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BLENDED INQUIRY LEARNING WITH ETHNO-STEM APPROACH FOR FIRST-SEMESTER STUDENTS' CHEMICAL LITERACY

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ABSTRACT

Chemical literacy, one of the most important aspects of chemistry teaching and learning, has been paid more attention. However, chemistry learning has not focused much on providing students with learning experiences that could improve chemical literacy. Ethno-STEM approach-integrated inquiry-based learning has been reported as an effective learning model in the chemistry learning. This study aims to analyze the effectiveness of blended inquiry learning with an ethno-STEM approach in improving students' chemical literacy. This study used a quantitative descriptive approach with a one-shot case study design. Ninety-four first-semester students participating in the General Chemistry course (3 credits) in the teacher education program were involved in the study. During the study, blended inquiry learning with an ethno-STEM approach was applied to the participating students for one semester. Questionnaires, descriptive questions, and interviews were used to collect the research data. A descriptive statistic was used to analyze the data. This study showed that the blended inquiry learning with the ethno-STEM approach was effective to improve the students' nominal and functional chemical literacy but ineffective to increase conceptual and multidimensional literacy. The students' prior knowledge in chemistry played an important role in the growth of chemical literacy. A continuing BIL-ethno-STEM in chemistry teaching and learning would allow a significant improvement in the conceptual and multidimensional literacy.

Keywords: blended inquiry learning; chemical literacy; ethno-STEM

INTRODUCTION

Chemical literacy is one of the crucial elements that must be developed in learning science or chemistry and is one of the most needed competencies in the 21st century (Cigdemoglu et al., 2017; Rahayu, 2017; Thumathong & Thathong, 2018; Prasemi et al., 2021). Various aspects of chemical literacy with direct application in everyday life must be integrated into chemistry learning (Cigdemoglu & Geban, 2015). Some topics in chemistry learning, such as environmental pollution and work safety in the laboratory, indicate the importance of integrating chemical literacy aspects during the teaching and learning processes. In addition, how students respond to the news related to the misuse of chemicals indicates that integrating the chemical literacy aspects in the chemistry learning is crucial.

However, observations in high schools showed that chemistry learning focuses on mastering concepts verbally, memorizing, and introducing formulas and terms (Yustin & Wiyarsi, 2019; Triyani & Azizah, 2020). In particular, high school teachers do not require students to be literate in chemistry. They usually focus more on the students' ability to work on evaluation questions to measure specific learning outcomes. In addition, the effort to provide students with chemical literacy is not optimal yet, as indicated by the prospective teachers' low levels of chemical literacy (Sumarni et al., 2017; Thummathong & Thathong, 2018). Prospective teachers' knowled-

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ge of chemistry concepts can not be adequately used to solve the problems during the course or lecture (Sumarni, 2018).

The government policies' role is essential in improving students' chemical literacy. The teacher might not provide students with chemical literacy skills if not required as the assessed aspect. As a result, students will not be required to be literate in chemistry, and their capability to apply the learned chemistry concepts will be low (Rahayu, 2017). Providing scientific or chemical literacy to students in learning was reported to significantly contribute to students' scientific or chemical literacy skills (Rohman et al., 2017; Sadhu & Laksono, 2018; Wiyarsi et al., 2020). Therefore, facilitating prospective teachers with chemical literacy-providing learning is very crucial. The prospective teachers with good chemical literacy will help students to achieve good learning outcomes. Moreover, prospective teachers can design learning strategies and support their students in developing chemical literacy skills (Fahmina et al., 2019; Muntholib et al., 2020).

Science, Technology, Engineering, and Mathematics (STEM) is an approach to science learning that stimulates affective aspects in developing chemical literacy and brings students to a deeper conceptual understanding through their experience of practicing what they learned (Ulger, 2018; Rahmawati et al., 2020; Lestari et al., 2021). Combining each aspect of STEM can help students comprehensively solve problems (Bertrand & Namukasa, 2022). Students will see chemistry's relevance and importance in everyday life in a better way by engaging in multidisciplinary experiments. Furthermore, STEM can help students acquire complete knowledge, be more skilled in dealing with real-life problems, and develop critical thinking (Hernandez et al., 2014).

