

## CHEMICAL LITERACY OF FIRST-YEAR STUDENTS ON CARBON CHEMISTRY

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**Abstract:** This research aims to develop and validate chemical literacy test instruments on competency and knowledge aspects and to measure the chemical literacy of first-year science education students. Instrument development involved expert consultation, expert judgment, and testing of 114 first-year students majoring in chemistry for the analysis of item validity and instrument reliability. The instrument was developed using the Research & Development model by Borg and Gall (1989). The developed instrument consisted of 30 valid item items with Cronbach's Alpha reliability coefficient of 0.718. The analysis was carried out on 28 first-year students of the Jember State University Science Education Study Program who had studied carbon chemistry. Data analysis showed that the average score of students' chemical literacy was 59.7 in the moderate category.

**Keywords:** chemical literacy, multiple-choice chemical literacy test instruments, carbon chemistry

### INTRODUCTION

Scientific literacy has gained concern from researchers, lecturers, and public policyholders (Impey, 2013) since it is required by modern society to encounter different issues related to science and technology (Turiman et al., 2012). According to Impey (2013), the indicator of a pre-service teacher who has great scientific literacy is their understanding of scientific and technological effects on daily living; taking individual decision related to science, health, use of energy sources; understanding substantial components related to science reported by media; criticize information, and participate in a discussion of science issues. Therefore, pre-service teachers should be prepared to encounter those issues. Besides, scientific literacy is essential to aid teachers in comprehending the content and components of scientific literacy while using the consistent learning methodology as the key mechanism to guide students to develop their scientific literacy through classroom learning (Traiwichitkhun & Wongwanich, 2014).

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Scientific literacy comprehension highly determines the learning activities conducted by those prospective teachers in the future. The significance of this scientific literacy is also emphasized by Norris & Phillips (2009), who state that one of the primary objectives of science learning is creating a society with excellent scientific literacy. In addition, scientific literacy is also the primary objective of contemporary science (Muntholib et al., 2020, as cited in DeBoer, 2000; Barnea et al., 2010; Cigdemoglu & Geban, 2015). As a part of science, chemical literacy becomes the central objective of science education (Celik, 2014). Consequently, according to Muntholib et al.(2020), one of the consequences for placing chemistry as the science education purpose is to ensure the availability of assessment instruments.

To attain this purpose, some chemical literacy frameworks have been developed. One of those frameworks is invented by (Shwartz et al., 2006) that consists of four domains, namely (1) knowledge on science and chemistry content; (2) chemistry in a context; (3) high-level learning skills; and (4) effective aspect. Besides, Bybee (1997) creates a chemical literacy framework that measures high school students' chemical literacy with the literacy domain of nominal scientific literacy, functional scientific literacy, conceptual scientific literacy, and *multi-dimensional scientific literacy*. Meanwhile, (PISA 2006) and (OECD, 2016) develop a scientific literacy test framework in *Programme for International Student Assessment* (PISA) that is continuously updated every three years. Muntholib et al. (2020) mention that the OECD framework is more explicit, simple, and popular so that it becomes the most implemented framework used to evaluate scientific literacy, especially chemical literacy.

The scientific literacy within PISA subsists of four aspects, namely contexts, scientific knowledge, competence, and attitude. The element of context is classified into three domains of personal, national, and global. Meanwhile, scientific knowledge is categorized into three parts of knowledge on content (information related to nature and human work, such as artefact and technology), procedural knowledge (insight on the creation of scientific ideas), and epistemic knowledge (knowledge on the basis of the scientific knowledge creation procedure and its usage justification). Competence represents the ability to explain and evaluate phenomena scientifically and design scientific inquiry and interpret data and evidence scientifically. Lastly, attitudes cover the manner toward science, shown from the interest in science and technology, respecting scientific approach during the inquiry process, perception, and awareness on environmental issues.

According to those literacy frameworks, a number of chemical literacy tests have been created. One of the chemical literacy test instruments is developed by Thummathong & Thathong (2018) that measures engineering students' chemical literacy. Besides, Cigdemoglu et

al. (2017) also create a chemical literacy test on the acid-base topic that measures science teacher argumentation using PISA 2006 literacy framework, while (Norris & Phillips, 2003) and (Duschl & Osborne, 2002) make literacy test on the competence aspects that evaluates the reading, writing, reasoning, and arguing ability. Laugksch & Spargo (1996) construct the scientific knowledge aspect using Miller's (1983) framework based on the American scientific project purpose, known as science for all. Several other researchers have also used that framework, such as Rahayu (2011) who creates a chemical literacy test on the electrochemical material using OECD 2015 framework, (De Ovira, 2018) initiates chemical literacy instrument on hydrocarbons, thermochemistry, petroleum, reaction rates and chemical equilibrium using OECD 2006 and 2012 frameworks. However, a chemical literacy test on the knowledge and competence aspect of carbon materials mentioned in all topics of the 2013 curriculum for high school has not been developed.

The test format selected in this study is multiple choice. This format helps the students complete the test items quickly and gives a more objective scoring while also can be adopted to measure all cognitive elements (Gurel et al., 2015). Muntholib et al. (2020) explain that a multiple-choice test is the most efficient test to identify misconceptions. Some multiple-choice test topics have been established. Adawiyah & Wisudawati (2017) construct a scientific literacy instrument that explains scientific phenomena toward junior high school students, Muntholib et al. (2020) developed a chemical literacy instrument on the chemical kinetics material for first-year students, and Gerlach et al. (2014) invent a multiple-choice test on general chemistry material to evaluate students' literacy scale in the pre-university chemistry course. Tarhan & Sesen (2010) created 25 multiple-choice items to identify students' initial knowledge on acid and base learning, consisting of chemical solutions, periodic systems, chemical bonds, chemical reactions, thermodynamics, and chemical equilibrium. Thus, it has confirmed the massive use of the multiple-choice test. The chemical literacy knowledge and competence aspects focuses on chemical knowledge and scientific cognitive skills that can be evaluated using multiple choice format (Muntholib et al., 2020).

