein (2006). Overall, the results were as follows:

a) Construction of Multiple-choice Chemical Literacy Test

The procedure in constructing an assessment instrument assessing knowledge and understanding of chemistry content is illustrated below.

Develop a table of specifications or test blueprints: The table was able to serve as a framework and a guide in writing and selecting of test items for assessing representative concepts of chemistry in 11 topics of fundamental chemistry and seven topics of general chemistry. The eleven topics related to the fundamentals of chemistry are 1) Theory of atoms, 2) Atoms, elements, and the periodic table, 3) Chemical bonds, 4) Mole and volume per mole, 5) Stoichiometry, 6) Gases, 7) Chemical equilibrium, 8) Acids-bases, 9) Electrochemical reactions, 10) Thermodynamics, and 11) Chemical kinetics. The seven topics of general chemistry are 1) Oil, 2) Pollution, 3) Food additives, 4) Cancer, 5) Polymers, 6) Detergents, and 7) Medicine.

Construction of 90 items of the multiple-choice test**:** The items were constructed with an item stem and four options according to a table of specifications with only one correct answer.

Index of congruence**:** To ensure relevance and adequacy of test items related to contents and concepts, three experts were asked to evaluate the congruence of test items and chemical concepts using a checklist as an assessment form.

Pilot testing**:** The revised test items based on the views of the thesis advisor and an expert were administered to a group of 50 students of the North-Eastern University. Appropriateness of words and time of testing were examined. Item analysis was investigated in terms of item discrimination indices, item difficulty indices, and distractor analysis.

Selection of items: Weak items identified in the analysis were discarded or revised and all item options that functioned well with wrong answers were plausible. Sixty items were chosen to comprise a test according to item difficulty indices ($.20 \leq p \leq .80$), item discrimination indices ($r \geq 0.2$), and a table of specifications.

Investigation of test quality: Sixty items were chosen to comprise a Multiple-choice Chemical Literacy test and the test was administered to a group of 400 students studying in the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces to examine the internal consistency reliability (K-R 20), item difficulty indices, and discrimination indices.

b) Construction of Written Chemical Literacy Test

***Develop a table of specifications*:** The table used for constructing situation-based questions required students to write down answers and express opinions towards situation-based questions. This essay test consisted of four parts: 1) knowledge and understanding of the relationship between chemistry, technology and society, 2) application of analytical thinking, 3) application of reasoning and 4) moral awareness and a sense of responsibility. Eighteen given situations were constructed based on the guidelines of the scientific literacy test of Eubanks et al. (2006) and PISA (2008). The 18 situations were about electric cars, chemistry of global warming, gasohol, chemistry in daily life, acid rain, the solubility of substances in daily life, acids-bases, temperature, pollution, classification of substances, molecules, pressure, chemical equilibrium, electric cells, marble reacting with acid, factory emissions scenario, owner of soft-drink factory, and role of engineer as a responsible citizenship.

***Construction of 22 items of essay test and scoring rubric*:** The items were constructed according to a table of specifications. The scoring rubric was developed to score answers based as follows:

Two points for a correct answer, which shows understanding of the relevant chemistry content and theories and/or demonstrates good reasoning ability.

One point for a partially correct answer, which shows some understanding of the relevant chemistry content and theories but lacks certain important elements and/or demonstrates limited reasoning ability.

Zero point for a wrong answer, which shows a lack of understanding of the relevant chemistry content and theories and/or demonstrates a lack of reasoning ability.

***Index of congruence*:** To ensure relevance and adequacy of the test items related to the contents and concepts, three experts were asked to evaluate the congruence of test items and chemical literacy concepts using a checklist as an assessment form.

***Pilot testing*:** The revised test items based on the views of the thesis advisor and an expert were administered to a group of 50 students of the North-Eastern University for the purpose of collecting information about the usefulness of the test itself, and for the improvement of the test and testing procedures. Appropriateness of words and time of testing were also examined.

