第 48 卷 第 2 期
2021 年 2 月

湖 南 大 学 学 报（自 然 科学版）
Journal of Hunan University（Natural Sciences）

Vol. 48. No. 2.
Feb. 2021

Open Access Article

Computerized Testlet Instrument for Assessing Students' Chemical Literacy in High School

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Abstract: Teaching chemistry must contribute to students' chemical literacy skills. However, the teacher pays a little attention to preparing assessment instruments to measure these skills. This research aims to assess students' chemical literacy skills by using a computerized testlet assessment instrument. The purpose-designed survey method was used in this research. The subjects used in this study were 240 students from 3 different representative schools in Boyolali, Central Java, Indonesia. This instrument was developed in the form of multiple choice, which is arranged hierarchically and consists of 10 stem and 30 supporting questions. Hypertext Preprocessor programming language was used to develop the computerized testlet assessment instrument. The analysis menu provided on this instrument includes analysis of item quality of students' chemical literacy skills The research result proves that the computerized testlet instrument facilitates the process of assessing for the teacher. The quality of the items used and students' chemical literacy skills can be analyzed automatically. The students have good chemical literacy skills in the indicators of identifying questions and finding scientific information. However, they still have low chemical literacy on the indicators of interpreting scientific evidence and drawing conclusions. This research provides novelty to the types of instruments used to measure students' chemical literacy skills.

Keywords: assessment instrument, chemical literacy, computerized testlet.

评估高中学生化学素养的计算机化睾丸仪

摘要：化学教学必须提高学生的化学素养技能。但是，老师很少注意准备评估工具来衡量这些技能。这项研究旨在通过使用计算机化的睾丸评估工具来评估学生的化学素养技能。本研究使用了专门设计的调查方法。这项研究使用的对象是来自印度尼西亚中爪哇省博伊奥拉利的 3 所不同代表学校的 240 名学生。该工具以多项选择的形式开发，它是按层次排列的，由 10 个词干和 30 个支持问题组成。超文本预处理程序编程语言用于开发计算机化的睾丸评估工具。该仪器提供的分析菜单包括对学生化学素养技能项目质量的分析。研究结果表明，计算机化的睾丸仪有助于教师进行评估。可以自动分析所用物品的质量和学生的化学素养技能。在识别问题和寻找科学信息的指标方面，学生具有良好的化学素养技能。但是，他们在解释科学证据和得出结论的指标上仍缺乏化学素养。这项研究为用来衡量学生化学素养技能的工具类型提供了新颖性。

关键词：评估工具，化学素养，计算机化的睾丸.

1. Introduction

Students consider chemical concepts difficult to learn and add little value to their social life [1]. This results in the chemistry subject not popular and less desirable by students. Such undesirable results are generally associated with conventional chemistry curricula, which lack linking theoretical knowledge with student life in the real world to increase their chemical literacy [2].

Received: 7 January 2021 / Revised: 22 January 2021 / Accepted: 22 February 2021 / Published: 28 February 2021

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A student who has chemical literacy will be able to understand chemistry and chemical relations with society and the environment, know the concepts, laws, theories, and basic principles of chemistry, and use scientific process skills [3, 4]. The researcher has greatly contributed to chemical literacy skills like the measurement of chemical literacy using a scale of scientific literacy consisting of nominal literacy, functional literacy, conceptual literacy, and multi-dimensional literacy [5-8]. In this research, chemical literacy skills are defined through three aspects: explaining phenomena using chemical concepts, using the chemical understanding of problem-solving, and analyzing strategies and benefits of chemical applications.

The achievement of chemical literacy in all students can be facilitated as long as the content and learning instructions are prepared professionally [2]. The research on preparing content and instructions in chemistry learning professionally to improve students' chemical literacy skills has focused on chemistry education [2, 9]. Teachers and researchers have made various innovations to develop chemical content in learning [10]. However, the teacher pays little attention to preparing good assessment instruments and can measure students' chemical literacy skills [11, 12]. This becomes a research opportunity to prepare a good chemical assessment instrument and measure students' chemical literacy skills.