Implementing the STEM approach in science or chemistry learning will be more effective when involved in authentic problem-solving activities in a social, cultural, and functional context (White, 2014). Those science-containing social, cultural and functional contexts are usually called as ethnoscience (Bertrand & Namukasa, 2020). Ethnoscience as a knowledge system organized from culture and social events can improve scientific or chemical literacy when integrated in the science teaching and learning (Utami et al., 2017; Sumarni, 2018; Wibowo & Ariyatun, 2020). This integration would further enhance the meaning of the studied science or chemistry concepts. Our ancestors widely applied the scientific and/or chemistry concepts in traditional technologies for generations. Various engineering techniques and mathematical calculations have been involved. Fermentation is one of the sustainable cultures used to produce tapai, tempeh, and *ciu*. Other ethno-technologies were also found in various traditional industries, such as preserving agricultural products, fisheries, traditional food processing, making food additives from natural ingredients, making red bricks, pottery, fertilizers, palm sugar, sand crackers, rambak crackers, batik, weaving, and handicrafts (Sumarni & Sudarmin, 2019). Clearly, these types of ethno-practices would make the knowledge more meaningful if integrated into learning (Torlakson, 2014). These local wisdoms that bring science, technology, engineering and mathematics together with the learning often called as ethno-STEM. Previous studies have proven that the learning model with an ethno-science-integrated STEM approach (Ethno-STEM) significantly affected the chemical literacy (Imansari et al., 2018; Al-Fialistyani et al., 2020; Wibowo & Ariyatun, 2020).

Various learning models such as PBL, PjBL, Discovery learning, and IBL have been integrated with ethno-STEM (Schmidt & Fulton, 2016). Taking a closer look at inquiry-based learning, applying guided inquiry learning with an ethnoscience approach could increase chemical literacy (Imansari et al., 2018; Al-Fialistyani et al., 2020). Likewise, the integration of Ethno-STEM in inquiry learning, besides increasing the level of chemical literacy, can also increase awareness and respect for ancestral cultural heritage (Gondwe & Longnecker, 2015; Tresnawati, 2018).

In this study, the ethno-STEM was integrated with blended inquiry learning. Further, this model is called BIL-Ethno-STEM. Blended inquiry learning integrated with ethnoscience with a STEM approach (BIL-Ethno-STEM) is a blended or face-to-face inquiry learning in class using synchronous and asynchronous multimedia (Dewi, et al., 2019). Synchronous learning used online forums through video conferences and online chatrooms, while asynchronous learning was carried out indirectly using independent or collaborative learning approaches anywhere and anytime using discussion media, such as blogs, chatrooms, and WhatsApp groups (Dziuban et al., 2018; Berga et al., 2021). In BIL-Ethno-STEM, students construct their knowledge and skills contextually through steps of the scientific method (Tang et al., 2009), i.e., formulating the problem, making observations or observations related to local wisdom relevant to the discussed concepts, reconstructing and analyzing observation results, and presenting or communicating the results.