To investigate the quality of the test items: The written test was administered to 400 students studying in the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces. Item analysis was investigated in terms of item discrimination power using item-total correlation coefficients, and item difficulty indices were calculated as a proportion of the average score and maximum score for each question. Internal consistency reliability (Cronbach's alpha) was computed for each part of the test. The results of the construction of an assessment instrument to assess the chemical literacy of undergraduate engineering students were summarized and discussed.

FINDINGS

The researchers constructed a chemical literacy test assessing chemical literacy of students studying in engineering according to components of chemical literacy based on scientific literacy tests developed by Chang and Chui (2005), Chin (2005), Mateapinitkul (2005), PISA (2008), and Shwartz et al. (2006) as indicated in Table1. There were two assessment formats. They were: 1) a multiple-choice test and 2) an essay test.

Table1. *Components of Chemical Literacy Test and types of assessment*

	Components of chemical literacy	Types of assessment	Item sources
1.	Knowledge and understanding of chemistry content	Multiple-choice	Chang and Chiu (2005), Mateapinitkul (2005), and PISA (2008)
2.	Knowledge and understanding of the relationship between chemistry, technology and society	Essay	Mateapinitkul (2005) and PISA (2008)
3.	Application of analytical thinking	Essay	Chang and Chiu (2005), PISA (2008), and Shwartz et al. (2006)
4.	Application of reasoning	Essay	Chang and Chiu (2005) and PISA (2008)
5.	Moral awareness and a sense of responsibility	Essay	Chang and Chiu (2005)

RESULTS OF ITEM ANALYSIS AND TEST VALIDATION

Four hundred first year students enrolled in the 1st semester of the academic year 2012 in the Faculty of Engineering at Rajamangala University of Technology Isan in Khon Kaen, Kalasin, and Nakhon Ratchasima provinces were randomly selected using a stratified sampling technique from a population of 5,841 students to be a sample in pilot testing the items. Items and test statistics were computed using the SPSS statistical package for windows.

a) Item analysis of Multiple-choice Chemical Literacy Test:

In scoring the test items, the students were awarded one point for a correct answer and zero point for a wrong answer. The item difficulty index (*p*-value) is the proportion of the number of students who answered an item correctly to the total number of students, whereas the point biserial correlation coefficient (r) between an item and the total score is used as the discrimination index. Internal consistency reliability (KR-20) is used to judge the consistency of results across items on the same test, whether the item measures the same construct or whether the items are homogeneous. Nunnally (1978) has indicated 0.7 to be an acceptable reliability coefficient. Content validity is the degree of correspondence between the test content and the content of the materials to be tested as evident by showing the test blue print and Index of Congruence between three experts. The results of the item analysis are summarized in Table 2.

Table 2. *Item statistics (IOC, p-values, and discrimination indices) for Multiple-choice Chemical Literacy Test (See example of test items in appendix part1)*

Items	IOC	p	r	Item	IOC	p	r
1	1	0.29	0.21	31	0.67	0.36	0.24
2	1	0.56	0.31	32	1	0.36	0.24
3	1	0.24	0.25	33	1	0.41	0.35
4	1	0.21	0.21	34	1	0.55	0.35
5	0.67	0.25	0.28	35	1	0.26	0.21
6	0.67	0.29	0.29	36	0.67	0.35	0.36
7	0.67	0.32	0.24	37	1	0.25	0.26
8	1	0.31	0.22	38	1	0.37	0.28
9	1	0.42	0.30	39	1	0.25	0.27
10	0.67	0.20	0.22	40	1	0.23	0.22
11	0.67	0.22	0.23	41	0.67	0.24	0.21
12	0.67	0.24	0.24	42	1	0.21	0.21
13	1	0.30	0.21	43	1	0.20	0.26
14	0.67	0.35	0.26	44	0.67	0.51	0.52
15	0.67	0.46	0.29	45	01	0.53	0.34
16	1	0.23	0.28	46	0.67	0.24	0.25
17	1	0.48	0.34	47	1	0.20	0.20
18	1	0.44	0.52	48	0.67	0.48	0.56
19	0.67	0.42	0.35	49	0.67	0.41	0.27
20	1	0.25	0.25	50	1	0.61	0.36
21	1	0.46	0.32	51	0.67	0.54	0.68
22	0.67	0.22	0.21	52	1	0.48	0.56
23	1	0.54	0.27	53	1	0.52	0.40
24	1	0.29	0.26	54	1	0.24	0.23
25	1	0.31	0.22	55	0.67	0.31	0.23
26	.67	0.37	0.45	56	1	0.26	0.23
27	1	1.32	0.30	57	1	0.42	0.27
28	0.67	0.23	0.23	58	0.67	0.25	0.24
29	1	0.24	0.23	59	1	0.37	0.50
30	1	0.24	0.29	60	1	0.50	0.61