One of the instruments that can be selected to measure students' chemical literacy skills is the testlet instrument. A testlet is a group of items (questions) related to a particular topic developed into a single unit containing several predetermined steps [13]. Furthermore, it has a relatively stratified response concerning the knowledge (construct) to be measured [13, 14]. Testlet instrument has been widely used in the world of education and psychological testing. Many test developers find this Testlet design interesting because it is efficient in writing items [15]. The researcher has used the testlet instrument for various measurement purposes, such as the measurement of science process skills [16], [17], and generic science skills [18]. It is also used as an instrument for diagnosing students' learning difficulties [19] and other educational measurement purposes [20-22].

Assessment in education is an important research area. The technology-based assessment has developed into a separate field of research in recent years. Technology-based assessment can be applied as a tool for traditional assessment and as a tool for presenting skills assessments that are usually difficult to measure [23, 24]. The use of technology in assessment has been conducted by researchers with various purposes and subjects, such as the use of an online assessment management system to improve ICT literacy [25], measurement of student learning satisfaction with e-assessment [26], and the use of an adaptive e-assessment system [27]. The need for good assessment instruments that can measure students' chemical literacy skills and opportunities for the use of technology in assessment instruments are the focus of this study. Therefore, this study aims to assess students' chemical literacy skills using a computerized testlet assessment instrument. This research is expected to contribute to the variation of a technology-based assessment instrument to measure students' chemical literacy skills. It is also expected to contribute to becoming one of the references for the development of computerized testlet assessment instruments.

2. Methods

2.1. Research Method and Sampling Technique

This research used a purpose-designed survey method. Specifically, This study conducted a survey of students' chemical literacy skills using a computerized testlet assessment instrument developed previously.

The total number of 240 tenth-grade students from 3 representative schools were involved in this research. These representative schools were chosen using a stratified random sampling technique. This technique was used to select schools based on high, medium, and low student achievement criteria in Boyolali district, Central Java, Indonesia.

2.2. Instrument

In this research, 30 questions were used in the form of the computerized testlet assessment instrument on the stoichiometry topic. This topic was chosen because students consider that it is difficult and unrelated to their daily lives. The 30 questions were divided into 10 stems, each of which has 3 supporting questions arranged hierarchically. The question items in this instrument refer to aspects of explaining phenomena using chemical concepts, chemical understanding of problem-solving, and analyzing strategies and benefits of chemical applications. The distribution of questions on the testlet instrument is shown in Table 1. The scoring guidelines are shown in Table 2. The examples of the testlet instrument are shown in Table 3.

Table 1 Distribution of questions in testlet instrument

No	Chemical Literacy Aspect	Indicators	Number of Questions
1	Explaining phenomena using chemical concepts	Identifying questions and finding scientific information	3
		Describing and interpreting chemical phenomena	7
2	Using the chemical understanding of problem-solving	Identifying descriptions, explanations, and predictions related to chemical problems	5
		Interpreting scientific evidence and drawing conclusions	7
3	Analyzing the strategies and benefits of	Applying chemical knowledge in a given situation	8

chemical applications	

Table 2 Testlet instrument scoring guideline

No	Assessment Aspect	Score
1	The answer in the first step is correct	0
2	The answer in the first step is correct, but the answers in the second and third steps are incorrect or not answered	1
3	The answer in the first and second steps are correct, but the answer in the third step is incorrect	2
4	The answers in all steps are correct	3

Table 3 Example of testlet instrument

Question	Chemical Literacy Indicator
STEM 6 In addition to softening the texture of a cake, tartar cream can also be used as yeast or leavening agent. A student reacts 12.6 grams of baking soda with 30 grams of tartar cream in hot water, with the reaction equation: $NaHCO_{3(S)}$ + $KHC_4H_4O_{6(s)} \rightarrow NaKC_4H_4O_{6(aq)} + H_2O_{(l)} + CO_{2(g)}$ (Already equivalent). If the tartar cream is put in the egg whites, then used to make cakes, the dough will not be deflated. It is known that the relative atomic mass is H=1; C=12; O=16; Na=23; K=39.	
1. The number of moles of tartar cream that reacts is ... a. 1.50 mole b. 0.15 mole c. 0.10 mole d. 0.05 mole e. 0.01 mole	Describing and interpreting chemical phenomena
2. The mass of tartar cream that reacts is ... a. 8.25 gram b. 16.40 gram c. 20.72 gram d. 28.20 gram e. 30.45 gram	Applying scientific knowledge in a given situation
3. The mass of the remaining tartar cream that reacts is ... a. 1.80 gram b. 3.60 gram c. 9.28 gram d. 13.60 gram e. 21.82 gram	Interpreting scientific evidence and drawing conclusions