The advancement of prospective teachers' scientific literacy remains a challenge in the university teaching and learning process. A survey conducted in 1988-2008 identifies a less significant scientific literacy improvement (10%-15%) of the students' across universities in the United States of America (Impey, 2013). At the same time, the scientific literacy of Turkey prospective teachers is also low (Akengin & Sirin, 2013). Additionally, Sunarti (2015) conducted a study on prospective physics teacher in Universitas Negeri Surabaya that obtains an average

score of 51.3 on the scientifically explaining a phenomena competence; 9.3 on evaluating and designing scientific inquiry; and 23.8 on scientific data and evidence interpretation. This low scientific literacy of prospective teachers results in the enactment of Regulation of Minister of Education and Culture no 49, the Year 2014 on the national standard of university (Kemendikbud, 2014). That regulation accentuates interactive, scientific, contextual, collaborative, and student-centred learning. Sunarti (2015) explains that the primary problem in Indonesian university learning is the lack of lecturers concerned about learning achievement, proper learning strategy, and method. Thus, the learning is dominated by lecturing that obstructs students' to comprehend the learning material. Besides, the limited opportunity to implement the learning material has also hindered the students to easily understand the material.

Ideally, conceptual and skill learning in the university is attained through courses that applied a scientific approach to real-life issues solvency, involving the skills to observe, question, experiment, reason, and present. However, Muntholib et al. (2020) mention that the scientific approach has been rarely implemented in the courses since the courses are broad and deep, so the expository approach becomes more prevalent in classroom learning. The expository approach is perceived to be more efficient in conveying broad information. However, this approach emphasizes procedural knowledge, designing inquiry, and competence in interpreting scientific data and evidence, which are crucial in scientific literacy.

Scientific literacy has a vast coverage, so that each science learning, including chemistry learning, is expected to contribute to the realization of a scientifically literate society (Shwartz et al., 2006). Osborne & Dillon, 2008; Shwartz et al., 2006 explain that chemistry is a branch of applied science that explicitly aims to train and enhance prospective science teachers' scientific literacy. Thummathong & Thathong (2018) argue that chemical literacy refers to someone's ability to comprehend and implement three significant aspects of knowledge, awareness, and application of chemistry in daily life, appropriately and effectively. Barnea et al. (2010) argue that chemical literacy covers an understanding of the particle, material, reaction, law, theory, as well as the application of chemistry in daily life. One of the chemistry materials obtained by natural science prospective teachers is chemical carbon material. The chemical carbon material explained in the national curriculum is given to the 11<sup>th</sup> and 12<sup>th</sup>-grade senior high school students (Permendikbud, 2016 No 20 ). That material comprises alkane and its derivatives, benzene and its derivatives, functional groups, carbon compounds' property, and the application in daily life. The teaching and learning process usually involves everyday phenomena, such as sodium benzoate and benzoic acid as a food preservative. This issue is highly relevant to students' daily life since almost every food requires a preservative. The other examples are the effects of fossil

fuel use on global warming, the use of bioethanol as alternative energy to reduce pollution, others alkene derivative compounds utilized as materials in some petrochemical industries, and many other hydrocarbon compounds that can be easily identified. Therefore, chemical carbon materials are closely related to students' daily life, so that it can be involved to increase their literacy skills. Additionally, carbon chemical compounds also offer different scientific literacy knowledge and competence aspects that can be seen in daily life. Consequently, the chemical literacy-based instrument should be developed for prospective teachers' chemical literacy (Sumarni et al., 2018). Cigdemoglu et al (2017) explain that chemical concepts that are related to a student's life should be investigated. To enhance prospective teachers' chemical literacy, a chemical literacy test instrument on the chemical carbon material is required.

This study has two primary objectives (1) to develop and validate multiple-choice chemical literacy test instruments and (2) to implement the instrument to attain information on prospective science teachers' chemical literacy comprehension, primarily on the chemical carbon material. This study is only limited to the aspects of context, knowledge, and competence, without the behaviour aspect.

## **METHOD**

### **Preparation of chemical literacy test instrument**

This study used the PISA literacy framework while replaced the science content knowledge with chemical carbon, following the formula from Shwartz et al.(2006). The chemical literacy framework is presented in Table 1.

**Table 1, PISA and Shwartz's Chemical Literacy Framework**

PISA Framework	Schwartz's Framework
<p><b>Context</b> Personal, local and global current or past issues that require scientific and technological understanding</p>	<p><b>Chemical Content Comprehension</b> It includes knowledge on general ideas involving scientific investigation, generalizing findings, using the skills to associate different disciplines to understand phenomena, and using understanding on chemical features or key ideas. It also includes the comprehension of explaining the macroscopic phenomenon by considering its structure, reaction process, energy transformation, living system's structure, and chemical language contribution toward chemistry.</p>
<p><b>Knowledge</b> Knowledge on primary facts, theories of the universe, theories of technological artefact (content knowledge), the process of scientific ideas are produced (procedural knowledge), along with rational reasoning for a scientific procedure selection and its justification (epistemic knowledge).</p>	<p><b>Chemistry in a Context</b> Chemical knowledge that explains daily phenomena, daily implementation of chemical understanding, the ability to make a decision effectively, involvement in society debate about issues related to chemistry, and knowledge on the relation between chemical innovation and social processes</p>
<p><b>Competence</b> The ability to scientifically explain phenomena, as well as the ability to evaluate and design scientific inquiry and scientifically interpret data and evidence.</p>	<p><b>High Level of Learning</b> The ability to question, study relevant and essential information, and evaluate the pro and contra</p>