b) Item analysis of Written Chemical Literacy Test

The students were awarded *two points* for a correct answer—that is, an answer which shows accurate understanding of the relevant chemistry content and/or demonstrates good reasoning ability; *one point* for a partially-correct answer—that is, an answer which shows some understanding of the relevant chemistry content but lacks certain important elements and/or demonstrates limited reasoning ability, and *zero point* for a wrong answer—that is, an answer which shows a lack of understanding of the relevant chemistry content and/or demonstrates a complete lack of reasoning ability.

Item difficulty index (p-value) of an item is the quotient of the average score of all students and the maximum score, whereas the Pearson Product Moment correlation coefficient (r) between an item and the total score is used as the discrimination index. Internal consistency reliability (Cronbach's alpha) was used to judge the consistency of results across items on the same test or items that measure the same construct or items that are homogeneous. The results of the item analysis are indicated in Table 3 and Table 4.

Table 3. *Item statistics (means, p-values, and discrimination indices) of Written Chemical Test (One item =one situation and/or one case, see example of items in appendix part 2)*

Components of Chemical literacy	Items	Frequency (N=400)			r	Mean score	*P*-value
		Score 0	Score 1	Score 2			
Knowledge and understanding of the relationship between Chemistry, technology and society	1	59	172	169	0.59	1.28	0.64
	2	49	199	152	0.66	1.26	0.63
	3	38	175	187	0.67	1.37	0.69
	4	54	169	177	0.62	1.31	0.66
	5	70	150	180	0.73	1.28	0.64
Average for each component					.65	1.30	0.65
Application of analytical thinking	1	189	187	24	0.55	.58	0.29
	2	221	136	43	0.67	.56	0.28
	3	213	150	37	0.58	.56	0.28
	4	215	126	59	0.65	.62	0.31
	5	158	150	92	0.68	.84	0.42
Average for each component					0.63	.64	0.32
Application of reasoning	1	225	116	59	0.72	.58	0.29
	2	157	173	70	0.74	.78	0.39
	3	198	154	48	0.71	.62	0.31
	4	151	169	80	0.68	.82	0.41
	5	240	89	71	0.58	.58	0.29
	6	276	88	36	0.63	.40	0.20
	7	148	186	66	0.67	.80	0.40
	8	72	101	227	0.51	1.38	0.69
	9	247	92	61	0.52	.54	0.27
Average for each component					0.64	.72	0.36
Moral awareness and a sense of responsibility	1	87	131	182	0.79	1.34	0.62
	2	69	117	214	0.86	1.36	0.68
	3	69	140	191	0.83	1.30	0.65
Average for each component					0.83	1.33	0.67

The Pearson Product Moment correlation coefficient (r) between an item and the total score is used as the discrimination index. Internal consistency reliability (Cronbach's alpha) is used to judge the consistency of results across items on the same test or items that measure the same construct or items that are homogeneous. Table 4 shows the summary of the analysis of test quality of the Chemical Literacy Test.