Table 1. BIL-Ethno-STEM Syntax with WSU-Ethno-STEM Stages

No	BIL-Ethno-STEM Syntax	Phase	Learning Activity
1.	***Wartakan*** **(Informing)**	Lecturers inform students about phenomena in society related to processes that involve chemical reactions.	Lecturers inform students about social phenomena related to chemical processes or reactions commonly used by the community in preserving food, making compost, and the like.
2	***Orientasi pada masalah*** **(Doing Problem Orientation)**	Lecturers orient students to problems in chemical reaction study topics in the context of traditional culture that must be solved.	Students are oriented to study topics through field and literature studies related to science, technology, engineering, and mathematical calculations in the context of traditional culture.
3	***Rumuskan Pertanyaan Mendasar atau Esensial*** **(Formulating Fundamental or Essential Questions)**	Lecturers invite students to formulate as many fundamental questions as possible regarding real societal problems in processing tempeh, tape, and the like.	Students formulate essential questions in problem formulation to provide as many ideas as possible, which will be answered through experiments.
4	***Organisasikan mahasiswa untuk belajar dan menyampaikan hipotesis*** **(Organizing students to study and present hypotheses)**	Lecturers organize students in groups and facilitate them to learn the basic concepts of chemistry and its application in everyday life as a basis for providing temporary answers (hypotheses) to formulated questions or problems.	Students in groups conduct literature studies on the basic chemistry concepts from various sources related to science, technology, engineering, and mathematics in traditional culture to obtain temporary answers to the formulated questions.
5	***Sajikan hasil rancangan*** **(Presenting Experimental Design)**	Students develop an experimental design to prove the hypothesis and present the results of the design in class discussions to get feedback.	Students with their thinking skills are trained to be critical, creative, logical, and predict what they must do to prove their hypotheses. By utilizing ICT, students design activity steps and manage them.
6	***Unjuk kerja hasil rancangan*** **(Performing Designs)**	Students start working in groups to perform the experiments based on the experimental designs.	Each group of students prepares tools and materials based on the experimental designs to perform the experiments.
7	***Membimbing pelaksanaan eksperimen*** **(Guiding Experiments)**	Lecturers guide students to manage their activities during experiments by always paying attention to the progress and obstacles they face.	Students practice their designs to examine the hypotheses.
8	***Analisis data hasil eksperimen*** **(Analyzing experimental data results)**	Lecturers monitor the data analysis activities of the experimental results for each individual or group.	Students and lecturers analyze the experimental data.
9	***Redesain prosedur eksperimen*** **(Redesigning experimental procedures)**	Lecturers help students if there are discrepancies in the results of data analysis and guide them to redesign experiments	Experimental activities are redesigned if the obtained results of the data analysis are not suitable or there are obstacles in carrying out the experiments
10	***Nyatakan hasil analisis data sebagai simpulan*** **(Stating the data analysis results as conclusion)**	Students conclude to answer hypotheses.	Students conclude based on experimental results and data analysis to get answers to hypotheses.
11	***Informasikan hasil temuan*** **(Informing the Findings)**	Lecturers invite students to inform their findings in written reports and oral presentations before other groups and assess learning processes and outcomes (knowledge, skills, and attitudes).	Students inform their findings in written reports and oral presentations before other groups.

The BIL-Ethno-STEM syntax used in this study was the WORO SUMARNI (WSU-Ethno-STEM) stages. The WSU-Ethno-STEM syntax has been developed by Sumarni and Kadarwati (2020). This syntax involves 11 comprehensive stages by maximizing the students' activity during the chemistry teaching and learning processes as is presented in Table 1. Students are engaged to do the problem orientation and orientation at the few-first stages. Students are also guided to formulate the hypothesis, design the experimental procedures, conduct the experiments and present the findings of the experiments.

It was reported that BIL-ethno-STEM was declared feasible by experts and received positive responses from teachers and students (Sumarni & Kadarwati, 2020). However, the BIL-Ethno-STEM model's effectiveness in improving students' chemical literacy has not been reported before. This study focuses on how the BIL-ethno-STEM can improve prospective teachers' chemical literacy and what literacy aspects will improve. The levels of chemical literacy measured in this study were nominal, functional, conceptual, and multidimensional literacy (Shwartz et al., 2006). The findings of this study will likely contribute to the innovation on the education quality in Indonesia. In addition, it could also support the students' awareness of the local culture as part of the nation's culture in learning science or chemistry at schools.

METHODS

This study used a quantitative descriptive approach with a one-shot case study design. The subject of this study was 94 first-semester students participating in the General Chemistry course (3 credits) in a teacher education program. The research was conducted by providing blended inquiry learning with an Ethno-STEM approach as a treatment for the subject of the study for one semester. The syntax used during the teaching and learning activities is listed in Table 1, as previously explained. Students' chemical literacy levels were evaluated at the semester's beginning, middle, and end.

The data collection method referred to Shwartz et al. (2006). The instruments used for each literacy level were different and explained in detail as follows.

Questionnaire 1, "Identify chemistry concepts," assessed the nominal and functional levels. It consisted of a list of concepts. Students were asked to assess the level of recognition of each concept on a Likert scale (1-3), which varied from "Not knowing the concept at all" to "Understanding its meaning." These concepts were grouped into categories related to Stoichiometry, Thermochemistry, Atomic Structure, Periodic Properties of Elements, Chemical Bonds and Molecular Shapes, Carbon Compounds, and Macromolecules. In the second part of the questionnaire, students had to explain in their own words the following ten concepts: mole, concentrations of solutions, enthalpy of reaction, electron configuration, affinity energy, chemical bonding, molecular shape, fruit ripening process by covering with leaves, iron corrosion prevention with oil, and the traditional manufacture of alcohol. The first seven concepts represented essential chemistry concepts (core concepts), and the last three were considered to be known life events. Student explanations were categorized as correct, partially correct, and incorrect.