2.3. Data Analysis Technique

The results of the students' chemical literacy skill test were analyzed using the quantitative technique. This technique was used to see the percentage of the student's mastery of the questions given and the students' chemical literacy skills.

2.4. Research Questions

There are two problems discussed in this research: What is the construction of the computerized testlet instrument? and What are students' chemical literacy skills?

3. Results and Discussion

3.1. Construction of the Computerized Testlet Assessment Instrument

Basically, teachers in schools usually use paper and pencil tests. The types of instruments used are usually constructed and selected responses. The testlet instrument was developed to combine the advantages of constructed response type to measure students' abilities in more depth and selected responses that have efficiency in conducting assessments [18]. The computerized testlet was developed to increase the ease of teachers in assessing, analyzing learning indicators that have been fulfilled, analyzing students' mastery, analyzing the quality of the items used, and knowing the students' profiles, including the category of their chemical literacy skills [12, 14, 28]. The example of schools that have used the computerized testlet instrument is presented in Figure 1. The analysis menu of test results is presented in Figure 2. Examples of student profiles are shown in Figure 3.

Fig. 1 Data display of schools that have used the computerized testlet instrument

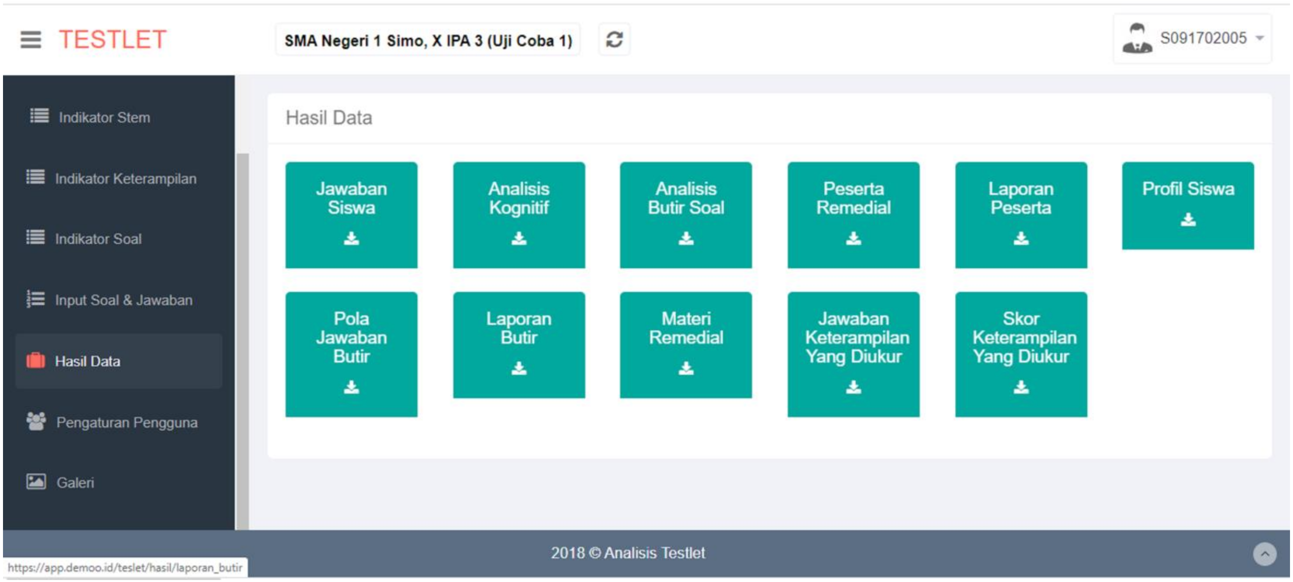

Fig. 2 Analysis menu

Profil Siswa

Satuan Pendidikan	: SMA Negeri 1 Simo
Nama Tes	: Penilaian Harian
Mata pelajaran	: Kimia
Kelas/Program	: X IPA 4
Tanggal Tes	: 21 Mei 2018
SK/KD	: Stoikiometri