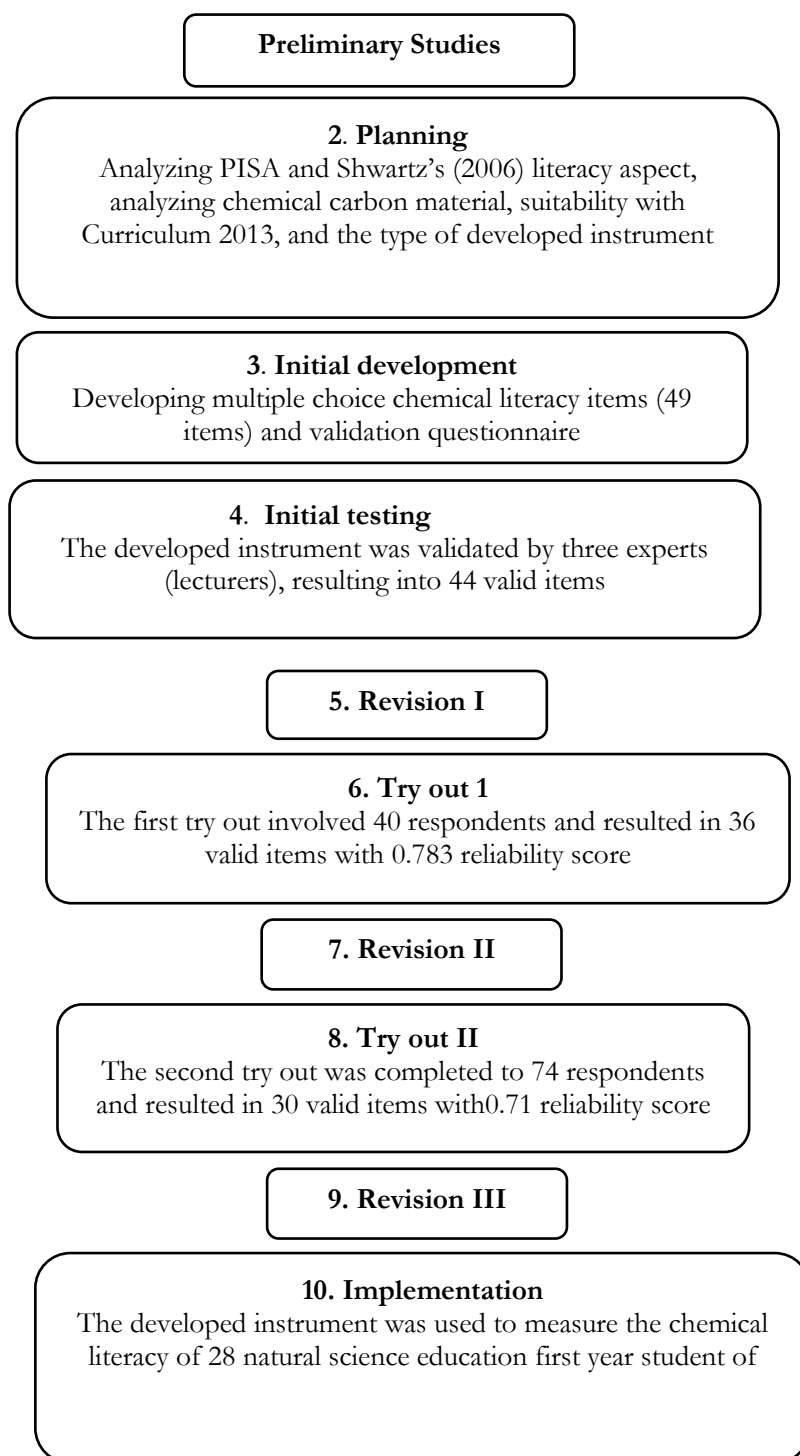
The stages of chemical literacy instrument development adopted the development model from Gall & Borg (1989). The detailed developmental stages are illustrated in Figure 1. The instrument consisted of seven contexts, with knowledge and competence aspects in each context, as shown in Table 2. The initial draft was subsisted of 44 items, while their distribution is also presented in Table 2.

**Table 2. Item Number, Chemical Literacy Context and Aspect**

Context	Indicator	Chemical Literacy Aspect*	Item No	
Ethylene, industrial raw materials	Analyzing reaction on the ethylene	MD; PK	1	
	Determining the compound structure formula	MD; PK	2	
	Analyzing the reaction of polymer formation	MD; PK	3	
	Analyzing the reaction of ethylene formulation	MF; PK	4	
	Identifying monomer based on the reaction	MD; PK	5	
	Reading scientific data in the form of graphic	MD; PE	6	
	Determining the ethanol level percentage	MF; PK	7	
Ethanol, benefits vs effects	Determining the glucose fermentation result's structure formula	MF; PK	8	
	Identifying the functional group on glucose			
	Classifying the alcohol types based on the functional group	MD; PK	9	
	Determining the reaction results based on data	MD; PK	10	
	Formulating conclusion based on scientific reason	MD; PK	11	
	Determining variable based on investigation question	MM; PE	12	
	Determining and designing research procedure based on the graphic		MM; PP	13
			MM; PP	14
			MM; PP	15
The catalytic converter, the solution to reduce pollution	Determining catalytic converter result compounds	MF; PK	16	
	Evaluating scientific claims following scientific evidence	MD; PE	17	
	Determining and designing research procedure	MM; PP	18	
	Essential compounds in our surrounding	Identifying aldehyde functional group	MD; PK	19
		Determining reaction types on the formulation of ethyl ethanoate compound	MD; PK	20
		Deciding the structure formula of aldehyde derivative compounds		
		Evaluating claim based on scientific data and evidence	MD; PK	21
		Determining isomer function on aldehyde derivative compound		
		Determining reaction result from aldehyde derivative compound	MF; PE	22
		Deciding the proper experiment procedure on the ester compound formation		MD; PK
			MD; PK	24
	MM; PP	25		
Refuelling station	Determining the number of moles on the fuel content	MD; PK	26	
	Determining the number of isomer on the fuel content	MD; PK	27	
	Determining the thermochemical equations on the LPG components	MD; PK	28	
	Deciding the formula of the compound in the gasoline	MD; PK	29	
	Determining the gasoline content percentage based on the molecule structure	MD; PK	30	
	Selecting the fuel quality based on its constituent components	MD; PK	31	
Identifying alkane compounds properties	Determining the IUPAC nomenclature of alkane compound based on the structure	MD; PK	32	
	Formulating conclusion following graphic	MM; PE	33	
	Formulating conclusion based on scientific reasoning	MM; PE	34	
	Identifying the boiling point based on scientific reasoning	MM; PK	35	
	Concluding scientific data based on the graphic	MD; PE	36	
Benzene and its function	Determining the reaction types on the formulation of benzene compounds	MD; PK	37	
	Determining the structure formula and reaction types of benzene	MD; PK	38	
	Classifying the benzene compounds nomenclature following the structure	MD; PK	39	
	Defining the reaction on the benzene compounds creation	MD; PK	40	
	Evaluating scientific claim based on scientific evidence	MD; PK	41	
	Determining structure formula on the benzene derivative compounds	MF; PE	42	
	Determining the bonding orbital on benzene compound	MD; PK MD; PK	43	
	Determining response on the benzene derivative compounds formulation	MD; PK	44	