Questionnaire 2: "Chemical explanations of everyday phenomena." In this questionnaire, the assessment of students' chemical literacy as a part of functional and conceptual literacy referred to chemical explanations of chemical phenomena that were familiar with everyday experience, e.g., avoiding the use of metal cookware, salted fish production, the use of coconut oil as a door hinge lubricant, adding salt to boiling meat, making tapai by fermentation, and making wood charcoal. Students who answered the questionnaire were asked to refer to several statements related to each phenomenon and determine whether the statement was true. They could also select the "I do not know" option. For example, "If you open a perfume bottle, the fragrance will spread throughout the room. Is that statement true or false?" Students' explanations of various chemistry concepts were categorized as follows: (1) incorrect or meaningless answers, (2) partially correct or containing several correct elements but incomplete or incomplete, and (3) correct.

Questionnaire 3: "Critically read unknown short paragraphs." This questionnaire assesses students' ability to analyze a paragraph involving chemical information. This aspect is considered part of conceptual and multidimensional literacy. Three short paragraphs were developed to assess the manifestation of higher cognitive skills (analysis, synthesis, and interpretation of information) in the context of chemistry: 'Renewable energy' which presents the role of chemistry in addressing the problem of demand for non-fossil energy; 'World of polymers and plastics' which presents the role of chemistry in the synthesis of various plastic materials, and 'Principles of green chemistry' which presents the role of chemistry in reducing environmental pollution levels. Four categories of open-ended questions followed the paragraph: (1) Understand the information in paragraphs (reading comprehension); (2) Relating to previous chemistry knowledge; (3) Decision-making or reasoning; (4) Ask further questions. Each student had to refer to one paragraph. The three paragraphs were given in each class randomly.

The analysis of questionnaires was carried out descriptively by comparing the results of measurements at the beginning, middle, and end of the course to assess the contribution of BIL-Ethno-STEM from various levels of chemical literacy. Students' answers were categorized according to a scale of 1-3 to analyze their responses to written paragraphs: (1) Incorrect: no relevant understanding or reasoning; (2) Partially correct: has limited understanding and reasoning; (3) Correct: demonstrates reasoning ability and understanding. The data were analyzed by describing the calculated results of the achievement percentage for each level of chemical literacy using Microsoft Office Excel.

RESULTS AND DISCUSSION

In this study, the prospective chemistry teachers were involved as subjects. They were expected to be psychologically interested in chemistry, so it was reasonable to assume that learning General Chemistry would further develop students' chemical literacy once it had been completed. Although naturally, the population of students taking the General Chemistry course turned out to be heterogeneous.

During the teaching-learning processes using the BIL-Ethno-STEM learning model, i.e., blended inquiry learning integrated with ethnoscience with a STEM approach, students and lecturers met in a "blended" way. It means that the chemistry teaching and learning processes were performed using a face-to-face inquiry learning in the classroom and synchronous and asynchronous platforms. Video conferences and online chatrooms are used in synchronous learning with online forums. Meanwhile, blogs, chatrooms, and WhatsApp groups were used as the asynchronous learning media with independent or collaborative learning approaches anywhere and anytime using discussion media. In the BIL-Ethno-STEM learning model, students were allowed to contextually construct their own knowledge and skills through steps of the scientific method using the WSU-Ethno-STEM stages as is previously presented in Table 1. Students were guided to formulate the problems, do the observations related to local wisdom, reconstruct and analyze the observation results, and communicate the results.