No Soal	Skor	Indikator Soal		Indikator -
		Tercapai	Belum tercapai	
1	2	Siswa dapat menentukan massa sebagian hasil reaksi dari suatu reaksi		Mengidentifikasi pertanyaan dan menemukan informasi ilmiah
2	0	-	Siswa dapat menentukan hukum dasar kimia yang berlaku pada suatu reaksi,	Mengaplikasikan pengetahuan sains dalam situasi yang diberikan
3	2	Siswa dapat memprediksi massa seluruh hasil reaksi dari suatu reaksi		Mengaplikasikan pengetahuan sains dalam situasi yang diberikan
4	0	-	Siswa dapat menentukan perbandingan massa unsur-unsur penyusun suatu senyawa,	Mengidentifikasi deskripsi, eksplanasi dan prediksi
5	2	Siswa dapat menentukan massa hasil reaksi dari suatu reaksiSiswa dapat menentukan massa hasil reaksi dari suatu reaksi		Mendeskripsikan dan menginterpretasi fenomena
6	2	Siswa dapat menentukan massa pereaksi yang tersisa dari suatu reaksi		Menafsirkan bukti ilmiah dan menarik kesimpulan

Fig. 3 Student profiles on mastery of learning indicators

The computerized teslet instrument was constructed based on the aspects of chemical literacy in table 1. Before it was computerized, the instrument was first validated by experts [11]. There are two forms of testlet instruments, the first is the independent testlet instrument, and the second is the dependent testlet instrument [13, 15]. In this study, the computerized testlet instrument was a dependent testlet type. Table 3 shows an example of the instruments used. There is a Stem that contains chemical phenomena related to daily life (chemistry in context) and 3 supporting questions on stoichiometry. Stem also functions as a source of data for 3 supporting questions arranged hierarchically. This question is based on a hierarchical arrangement of concepts on the stoichiometric topic. Thus, with this instrument, it is expected to measure chemical literacy skills and chemical concepts in the stoichiometry material.

In this study, what is meant by the dependent testlet is the interrelation between supporting questions 1, 2, and 3. However, one stem with another stem remains independent or unrelated. This makes this testlet meet the assumption of independence between questions on multiple-choice instrument types [20], [29]. Besides, each supporting question has its chemical literacy skills indicator. This makes the developed testlet instrument specifically measure students' chemical literacy skills from the distribution of chemical literacy indicators. Due to the interrelationship between one supporting question and another supporting question on one stem, this instrument has its scoring guidelines shown in Table 2. Dependencies on supporting questions make the testlet instrument reduce the guessing factor of students' answers [30].

After the testlet instrument has been developed, the next step is to computerize the testlet instrument. Computerization aims to facilitate the assessment process conducted by the teacher and increases the significants of the measurement results. Figure 1 shows one of the features of the computerized testlet, which is a list of schools that have used the computerized testlet instrument facility. Figure 2 displays an analysis menu of test results. The analysis menu includes analyzing the quality of the items, including distinguishing power, level of difficulty, distractor function and reliability, analysis of remedial participants, analysis of mastery of learning indicators, and analysis of student profiles. Student profiles provided on this software are their scores on tests, indicators they have and have not yet mastered, and classifications of chemical literacy levels. All analysis is done automatically using a program that has been developed. Examples of student profiles are shown in figure 3. This profile contains data on learning indicators that have been and have not been mastered by students.