The product design process was started by arranging the chemical literacy instrument based on the literature review results and consultation with experts. The expert consultation was completed to attain suggestions on the instrument compatibility with the selected literacy framework. Additionally, chemical carbon was selected as the instrument topic based on the results of the investigation on various concepts. The initially developed instrument was validated by experts. The validation includes four aspects of (1) indicator conformity, literacy aspect, and cognitive demand; (2) scientific truth of the material; (3) question clarity on each item; and (4) language effectiveness. From the expert validation results, a 44 items chemical literacy instrument draft was obtained.

The test instrument draft was tried out to 114 students to identify the items' validity and reliability. The limited scale testing was carried out to 40 chemical education students of Universitas Negeri Malang. After being analyzed using Cronbach's Alpha, the test obtained a 0.738 reliability score with 36 valid items. Meanwhile, wide-scale testing was conducted on 74 first-year students in chemistry education of Universitas Negeri Malang. The result of the wide-scale testing was analyzed to discover the test validity, reliability, item discrimination, and item difficulty. The analysis result shows the test has 0.718 reliability with 30 valid items. Consequently, the developed chemical literacy test instrument has 30 items.



**Figure 1. The stages of chemical literacy development**

### **Students' Chemical Literacy Assessment**

The respondent in this study was the first-year natural science education students of Universitas Negeri Jember, the academic year 2019/2020. The respondents had obtained

chemical carbon material in their high schools, which according to the Ministry of Education and Culture Regulation, the material is distributed to 11<sup>th</sup> and 12<sup>th</sup> graders (Permendikbud, 2014). The data analysis was carried out by calculating the students' answer percentage based on the scientific literacy and literacy level.

## **RESULTS AND DISCUSSION**

### **Chemical carbon scientific literacy test instrument**

The instrument analysis carried out after the try-out consists of validity, reliability, item difficulty, and item discrimination analysis.

#### **Content validity**

The validity analysis carried out in this study includes content validity and item validity. The content validity has been carried out through an assessment involving three experts in the chemical education field. Besides the scoring, the experts also provide test suggestions and revisions, including language selection and the conformity between the literacy aspect and the measured concepts. The items determined to have good content validity were tried out to 114 first-year chemistry education students of Universitas Negeri Malang. The try-out results were analyzed to attain the test's item difficulty, item discrimination, item validity, and reliability.

#### **Item validity**

The item validity was completed after a try-out that involved 74 respondents. The respondents were asked to fine-tune the test with 36 items. The SPSS analysis results show 30 valid and six invalid items.

#### **Test instrument reliability**

The test instrument reliability was determined based on the Cronbach alpha coefficient, while the analysis was carried out using SPSS 21.0 for windows. The test reliability coefficient from the first and second try out are 0.738 and 0.718, respectively. This coefficient has exceeded the minimum reliability coefficient of 0.5 and 0.7. Thus, the chemical carbon test instrument can be used as the data collection instrument.

#### **Item difficulty**

Item difficulty represents the difficulty level of an item for the respondent. It is calculated by comparing the number of respondents with correct answers with the total number of respondents. The results demonstrate that 40 items are classified as moderate, and four items are

categorized as easy. Meanwhile, the results of wide-scale testing show that 30 items are categorized as moderate, and six items are classified as easy. The average item difficulty index of this instrument is classified as moderate, with a difficulty index range from 0.31 to 0.70.

### **Item discrimination**

The item discrimination was analyzed from the results of a test involving 114 students. According to Arikunto (2012), item discrimination score is classified into poor (0.00-0.20), sufficiently good (0.21-0.40), good (0.41-0.70), and great (0.71-1.00). Item discrimination represents the ability of an item to discriminate between high and low-achieving students. The analysis of the first try-out results shows 13 items classified as great, 19 items classified as good, 11 items classified as sufficiently good, and 1 item classified as poor. Meanwhile, from the second try out, 8, 20, 6, and 1 item are categorized as great, good, sufficiently good, and poor, respectively. The average item discrimination of the instrument is classified as sufficiently good, with a score range from 0.21 to 0.40.

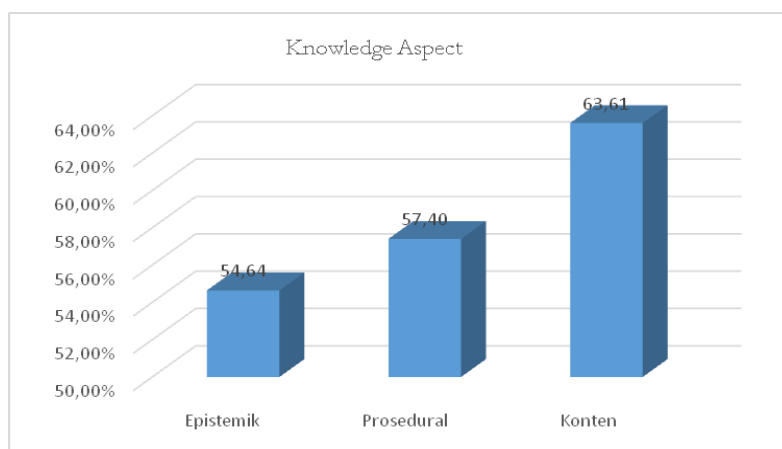
### **Students' scientific literacy on organic compounds material**

Students' chemical literacy on the chemical carbon material was measured using 30 items on the instrument. Each item has knowledge and competence scientific literacy aspect. The scientific literacy test was completed for 28 first-year natural science education students of Universitas Negeri Jember who have obtained chemical carbon material previously. The average students' literacy attainment is presented in Table 3.