Table 2. Prospective Teachers' Conceptual Understanding

No	Conceptual Understanding	Pre (N=94)			Mid (N=94)			Post (N=94)		
		DU (%)	PU (%)	U (%)	DU (%)	PU (%)	U (%)	DU (%)	PU (%)	U (%)
1	Stoichiometry	0	46.12	53.88	0	35.27	64.73	0	31.16	68.84
2	Thermochemistry	0	63.45	36.55	0	46.93	53.07	0	30.97	69.03
3	Atomic Structure	0	52.64	47.36	0	32.75	67.25	0	25.43	74.57
4	Periodic Properties of Elements	0	68.32	31.68	0	53.18	46.82	0	43.72	56.28
5	Chemical Bonds and Molecular Shapes	0	66.23	33.67	0	46.67	53.33	0	42.48	57.52
6	Carbon Compounds	0	69.98	30.02	0	41.06	58.94	0	37.45	62.55
7	Macromolecules	0	74.26	25.74	0	57.14	42.86	0	40.96	59.04

Information: DU = Do not Understand; PU = Partially Understand; U = Understand

As mentioned before, students' chemical literacy was measured using three different questionnaires. An increase in the results of the pre-test, mid-term test, and final assessment at the end of the semester on students' chemical literacy levels at the nominal, functional, conceptual, and multidimensional levels after applying BIL-Ethno-STEM was observed. The details of the students' chemical literacy improvement are explained as follows.

(1) Nominal Literacy. Understanding of various chemistry concepts before, during, and after attending the General Chemistry course was analyzed. These concepts were grouped into categories related to Stoichiometry, Thermochemistry, Atomic Structure, Periodic Properties of Elements, Chemical Bonds and Molecular Shapes, Carbon Compounds, and Macromolecules. Students' understanding of chemistry concepts was analyzed, and the result is presented in Table 2. In the table, before attending the lectures, most students have understood many chemistry concepts, both macroscopic concepts (i.e., types of general substances and specific materials) and

sub-microscopic concepts that involve skills and reasoning (Astuti, 2020) as they studied chemistry in high school and everyday life. Even so, there were still difficulties in understanding related symbols, nomenclature, writing chemical formulas, and molecular shapes of organic and inorganic compounds since no deep discussion was undertaken about these concepts in high schools (Adlim et al., 2017; Priliyanti et al., 2021; Dewi, 2022).

Table 3. Students' Explanations of Chemistry Concept (N=94)

No	Concept	Correct (%)	Partially Correct (%)	Incorrect (%)
1	Mole	30.85	59.57	9.60
2	Concentrations of solutions	22.34	52.13	32.98
3	Enthalpy of reaction	22.34	56.38	27.66
4	Electron configuration	44.68	51.06	10.64
5	Affinity energy	32.97	50.00	23.40
6	Chemical bonding	24.47	55.31	26.60
7	Molecular shape	23.40	45.74	37.23
8	Fruit ripening process	37.23	48.94	20.21
9	Iron corrosion prevention	39.36	51.06	16.00
10	Traditional manufacture of alcohol	29.79	55.32	10.64

This study also showed a significant increase in student outcomes at the beginning of learning compared to the mid-semester on all the concepts studied. An increase in the number of understood concepts was also observed, as indicated by the change in the percentage of students' understanding of concepts that were previously not understood or less familiar at the beginning of the course. Moreover, a high level of recognition of chemistry concepts was observed at the end of BIL-Ethno-STEM learning.

Table 3 presents students' explanations of the ten concepts in the General Chemistry course. The first seven represent essential chemistry concepts (core concepts), and the last three are considered well-known life events. The overall picture showed that the General Chemistry course contributed to the nominal level of chemical literacy and a little functional literacy in introducing concepts and their application.

(2) Functional Literacy. The second stage of categorization checked whether students' explanations contained molecular or macro representations and whether they included some elements of chemical language (symbols or pictures of molecules). It corresponded to three levels of chemical representation: macroscopic, sub-microscopic, and symbolic (Treagust et al., 2003). The macroscopic level representation is a concrete level that can be observed because it is a phenomenon that occurs directly through experimentation or everyday life (Fahmi & Fikroh, 2022). Submicroscopic representations are phenomena that can only be observed indirectly to seem abstract, such as ions, atoms, and molecules (Imaduddin, 2018). Symbolic aspects represent macroscopic-level phenomena, such as atomic symbols, molecular formulas, mathematical equations, chemical reaction equations, curves or graphs, tables, reaction mechanisms, and analogies (Talalanquer, 2011).