The computerized testlet instrument was developed with the PHP programming language. PHP (hypertext preprocessor) is the widely used programming language to handle website creation and development. This programming language can be used in conjunction with HTML. On the left side of figures 1 and 2, there is a choice of other computerized testlet instrument features, such as the option to include school profiles, learning indicators, even changing the Stem and supporting questions for other learning topics. The use of technology-based assessment (e-assessment) has been accepted in the world of education and is widely used [31, 32]. This use has the advantage of low costs for the test, the ability to reuse assessment items, produce good and adaptive tests, or help improve systems such as administration systems. E-assessment is more than just an alternative for conducting an assessment. There are a lot of evidence and research results that report the examples of the expansion of various skills and knowledge, provide diagnostic information that has never been given before, and provide personal information. Therefore, e-assessment has the potential to support innovation in the world of education and develop 21st-century skills [23, 33-35].

3.2. Students' Chemical Literacy Skills

Measurement of students' chemical literacy skills with a computerized testlet instrument was conducted in 3 representative schools. High, medium, and low representative schools are based on the students' achievements. This measurement involved 240 students. The results of the measurement of students' chemical literacy skills are presented in Table 4.

Table 4 Mastery indicators of chemical literacy skills

Indicators	**Percentage**		
	High	**Medium**	**Low**
Identifying questions and finding scientific information	80.6	75.1	54.3
Describing and interpreting phenomena	73.6	65.3	51.5
Identifying description, explanation, and prediction	67.2	46.2	35.8
Applying scientific knowledge in a given situation	58.9	41.3	29.7
Interpreting scientific evidence and drawing conclusions	53.9	37.5	23.6
Mean	66.84	53.08	38.98

Table 4 gives an overview of the distribution patterns of the percentage of students' chemical literacy skills. The indicators of identifying questions and finding scientific information obtain the highest percentage in each representative school. This proves that the students already have known scientific information from stoichiometry and can interpret phenomena in stoichiometry. This interpretation ability requires the ability to see facts and to remember well [17, 36, 37].

However, the indicators of interpreting scientific evidence and drawing conclusions obtain the smallest percentage of answers. This can be caused by the fact that the students only know the basic concepts of the stoichiometry material. However, when faced with a new problem situation, where they must predict, apply scientific knowledge from existing data, and make conclusions from all the existing information, they still experience difficulty. The stoichiometry material requires good numerical skills. The findings show that the students tend to find difficulties in chemical materials that require mathematical abilities such as stoichiometry. This is because they may solve simple numerical problems that involve multiplication and division but cannot connect concepts or solve the problems they have not encountered before [38]. If they cannot connect concepts, they might not choose the right algorithm and manipulate equations to reach solutions to complex scientific, mathematical problems [39].

The results of this test can also be used for categorizing students based on their scientific literacy skills. In this research, the student categorization is divided into 3, namely, students with high, medium, and low chemical literacy skills. The classification results are shown in Figure 4.

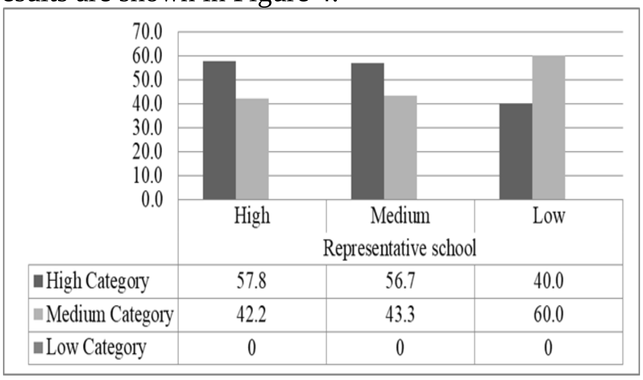

Fig. 4 Percentage of mastery of stoichiometry concepts

Figure 4 is a chart of the percentage of the students' mastery of stoichiometric concepts. Measurement of the mastery of cognitive concepts in the stoichiometry topics is conducted using the same instrument as the computerized testlet instrument to measure students' chemical Literacy. However, the scoring guidelines used are different. In the measurement of conceptual mastery, each correct answer is given point one while the incorrect answer is given point 0. This can be done because each item has a stoichiometric concept. As a result, none of the three schools are classified as having a low stoichiometric concept. This proves that the students find it easier to solve chemical problems according to the concept, but they find it difficult to relate them to context. In general, students who can link science learning concepts in class with their everyday life context have good scientific literacy [40]. Chemical literacy is part of scientific literacy.