Table 4. *Summary analysis of test quality of Chemical Literacy Test (N=400)*

Assessment formats	Components of chemical literacy	Test quality
60-item Multiple-choice Chemical Literacy Test (Objective test for 80 minutes)	(1) knowledge and understanding of chemistry content	IOC = 0.67-1.00, p = 0.20-0.61, *r* = 0.20-0.68, *KR-20 = 0.72*
22-item Written Chemical Literacy Test (80 minutes for18 situation-based questions)	(2) knowledge and understanding of the relationship between chemistry, technology and society	IOC = 0.67-1.00 p = 0.63-0.69 r = 0.59-0.73 Cronbach's alpha =0.66
	(3) application of analytical thinking	IOC = 0.67-1.00, p = 0.28-0.42 r = 0.55-0.68 Cronbach's alpha = 0.61
	(4) application of reasoning	IOC = 0.67-1.00, p = 0.20-0.69 r = 0.51-0.74 Crobach's alpha = 0.82

	(5) moral awareness and a sense of responsibility	IOC = 0.67-1.0, p = 0.65-0.68 r = 0.79-0.86 Cronbach's alpha=0.77

DISCUSION

As a result of the development of the assessment instrument and investigation of the test quality of paper and pencil testing in assessing and reflecting the chemical literacy of students studying basic chemistry in college, the Chemical Literacy Test was constructed consisting of two assessment formats: Multiple-choice Chemical Literacy and Written Chemical Literacy. The Written Chemical Literacy Test consisted of four parts for assessing: knowledge and understanding of the relationship between chemistry, technology and society, application of analytical thinking, application of reasoning and moral awareness and a sense of responsibility.

a) Multiple-choice Chemical Literacy Test

This test had quality in terms of internal consistency reliability of 0.72 which was acceptably enough to assess the knowledge and understanding of chemistry content of students studying basic chemistry in Thai higher education institutions. This result was consistent with the results derived from studies of Chang and Chiu (2005), Mateapinitkul (2005), and PISA (2008). According to Chang and Chiu (2005) and PISA (2008), scientific literacy was measured as the understanding of scientific concepts, scientific methods, and the nature of science, whereas Mateapinikul (2005) measured students' knowledge and understanding of scientific concepts for students under 15-year-old.

b) Written Chemical Literacy Test

This test used situation-based questions in the context of chemistry in Thailand, assessing chemical literacy in four components. The first component was knowledge and understanding of the relationship between chemistry, technology and society. This aspect of chemical literacy was a part of the knowledge and understanding of the relationship between science, technology and society investigated by Mateapinitkul (2005) and PISA (2008) which used free responses in writing. The second component was application in analytical thinking, and the third component was application in reasoning. These components were situation-based questions that involved higher-order thinking skills that required students to apply analytical thinking in solving problems and answering problematic situations in chemistry in context and to create rational and reasonable conclusions based on evidence, or to evaluate whether or not conclusions made by others were consistent with the evidence. It can be seen that the Written Chemical Literacy Test was able to assess students' thinking skills and to relate scientific data to claims and conclusions (use of scientific evidence, which is similar to scientific literacy developed by Chang and Chiu (2005) and PISA (2008). The fourth component was moral awareness and a sense of responsibility toward the result of development of science and technology in solving problems in everyday life. Moral awareness and a sense of responsibility component was assessed using an assessment tool constructed by the researchers to reflect on the situation that the chemical was a virtue so that students should have a social responsibility as citizens regarding the impacts of social and environmental issues caused by the chemicals. Social responsibility was a new issue of concern in the perspectives of science education, which lacks monitoring and checking of such aspects.

The construction of the Chemical Literacy Test, an assessment instrument assessing chemical literacy and investigation of test quality, was found to be able to assess higher education students' chemical literacy as aforementioned in a similar way to the development of assessment tools by Shwartz et al. (2006). They constructed assessment tools measuring students' ability to: a) recognize chemical concepts, b) define some key-concepts, c) use their understanding of chemical concepts to explain phenomena and d) use their knowledge in chemistry to read a short article, or analyze information provided in commercial ads or internet resources. They developed tests to measure different levels of chemical literacy. Likert–type scales, open-ended questionnaires, and multiple-choice questionnaires were used to assess high-school students' levels of chemical literacy in Israel. Celik (2014) used some parts of the tests developed by Shwartz et al. (2006) to assess the chemical literacy of first-year students in the Department of Secondary Science and Mathematics Education in Turkey. In addition, Witte and Beers (2003) used a test to assess chemical literacy in aspects of knowledge and skills to understand information relevant to issues in everyday life using essay type questions by writing answers in chemistry in context in the examination for 17-year-old students in the Netherlands.