**Table 3. Students' scientific literacy**

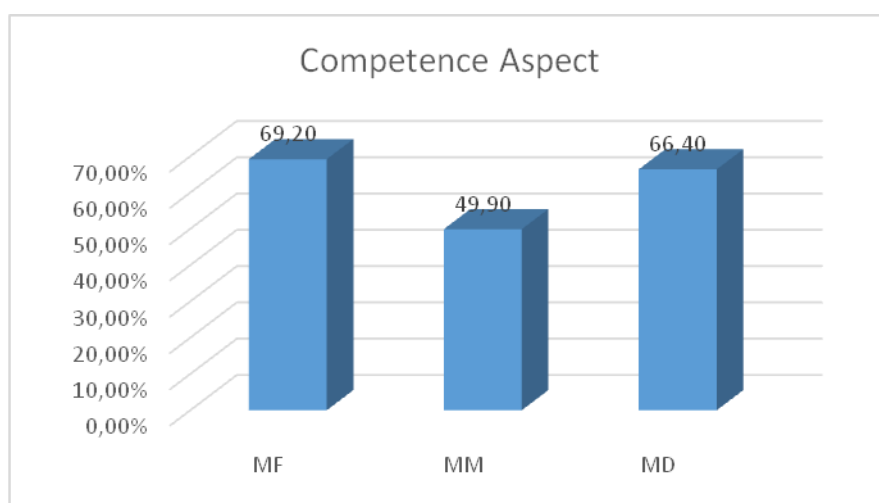
<b>N</b>	<b>Total item</b>	<b>Lowest score</b>	<b>Highest score</b>	<b>Average score</b>
28	30	15 (50)	22 (73,3)	59,7

According to Table 4, the first-year students' scientific literacy scores range from 50 to 73.3, with an average score of 59.7. Students' scientific literacy in each literacy aspect is illustrated in Figures 2 and 3.



**Figure 2. Students' scientific literacy score on knowledge aspect (content, epistemic, procedural)**

From the knowledge perspective, scientific literacy consists of three aspects, namely chemical content, procedural knowledge, and epistemic (knowledge on a specific chemical procedure selection reasoning and its justification) knowledge domains. Generally, the average score of students' knowledge aspect score is classified as low. As shown in Figure 2, there are significant differences in scores between students' content, epistemic and procedural knowledge. Besides, content knowledge gains the highest score. This result is similar to the result of a study conducted by Muntolib et al. (2020) that shows a 63.24 average chemical literacy score of the first-year students in Universitas Negeri Malang.



**Figure 3. Students' scientific literacy score on competence aspect**

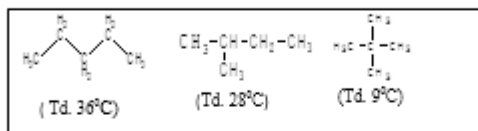
In the competence perspective, chemical literacy is divided into scientifically explain a phenomenon (MF), evaluate and design scientific inquiry (MM), as well as interpret scientific data and evidence (MD). As illustrated in Figure 3, the students attain the highest score in the scientifically explain phenomena aspect, followed by interpreting scientific data and evidence. Meanwhile, the evaluation and design inquiry aspect gains the lowest score.

Chemical content knowledge covers factual and conceptual knowledge, such as ideas, laws, principles, and theories on true and acceptable natural phenomena ( OECD, 2015). The developed instrument has 21 items that discuss chemical content knowledge used to measure students' chemical content knowledge. The results of data analysis show that students have obtained the highest score of 66.4 on this aspect, compared to other aspects. According to the chemical literacy skills level from Thummathong & Thathong (2018), this content knowledge score can be classified as moderate (50-69 score). One of the items that measure students content knowledge is presented in Figure 4, in which 57% students gives correct answer on that item. This item is in the moderate cognitive domain category with an average difficulty index and good discriminating power. To provide a correct answer for this item, respondents have to comprehend the compounds nomenclature concept and the relation between alkene compounds property and compound structure. Thus, the result represents that many respondents have a low understanding of compounds' physical and chemical features with structure formulas. Therefore, the students still have not had an excellent knowledge of this aspect.

**Konten 5**

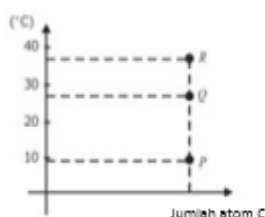
**Bacaan untuk soal nomor 24 - 27. Mengenal Sifat senyawa Alkana**

Alkana merupakan salah satu senyawa hidrokarbon yang memiliki banyak manfaat dalam kehidupan. Alkana banyak diperoleh dari fraksi minyak bumi yang dimanfaatkan dalam berbagai keperluan, baik sebagai bahan bakar maupun bahan baku industri. Senyawa alkana memiliki sifat fisis dan sifat kimia. Sifat fisis senyawa alkana diantaranya adalah memiliki massa molekul relatif dan titik didih yang semakin tinggi seiring dengan bertambahnya jumlah atom karbonnya. Sedangkan sifat kimia diantaranya, struktur alkana terdiri dari rantai lurus dan bercabang serta dapat membentuk isomer.



Gambar 1: contoh isomer senyawa alkana (pentana)

26. Berdasarkan sifat fisis senyawa alkana pada bacaan, diberikan 3 buah isomer dari senyawa  $\text{C}_5\text{H}_{12}$ , yaitu senyawa P, Q, R. Data titik didih ketiga senyawa tercantum pada grafik berikut:



Berdasarkan grafik dapat diprediksi bahwa senyawa P, Q dan R berturut – turut adalah....