Table 4. Results of Functional Literacy Measurement Analysis (N=94)

No	Concept	Molecular Explanations			Macroscopic Explanations		
		Incorrect (%)	Partially Correct (%)	Correct (%)	Incorrect (%)	Partially Correct (%)	Correct (%)
1	Avoiding the use of metal cookware	21.28	61.70	17.02	14.89	55.32	29.79
2	Salted egg production	36.17	50.00	13.82	29.79	42.55	27.65
3	Using coconut oil as a door hinge lubricant	12.77	59.57	27.65	10.64	60.64	28.72
4	Adding salt to boiling meat	38.30	45.74	15.60	30.85	44.68	23.40
5	Making *tape* by fermentation	28.72	41.49	29.79	17.02	46.81	36.17
6	Making wood charcoal	24.47	43.62	31.91	21.27	44.68	34.04

The assessment consists of correct, partially correct, and incorrect molecular explanations and correct, partially correct, and incorrect macroscopic explanations. Table 4 presents the percentage of students who gave correct, partially correct, and incorrect answers. Although most students explained 'partially correctly' and there were still 'incorrect' explanations, some students explained six phenomena given 'correctly' at the macroscopic and molecular levels. It was possible because the applied BIL-Ethno-STEM also allowed students to explore knowledge through cyberspace (Nurhayati et al., 2019). Students found much more information through various applications that display microscopic simulations of chemical phenomena that have only been observed macroscopically. This finding means that BIL-Ethno-STEM learning contributed to students' functional chemical literacy.

The results in Table 4 show some interesting trends, i.e., (1) No more than 34 students gave correct answers on microscopic and macroscopic aspects (N=94); (2) For all items, most students gave partially correct answers or answers with a few correct elements but were not complete and accurate; (3) Most of students explained more about concepts at the macroscopic level than at the molecular level.

The results of in-depth interviews were conducted to identify the causes of the low level of chemical literacy on the students' explanation. Students' answers indicated that they felt they did not have much knowledge about specific items. They also stated that they could not use the knowledge they had adequately. For example, students have known about the concept of the fundamental law of chemistry, i.e., Lavoisier's law, where the mass of a substance before and after the reaction is always the same. However, when faced with burning wood to make charcoal, they could not write down the complete reaction of burning the wood charcoal, or if they could write the reaction equation correctly, the reaction equation was not balanced.

Another example would be elaborated as follows. Students know very well that compounds are formed from a combination of elements. The combination of these elements will determine the properties of certain materials. Some materials are composed of metallic and non-metallic elements, and some are composed of non-metallic and non-metallic elements. These correct student answers only reflected an understanding of the concept of forming compounds from elements but did not provide any clues to understanding at the molecular level. These findings indicated that students' understanding of molecular concepts was still limited, and they experienced difficulty relating their understanding to a broader conceptual scheme of the structure of matter.

Some students also still misdescribe certain concepts. For example, the concept of 'chemical reaction' related to the Law of Conservation of Mass: "A chemical reaction occurs when reactants react with products" or "A chemical reaction is when you write reactants, then arrows, and finally you write products. You also have to balance it". This explanation indicated that students used the newly acquired knowledge but could not demonstrate a deep understanding of the concept.

Table 4 also shows relatively more correct macroscopic explanations than molecular ones. Most answers students gave were in the 'partially correct' category in macroscopic and molecular aspects. It further strengthened the opinion that the ability of students to produce explanations did not meet the criteria for correct and appropriate answers. Although it could be, the lack of explanation was not caused by a lack of knowledge but because students were not used to giving detailed explanations about something, especially in chemistry. Behind the phenomena visible to our eyes or that we can see and feel, there were molecularly viewable explanations that required more knowledge to be understood. It caused most students not to meet the functional chemical literacy level.

(3) Conceptual Literacy. Table 5 presents the results of the BIL-Ethno-STEM pre- and post-learning tests regarding the correct explanation of chemistry in everyday life. Table 5 shows students' conceptual chemical literacy after learning was still low. The ability of students to determine the correct chemical statements about phenomena was very poor. In the results of in-depth interviews with students regarding their low scores, most students revealed that the items given were perceived as complex tasks and contained chemistry knowledge not discussed during learning. It showed that most students could not use the chemistry knowledge they acquired in lectures in different contexts.