The main objective of teaching science in secondary schools is to make all students have scientific literacy skills, as evidenced by the issuance of new standards regarding content, pedagogy, and assessment of science [5]. The term scientific literacy embodies scientific ideas, concepts, and practices in many disciplines [5]. Common dimensions that are usually associated with scientific literacy are: (a) understanding the nature of science — scientific norms and methods, and the nature of scientific knowledge; (b) understanding the main scientific concepts, principles, and theories (content science); (c) understanding how the relationship between science and technology is interrelated; (d) respecting and understanding the impact of science and technology on society; (e) communication competence in a scientific context — the ability to read, write and understand systematic human knowledge; and (f) applying some scientific knowledge and reasoning skills in daily life.

Scientific literacy is a broad concept. The teaching of any special subjects in science education must contribute to training students to have scientific literacy skills. Therefore, teaching chemistry must contribute to chemical literacy in particular and scientific literacy in general. Chemical literacy includes knowledge, competence, and attitudes. Besides, chemical literacy includes four components. The first component is chemical content knowledge. This component explains how chemically literate students must understand: (a) general chemical ideas, including scientific inquiry, how to generalize findings, and how to use their knowledge to explain phenomena in other scientific disciplines; (b) main ideas of chemistry required to explain the processes, reactions, changes in energy, structure of living systems, and the contribution of scientific language to chemistry.

The second component is chemistry in the context stating that chemically literate students must be able to use chemical knowledge to explain everyday situations, understand chemistry in everyday life, make effective decisions, engage in social arguments about chemically related problems, and see the interrelationship of innovation in chemistry and social life. The third component is about higher-order thinking skills, which refer to the questions asked, investigate relevant information when needed, and evaluate the pros/cons of the debate. The fourth component covers the affective aspect: literate people must show interesting chemical problems, especially in non-formal environments, such as mass media.

The achievement of the four components of chemical literacy for all students can be facilitated as long as the content and learning instructions are prepared professionally [2]. The research on preparing content and instructions in chemistry learning professionally to improve students' chemical literacy skills has become a focus in chemistry education [2]. The emphasis of the science-technology-society movement on science education, including chemistry education, has been conducted to improve student chemical literacy.

Chemical literacy skills and chemical concepts in the stoichiometry topic in this research produce the same tendency. Other researches have used various assessment instruments to measure students' skills, such as the use of two-tier multiple-choice instruments to measure mastery of chemical concepts, computer-assisted formative test instruments, and three-tier instruments to measure chemical concept skills. The computerized testlet instrument to measure the students' chemical literacy and conceptual skills together provides a novelty and contribution to the alternative assessment instruments in chemistry education.

This research helps teachers prepare quality assessment instruments to improve students' chemical literacy skills. With the development of computerized testlet instruments, teachers can easily assess students' chemical competencies and chemical literacy. The use of technology in assessment also provides its advantages in terms of effectiveness and time efficiency [25]. Aside from having advantages, this research is realized that it still has limitations. Computerized testlet instruments may only accommodate the components of chemical literacy in chemical content knowledge and chemistry in the context. However, they cannot yet facilitate higher-order thinking skills and affective aspects components. This can be a concern for further research.

4. Conclusion

The computerized testlet instrument is constructed by combining the advantages of constructed and selected response instruments. Chemical concepts and contexts in daily life can be combined in the stem used in this instrument. Chemical concepts arranged hierarchically make the computerized testlet instrument measure students' chemical literacy skills and mastery of concepts simultaneously. The use of computerized testlet assessment instruments has the advantage of low costs for the test, the ability to reuse assessment items, or producing good and adaptive tests, or helping improve systems such as administration systems. With the development of computerized testlet instruments, teachers can easily assess students' chemical competencies and students' chemical literacy skills.

The students have good chemical literacy skills in the indicators of identifying questions and finding scientific information. However, they still have low chemical literacy on the indicators of interpreting scientific evidence and drawing conclusions. Overall, the students' conceptual skills on the stoichiometry topic can be classified as high. This research provides novelty to the types of instruments used to measure chemical literacy skills.

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