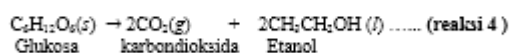
Opsi	P	Q	R
A	2-metil butana	n-pentana	2,2-dimetil propana
B	n-pentana	2,2-dimetil propana	2 metil butana
C	2,2-dimetil propana	2-metil butana	n-pentana
D	2,2-dimetil propana	n-pentana	2-metil butana
E	n-pentana	2-metil butana	2,2-dimetil propana

Figure 4. Example of the item with content knowledge aspect

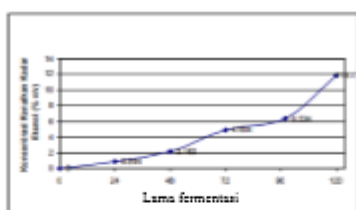
In chemistry learning, procedural knowledge is required to obtain conceptual knowledge and sharpen scientific procedural skills in determining the proper solution for a problem. This knowledge is highly demanded in scientific investigation and critical review of the evidence supporting a scientific claim. Five items on the developed instruments evaluate students' procedure; knowledge. The average score obtained from this aspect is 57.4. Students' attainment on this aspect can be seen in an item presented in Figure 5. On that item, 57.14% of students have been successfully given the correct answer. To answer this question, students have to understand the types of research variables, consisting of independent, dependent, and control variables.

**Bacaan untuk Soal nomor 6 – 12 : Etanol, Manfaat & dampak**

Indonesia pada tahun 2018, impor etanol (salah satu jenis alkohol) mencapai Rp 1,085 triliun. Secara luas etanol banyak digunakan sebagai pereaksi, pelarut dan bahan bakar. Etanol selain bermanfaat, juga berbahaya jika disalah gunakan sebagai minuman yang memabukkan. Selain itu, dalam industri etanol banyak digunakan sebagai campuran bahan bakar yang dikenal dengan bioetanol. Sebagai campuran bahan bakar, bioetanol dapat meningkatkan efisiensi bahan bakar karena memiliki angka oktan yang tinggi. Etanol dapat diperoleh melalui proses fermentasi karbohidrat, misalnya pada fermentasi tape singkong. Etanol dihasilkan melalui reaksi fermentasi sebagai berikut:



Berikut diberikan grafik hubungan antara lama waktu fermentasi tape singkong dan kadar konsentrasi etanol yang dihasilkan



Grafik 1. Hubungan waktu fermentasi dengan kadar etanol

9. Anda diminta menjawab pertanyaan bagaimana pengaruh waktu fermentasi tape terhadap kadar etanol yang terbentuk berdasarkan grafik 1 ?

Komponen apakah yang anda pilih sebagai variabel terikat

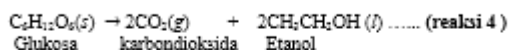
- A) Teksutur tape
- B) Massa tape
- C) Konsentrasi etanol
- D) waktu fermentasi
- E) Gas karbondioksida yang dihasilkan

Figure 5. Example of procedural knowledge question

Epistemic knowledge illustrates students' rational comprehension that underlies a scientific procedure and decision or the consideration of its usage ( OECD, 2015). The epistemic knowledge domain is one of the indicators of improvements in making scientific argumentation and drawing a scientific conclusion. Four items in these developed instruments cover epistemic knowledge. The results show that the average students' epistemic knowledge score is 54.64. One of the items that measure epistemic knowledge is presented in Figure 6. This item is categorized as a high cognitive demand question with a low difficulty level and good discriminating power. There are only 32% of students who can give a correct answer to it. To provide the right answer, students have to understand the isomer concept and molecular interaction between carbon compounds and their relation with carbon compounds' physical properties. The results confirm students' very low literacy on the epistemic knowledge aspect. It causes by the carbon compounds' physical feature material delivery, which is rarely associated with molecular interaction in high school. In most high school textbooks, the physical characteristics are only determined by identifying the number of C atoms on the carbon compound.

**Bacaan untuk Soal nomor 6 – 12 : Etanol, Manfaat & dampak**

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Beberapa sifat alkohol adalah memiliki gugus hidroksi, dapat membentuk senyawa alkil klorida ketika bereaksi dengan HCl. Selain itu dan berisomer fungsional dengan eter.

10. Etanol berisomer fungsi dengan dimetil eter. Seorang siswa menyimpulkan bahwa, karena memiliki massa molekul yang sama, "kedua senyawa tersebut memiliki titik didih yang sama" menurut anda benarkah kesimpulan siswa tersebut ?

- A) Salah, Karena massa molekul etanol lebih besar dari pada dimetil eter, sehingga etanol lebih polar menyebabkan titik didih etanol lebih tinggi dari pada dimetil eter
- B) Salah, Karena etanol memiliki ikatan hidrogen, sedangkan dimetil eter tidak, dengan adanya ikatan hidrogen pada etanol membutuhkan energi yang lebih besar untuk memutuskan ikatan hidrogen antar molekulnya, sehingga titik didih etanol lebih tinggi dari pada dimetil eter
- C) Salah, Karena dimetil eter memiliki ikatan hidrogen, sedangkan etanol tidak, dengan adanya ikatan hidrogen pada eter, membutuhkan energi yang lebih besar untuk memutuskan ikatan hidrogen antar molekulnya, sehingga titik didih dimetil eter lebih tinggi dari pada dimetil eter
- D) Benar, karena etanol dan dimetil eter memiliki rumus struktur yang sama, maka kedua molekul memiliki ikatan hidrogen antar molekul yang sama, sehingga memiliki titik didih yang sama
- E) Benar, Karena etanol memiliki ikatan hidrogen antarmolekulnya sedangkan dimetil eter membentuk ikatan Hidrogen dengan etanol, dengan adanya ikatan hidrogen, etanol dan dimetil eter membutuhkan Energi yang sama sehingga titik didih keduanya sama.