Furthermore, students' chemical literacy was relatively low and tended to be at the nominal and functional level. This result followed Prasemmi et al. (2021), Wiyarsi et al. (2020), and Imansari et al. (2018), who reported that most students excelled at nominal and functional levels, and some were still at the illiterate level.

Table 5. Comparison of Average Scores of Explanations about Phenomena Before, During, and After the Application of BIL-Ethno-STEM

No	Explanation about Phenomena	Average Score		
		Before	Mid	Post
1	Stoichiometry	24.56	39.70	43.89
2	Thermochemistry	32.02	32.67	36.13
3	Atomic Structure	26.70	34.80	42.58
4	Periodic Properties of Elements	35.18	34.12	37.46
5	Chemical Bonds and Molecular Shapes	44.78	39.39	56.34
6	Carbon Compounds	24.92	39.12	40.12
7	Macromolecules	40.21	46.40	54.06

Judging from the concept, students got good results on the Chemical Bonding topic. This result did not follow Yustin and Wiyarsi (2019), who stated that students' chemical literacy skills on the Chemical Bonding topic were still low. Students' chemical literacy skills must still be developed, especially in connecting and analyzing scientific information (Yustin & Wiyarsi, 2019). This study found that BIL-Ethno-STEM could not increase students' chemical literacy in the Thermochemistry topic, as evidenced by the lowest chemical literacy of students. It showed that after implementing the BIL-Ethno-STEM, the lecturer still had to facilitate students with an appropriate and conducive learning environment. It helped to increase the students' chemical literacy, primarily by conducting context-based chemistry learning (Dewi et al., 2022). These results differed from Cigdemoglu and Geban (2015), who reported that the context-based learning could increase students' chemical literacy levels in the Thermochemistry topic.

Even though the results obtained by students are only limited to nominal and functional literacy, the important thing was that achieving all levels of chemical literacy was not always the primary goal of the teaching and learning process (Kohen et al., 2020). For some teachers, the main goal of basic learning was to find students interested in learning more and provide the basic knowledge they need (Priyasmika & Yuliana, 2021).

(4) Multidimensional Literacy. The measurement of multidimensional chemical literacy was performed by assessing students' ability to read and understand a short article that assessed the relationship between chemistry and technology, engineering, mathematics, and social aspects. The assessment of multidimensional chemical literacy was more complex than conceptual literacy. Therefore, in this study, the multidimensional chemical literacy assessment was limited to reading, understanding, connecting new information with previous knowledge, criticizing, and asking additional questions related to the selected articles provided. The questions posed included "Explain in your own words: What are the main ideas presented in the article?". Different articles triggered different student responses, as is shown in Table 6. There was no significant difference in students' abilities to understand the selected articles for most categories.

Table 6. Results of Reading Article (on a scale of 1–3).

Category	Average Score		
	Pre	Mid	Post
Scientific concepts	2.67	2.61	2.77
Sub-micro concepts	2.85	2.81	2.83
General types of substances	2.55	2.56	2.63
Specific substances	2.73	2.69	2.74
Chemical reaction	2.49	2.56	2.59

The interviews showed that almost all students said that reading articles was a task that had never been done before. Some students answered the wrong questions given in each paragraph. For example, in the "Green Chemistry" paragraph, students were asked to explain why more synthetic rubber is produced than natural rubber. Why didn't students understand? According to students, the concept was never discussed during the learning. It significantly influenced the students' dimensional literacy abilities. Students were less interested in reading knowledge other than what was being studied in class. Students' understanding of the relationship between science, technology, engineering, and mathematics was still low, as was reported by Sofiyah (2016).

Based on the results of the current study, the General Chemistry course with the BIL-Ethno-STEM empirically could increase students' nominal and functional literacy. Meanwhile, the higher level of chemical literacy (i.e., conceptual and multidimensional literacy) was only partially fulfilled as defined in this framework. It aligned with Sofiyah (2016), which showed that students' initial scientific literacy skills were still mainly in the nominal and functional categories, with 39% and 36%, respectively. In the conceptual or procedural category, there were 20% of students, while in the multidimensional category, there were still 4%. Students who did not give answers on the scientific literacy test were 1%. Nonetheless, the results of previous studies showed that when compared to conventional learning, contextual learning such as applied BIL-Ethno-STEM would give better chemical literacy results (Cigdemoglu et al., 2017; Rahayu, 2017; Yustin & Wiyarsi, 2019).