Therefore, the Chemical Literacy Test developed by the researchers was considered as a key part to be used as guidelines to assess the important construct of chemical literacy of students which is a major goal in teaching and learning chemistry in Higher Education of Thailand.

CONCLUSION

This research aims to develop an instrument with quality to assess the chemical literacy of students studying chemistry in Higher Education (University level). According to the aforementioned results, two assessment types of the Chemical Literacy Test were developed. The first type of assessment was the Multiple-choice Chemical Literacy Test to assess knowledge and understanding of chemistry content. The second type of assessment was a Written Chemical Literacy Test to assess four components of chemical literacy in knowledge and understanding of the relationship between chemistry, technology and society, application of analytical thinking, application of reasoning and moral awareness and a sense of responsibility. The Chemical Literacy Test was used to assess the chemical literacy of undergraduate engineering students because this test is acceptable in analysis of test items (Berk, 1984) and test validation in terms of content validity and reliability as indicated in the aforementioned results (Johnson & Christensen, 2008).

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APPENDIX
Example of Chemical Literacy Test (CLT)

Part 1: Multiple Choice Test Items *(Some examples of questions)*

Ex1. Which of the statements below is ***not*** the answer to explain Dalton's atomic model?

a. Atoms are small and indivisible.
b. Atoms of different elements can have the same mass of the neutrons.
c. Atoms of the same element have the same properties.
d. Elements react with each other in a simple ratio.

Ex2. Sulfur hexafluoride (SF_6) gas is colorless, odorless and non-reactive. Calculate the pressure (in atm) of 1.82 moles of gas with a volume of 5.43 liters stored in steel tanks at a temperature of 69.5 ^{0}C?

a. 4.5 atm b. 9.42 atm c. 12.52 atm d. 15.42 atm

Ex3. Which of the following about gasohol 91 is ***not*** correct?

a. It is a mixture of 95% of gasoline and 5% of ethanol.
b. It has an octane number of 91.
c. Reduces global warming.
d. Arises from the use of ethanol instead of using the MTBE.

Ex4. What are synthetic drugs?

a. Morphine and heroin
b. Marijuana and opium
c. Seconal and opium
d. Amphetamine and marijuana

Part 2: Written Test Items *(some examples of situations and cases)*

Part 2.1 Situations

Situation #1: Electric cars

Some people advocate the use of cars that use electricity as an alternative instead of a gasoline car, which seems to be the hope for the future. But currently, it is only possible for some areas. You are going to use the criteria in deciding what car to buy using such power. Therefore, if you are going to make a decision about buying an electric car, what criteria would you use in deciding to buy such car?

Answer

……………………………………………………………………………………………………

Situation # 5: Acid rain

The case of atmospheric pollution is due to "acid rain". Do you think that the conditions of acidity of the rain in the area of your house and Metropolitan areas of Bangkok are different? Explain how and why.

Answer

……………………………………………………………………………………………………

Situation #15:

Mr. Smith puts a small piece of marble with a mass of 2 grams in vinegar. After he puts it into vinegar, he leaves it overnight. He puts another marble into pure water and leaves it overnight as well. The next day, he takes the debris and makes it dry. What are the changes in the mass and shape of the marble after putting it in vinegar? Why does Mr. Smith conduct an experiment with the marble in water?

Answer

……..……..................................

Part 2.2. Case Studies

Case study # 1: The factory in an industrial estate is releasing toxins.

Currently found is an area of an industrial estate with many factories that use chemicals in the manufacturing process. The results of such a process cause the formation of toxins that are released into the atmosphere, with impact on health. Some have severe effects leading to death. In many other people, the toxins accumulate in the body so that the chronic hazard results in the need for medical treatment. As you are likely to be part of the industry in the future, do you think anyone else would have to be involved in solving the problem? What should be the approach to handle the problem?

Please express your opinions and answer the question about this case study

……………………………………………………...

Case study # 3: An engineer

You will be an engineer in the future. Do you think you will take responsibilities as a citizen of Thailand who will be critical to growth and sustainable development?

Please express your opinions and answer the question about this case study

……………………………………………………...