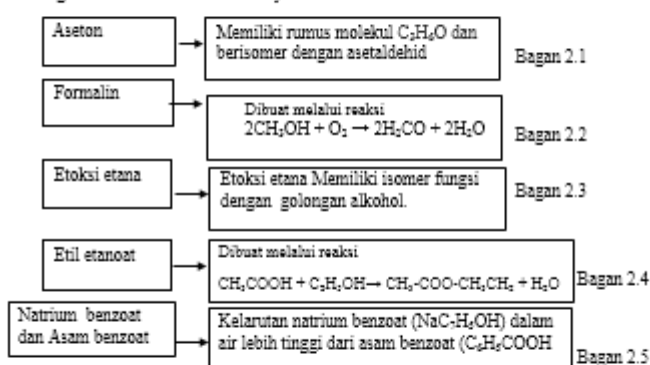
Figure 6. Example of items with epistemic knowledge aspect

The results obtained in this study show that students' chemical literacy on the epistemic knowledge gains the lowest score, compared to the other two aspects. It shows that students have great reasoning in identifying the proper conclusion according to facts and logical thought, while they have low ability in proposing scientific claims supported by scientific data and logic.

In addition, the competence aspect represents the ability to explain phenomena scientifically. According to PISA, it includes accepting, giving, and evaluating various explanations related to natural phenomena (OECD, 2016). Eight items cover the competence aspect in explaining natural phenomena. This competence domain gains 69.2 scores, classified as moderate. One of the items that discuss this domain is illustrated in Figure 7, in which 82.14 students have been successful in choosing the correct answer. This item belongs to one of the items which have gained the right answer. This item has moderate difficulty and good discriminating power.

**Bacaan untuk soal nomor 13-19 : Senyawa penting di sekitar kita**

Dalam kehidupan sehari-hari kita banyak memanfaatkan senyawa organik. Beberapa senyawa organik dalam kehidupan sehari-hari yang kita manfaatkan diantaranya: aseton, formalin, etoksi etana, etil etanoat dan natrium benzoat. Aseton digunakan sebagai pembersih kutek, dietil eter sebagai obat anestesi, etil etanoat digunakan sebagai pelarut, formalin digunakan sebagai pengawet spesimen dan asam benzoat digunakan sebagai pengawet makanan. Namun, garam natrium benzoat lebih banyak digunakan sebagai pengawet dari pada asam benzoat karena kelarutannya dalam air. Beberapa senyawa tersebut selain bermanfaat, juga berdampak buruk jika disalah gunakan misalnya penggunaan formalin sebagai pengawet makanan dapat berbahaya bagi kesehatan sehingga pemerintah melalui peraturan Menkes No. 1168/1999 telah melarang penggunaan formalin sebagai pengawet makanan. Namun berdasarkan hasil investigasi yang dilakukan Balai Besar Pengawas Obat dan Makanan (BPOM), masih ditemukan sejumlah produk pangan di pasaran yang masih mengandung formalin. Sifat senyawa-senyawa diatas sangat ditentukan oleh gugus fungsinya. Berikut ini diberikan bagan senyawa-senyawa organik tersebut serta sifat-sifatnya.



15. Berdasarkan bagan 2.5, Fatih beranggapan bahwa kelarutan dalam air natrium benzoat lebih mudah dari pada asam benzoat. "Bagaimanakah menurut anda pendapat Fatih tersebut ?

- Setuju, karena natrium benzoat merupakan senyawa polar, sehingga dapat larut dalam pelarut polar seperti air
- Setuju, natrium benzoat merupakan senyawa ion, yang dapat membentuk campuran homogen dengan air
- Setuju, karena natrium benzoat merupakan senyawa ionik, sedangkan asam benzoat bukan sehingga natrium benzoat lebih mudah terion dari pada asam benzoate
- Tidak setuju, asam benzoat lebih mudah larut dalam air karena terdapat gugus hidroksi yang dapat berikatan hidrogen dengan air
- Tidak setuju, karena asam benzoat bersifat asam, sehingga mudah melepaskan  $H^+$  dalam air dari pada natrium benzoat

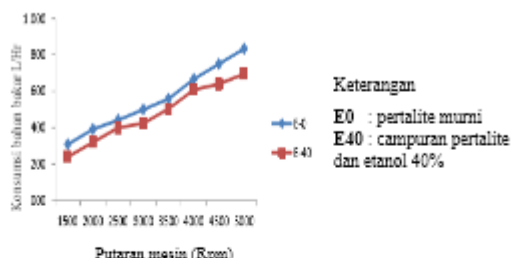
Figure 7. Example of an item explaining scientific phenomena

To answer the above question, students have to have a great comprehension of the acid and base concept, along with chemical bonds, in which the sodium benzoate compound and benzoate acid solubility can be detected from the compound property. Some of the students have gained the ability to associate some abstract chemical concepts by explaining the scientific reason why sodium benzoate is more popular as a food preservative than benzoate acid. The question has a scientific phenomenon that is closely related to students' daily life.

OECD (2016) explains the ability to design and evaluate inquiry involves knowledge on the scientific investigation to identify the question and analyze the procedure's suitability by proposing stages to find a solution for a scientific problem. Four items in the instrument cover the competence to evaluate and design inquiry. This competence gains an average score of 49.9, with a low category. One of the questions that represent this competence is presented in Figure

8, where 35.71% of students give the correct answer. This item belongs to the difficult cognitive demand category with moderate difficulty and sufficiently good discriminating power.

11. Berikut diberikan grafik pengaruh penggunaan etanol sebagai campuran bensin terhadap konsumsi bahan bakar



Berdasarkan grafik diatas anda diminta merancang sebuah penelitian. Pertanyaan manakah antara campuran etanol dan pertalite murni sebagai bahan bakar yang paling efektif mengurangi konsumsi bahan bakar ?

manakah diantara rancangan berikut yang akan anda pilih ?