Students said that participating in BIL-Ethno-STEM made them feel they knew many chemical concepts and understood their meanings. It means that most students who completed the General Chemistry course knew the fundamental laws of an atom and its electron configuration. They also understood the periodicity of elements and could argue about societal processes related to the studied chemical concepts. The level of chemical literacy students achieved, especially in nominal and functional literacy, was due to them finding the right way of learning in BIL-Ethno-STEM. Therefore, they are motivated to study chemistry further because of their curiosity and creativity. Their curiosity was shown by their enthusiasm for asking questions, seeking new information, and conducting scientific investigations to find the answers.

Although this level of chemical literacy was not considered sufficient because conceptual and dimensional literacy was still low, these findings were essential for addressing chemistry-related problems in the future. An increase in functional chemical literacy, as indicated by the ability to define concepts correctly, was shown by students at the end of the course. Students also used new terms that did not appear in their explanations in the pre-test. The problem was that the newly acquired knowledge was not appropriately assimilated, so it did not significantly contribute to students' ability to explain basic chemical concepts.

Conceptual chemical literacy, assessed from the ability to determine the correctness of chemical explanations for everyday phenomena, showed that most students did not reach this literacy level (Fahmina et al., 2019). There was no significant difference between student achievement before and after lectures, indicating that the General Chemistry lectures did not contribute to students' ability to refer to complex phenomena. It could result from being introduced to chemical concepts and topics without sufficient links to connect them. For example, the law of the conservation of mass was used primarily to balance chemical equations. The complete combustion of carbohydrates produces H_2O and CO_2, which was usually discussed during laboratory practice, and the products were identified using specific indicators. However, connecting the two parts of knowledge, the law of conservation of mass with the combustion reaction, by explaining why the candle used for lighting wore out over time was complex for students. The results of this study were quite similar to those of Prasemmi et al. (2021), who reported that students' chemical literacy level was still low after the teaching and learning process, and the learning activities carried out required further improvement.

Thus, implementing the BIL-Ethno-STEM model in the General Chemistry course to prepare for the next level of chemistry learning only equipped students with relatively narrow aspects of chemistry. Students have learned theoretical concepts and got acquainted with chemical elements that might not be useful to most students in the future. The lecturers may assume that more general chemical knowledge or concepts would be acquired at the next level of learning. Thus, rethinking the BIL-Ethno-STEM content and emphasis in the General Chemistry course was necessary to increase chemical literacy for all students. Improving reading and reasoning skills was necessary because the learning process tended to ignore these aspects and concentrate on practice questions that only contributed to students' success in the final exam. Critical reading and reasoning in the classroom would allow students to develop aspects of further chemical literacy.

CONCLUSION

The BIL-Ethno-STEM was proven effective in increasing students' nominal and functional literacy. This level could be achieved by memorizing concept definitions but did not always reflect a deep understanding. Even though only limited to nominal and functional literacy, applying the BIL-Ethno-STEM could equip students with an increased willingness to ask questions, courage in expressing opinions, and a willingness to respond to issues discussed by lecturers and other students. Students also respond objectively and scientifically to questions from other friends according to scientific procedures. However, the BIL-Ethno-STEM has not effectively increased students' conceptual and dimensional chemical literacy. Even so, regarding the quality of the answer material, an increase in these two chemical literacy levels was observed, as seen from the changes in conceptual chemical literacy levels before and after the teaching and learning on the General Chemistry course. These results were consistent with the findings and the general argument that new science programs led to a level of functional literacy. Thus, the criteria for high chemical literacy, as defined in the framework of this study, were only partially achieved. As a recommendation, achieving a higher level of chemical literacy for all students required changes in the emphasis on the chemistry content, pedagogy, and curriculum. Placing the achievement of conceptual and multidimensional chemical literacy as a teaching goal in the General Chemistry course would result in a higher level of chemical literacy. If that were the case, achieving chemical literacy was considered an important goal. Therefore, the General Chemistry course must also aim to achieve all aspects of chemical literacy. For example, critical reading material would be mandatory in the final exam.

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