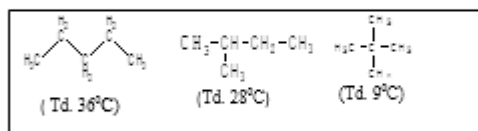
- A) Mengambil dua jenis sepeda motor yang sama, jenis 1 digunakan pertalite murni 100 %, jenis dua digunakan campuran pertalite 60 % dan etanol 40 %, pengukuran konsumsi bahan bakar dilakukan pada putaran mesin yang sama
- B) Mengambil dua jenis sepeda motor yang berbeda, jenis 1 digunakan pertalite murni 100 %, jenis dua digunakan campuran pertalite 60 % dan etanol 40 %, pengukuran konsumsi bahan bakar dilakukan pada putaran mesin yang sama
- C) Mengambil dua jenis sepeda motor yang sama, jenis 1 digunakan pertalite murni 60 %, jenis dua digunakan etanol 40 %, pengukuran konsumsi bahan bakar dilakukan pada putaran mesin yang sama
- D) Mengambil dua jenis sepeda motor yang sama, jenis 1 digunakan pertalite murni 100 %, jenis dua digunakan etanol 40 %, pengukuran konsumsi bahan bakar dilakukan pada putaran mesin yang berbeda
- E) Mengambil dua jenis sepeda motor yang sama, jenis 1 digunakan pertalite murni 100 %, jenis dua digunakan campuran pertalite 60 % dan etanol 40 %, pengukuran konsumsi bahan bakar dilakukan pada putaran mesin yang berbeda

Figure 8. Example of the item on evaluating and designing scientific inquiry competence aspect (modified from Rifal & Rauf, 2018)

OECD (2016) explains that interpreting scientific data and evidence covers the ability to scientifically read data and facts to evaluate if the conclusion can be justified. An individual who understands science should have the skill to construe data and understand the fundamental and evidence used to support a claim in drawing a conclusion. 18 items in this developed instrument cover the competence to scientifically interpret data and evidence, which obtain an average score of 64.7, categorized as moderate. One of the items that discuss this competence is shown in Figure 9, which is classified as medium cognitive demand with moderate difficulty and good discriminating power. In this item, 57.14% of students give the correct answer. The results show that most students can interpret the data about alkene compounds' properties and create a correct claim while also drawing a conclusion based on scientific evidence.

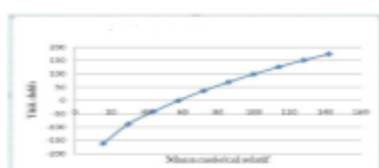
**Bacaan untuk soal nomor 24 - 27. Mengenal Sifat senyawa Alkana**

Alkana merupakan salah satu senyawa hidrokarbon yang memiliki banyak manfaat dalam kehidupan. Alkana banyak diperoleh dari fraksi minyak bumi yang dimanfaatkan dalam berbagai keperluan, baik sebagai bahan bakar maupun bahan baku industri. Senyawa alkana memiliki sifat fisis dan sifat kimia. Sifat fisis senyawa alkana diantaranya adalah memiliki massa molekul relatif dan titik didih yang semakin tinggi seiring dengan bertambahnya jumlah atom karbonnya. Sedangkan sifat kimia diantaranya, struktur alkana terdiri dari rantai lurus dan bercabang serta dapat membentuk isomer.



Gambar 1: contoh isomer senyawa alkana (pentana)

24. Berdasarkan sifat fisik senyawa alkana, seorang siswa bernama Fatih menemukan grafik hubungan titik didih dengan massa molekul relatif sebagai berikut:



Berdasarkan grafik di atas, Fatih menyimpulkan bahwa semakin besar massa molekul relatif, semakin tinggi titik didihnya. Benarkan kesimpulan Fatih tersebut ?

- A) Benar, karena semakin besar massa molekul relatif, molekul semakin polar, gaya London makin kuat, sehingga titik didih semakin tinggi.
- B) Benar, karena semakin besar massa molekul relatif, semakin panjang rantai karbonnya, energi untuk memutuskan ikatan antar molekul menjadi makin tinggi sehingga titik didih semakin tinggi.
- C) Benar, karena semakin besar massa molekul relatif, semakin panjang rantai karbonnya, molekul semakin polar, gaya London makin lemah, sehingga titik didih semakin tinggi.
- D) Salah, karena semakin besar massa molekul relatif, semakin panjang rantai karbonnya, molekul semakin tidak polar, gaya London makin lemah, sehingga titik didih semakin kecil.
- E) Salah, karena semakin besar massa molekul relatif, rantai karbon semakin panjang, interaksi molekul semakin lemah, energi untuk memutuskan ikatan semakin kecil sehingga titik didih alkana makin kecil.

Figure 9. Example of item that discusses scientifically interpret data and evidence competence

## CONCLUSION

The developed chemical literacy instrument consists of 30 valid items with *Cronbach's alpha* coefficient of 0.718. The reliability coefficient has exceeded the minimum score so that it can be used as an instrument to measure the first-year natural science education students' chemical literacy in Universitas Negeri Jember. The obtained average students' score is 59.7, demonstrating that most of the students' have moderate chemical literacy. However, following the standard of natural science graduates, the score is far below the minimum requirements, so that their chemical literacy should be enhanced.

The average score of each chemical literacy aspect is 49.9, 54.64, 57.14, 62.8, 64.7, and 69.2 for evaluating and designing chemical inquiry, procedural knowledge, epistemic knowledge, content knowledge, interpreting scientific data and evidence, and scientifically explaining phenomena, respectively. These results confirm that the lowest score is in evaluating and

designing chemical inquiry competence. Consequently, these students' ability on this competence should be increased.

## IMPLICATION FOR CHEMISTRY LEARNING

The implication of these research findings on chemistry learning include: (1) the research instrument can be used to train students' scientific literacy, primarily on chemistry learning; (2) college students' scientific literacy should be enhanced by implementing approaches that focus on the literacy improvement; (3) the chemical literacy test should be used to measure students achievement to habituate them to scientifically solve problems and being sensitive upon scientific issues in their everyday life.

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