Validity and Reliability of Green Chemistry Literacy Test Questions for Secondary School Students

Wan Mazlina Wan Mehammud, Nur Jahan Ahmad*

School of Educational Studies, Universiti Sains Malaysia, 11800 USM Penang, Malaysia

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.907000409

Received: 14 July 2025; Accepted: 20 July 2025; Published: 20 August 2025

ABSTRACT

Several studies have been conducted to ascertain the understanding of Green Chemistry among secondary school students. It is believed that students' comprehension of Green Chemistry concepts has impacted their understanding of environmental issues. The development of an instrument to assess the literacy of Green Chemistry among secondary school students in a Malaysian context was conducted in this study. This study also aimed to determine the validity and reliability processes that were carried out to establish test questions measuring Green Chemistry literacy among secondary school students during activity learning in schools. This instrument was adapted from the Green Chemistry High School Test Questions used before. The validity of all items in this test questions was checked and verified by three (3) experts. The structure of the items was reviewed using content validity index (CVI) rates and received feedback from the experts. According to face validity analysis which was conducted, the instrument with a total of 43 items was validated, and the S-CVI/Ave value is 0.99. A pilot study was conducted with 30 respondents to determine the reliability of the instrument to assess Green Chemistry literacy among Malaysian secondary school students. The Correlation Coefficient of the test questions analysed by using Kuder-Richardson 20 showed a score of 0.95, thus establishing the validity and reliability of this instrument in assessing the Green Chemistry literacy among secondary school students.

Keywords: Green Chemistry; Literacy; Test Questions; Validity; Reliability

INTRODUCTION

Sustainable development is the capacity for both cultural and physical development, along with the preservation of natural resources for the benefit of future generations. The link between economic growth, environmental quality, and social equality forms the foundation of sustainable development. Sustainable development education is a learning method founded on the idea of balancing universal well-being at all educational levels (UNESCO, 2009). Restructuring the curriculum and the teaching and learning process is necessary to execute this sustainable development education (UNESCO, 2009). It is also necessary to modify the teaching and learning process throughout the curriculum to incorporate the fundamental components of sustainable development education.

The reduction or elimination of harmful compounds and pollution control have been the two main concepts associated with Green Chemistry for the majority of the last 30 years (EPA, 2021). Green Chemistry is a new area that focuses on molecular attempts to attain sustainability (Anastas & Eghbali, 2010). In addition to avoiding the use and manufacturing of chemicals that are detrimental to both human health and the environment, Green Chemistry is a strategy for developing ways to prevent the synthesis of toxic substances (Tugce et al., 2017). Furthermore, the design, production, and application of safe, effective, and environmentally friendly chemical products and processes are all included in sustainable chemistry (OECD, 2019). Sustainable Chemistry is still focused on the products and their manufacturing process, much as Green Chemistry's 12 guiding principles.

Education for Sustainable Development (ESD) is introduced as an approach to teaching and learning that can promote sustainable development. Chemistry may be involved in sustainable and green development (Ithnin et al., 2015), as well as plays an important role in promoting sustainable chemistry (Ramakrishna et al., 2020). The principles of green and sustainable chemistry (GSC), as recently detailed in the United Nations Environment Programme's Global Chemicals Outlook II (GCO II), provide Chemistry's contribution to sustainable development (Environment, 2019). Green Chemistry can be applied to scientific courses in general and chemistry courses in particular. Besides, Green Chemistry techniques and the idea of sustainable development education are excellent for fostering environmental values, attitudes, and skills. Since the curriculum's components help the nation move toward sustainable development in the future, education is essential to solving the current environmental issues (Mahat et al., 2014).

Environmental education is an important tool in order to promote environmental literacy, environmental awareness, as well as sustainable development (Vladova, 2023). Therefore, students should equip themselves with knowledge about sustainability and human nature, learn how to make decisions based on ethical, social, environmental, and economic considerations, and act and behave in a way that aligns with the principles of sustainable development (Chen et al., 2020). This calls for improved instruction and capacity building, as well as a much wider comprehension and use of Green Chemistry curricula at all educational levels, from high school to university, worldwide (Zuin et al., 2021). To turn intention into action, it is also critical to incorporate practical projects and thorough sustainability teaching into university curricula (Tawok & Saidin, 2025).

There are components of the Chemistry curriculum that are taught in schools that deal with environmental awareness, but this topic is rarely highlighted during the teaching and learning process. Students' critical thinking, problem-solving, and communication abilities can be enhanced through Green Chemistry practice, which supports sustainable development. A problem-based learning approach can motivate the active participation of students when solving problems (Salgado-Chavarría & Palacios-Alquisira, 2021). Thus, it is necessary to investigate and determine the level of green chemical literacy among students to facilitate practice changes most effectively. An instrument to assess students' understanding of Green Chemistry must be developed to ensure sustainability in the future. Teachers and other stakeholders can use this instrument to assess students' knowledge of Green Chemistry and to supplement current environmental instruments.

PROBLEM STATEMENT

Education was acknowledged as the cornerstone of sustainable development and environmental protection during the 1977 USSR conference in Tbilisi, Georgia, and schools will be a site of change to address environmental challenges (Moroye, 2005). Environmental Education (EE) was first established in 305 pilot primary schools by the Malaysian Ministry of Education (MOE) in 1982, and it was completely adopted in 1983 (Harliza, 2017). The Cabinet Committee was formed in 1974 to examine the National Education Policy with the aim of enhancing its implementation in order to meet the needs of those trained for national development and to create a cohesive, disciplined society (Ministry of Education Malaysia, 2016). Environmental sustainability is one of the cross-curricular components that are upheld in curriculum requirements; it is crucial for preparing students to interact with the outside world and become effective global citizens (Ministry of Education Malaysia, 2016). The Environmental Education (EE) in Malaysia includes knowledge, comprehension, environmental awareness, and learning about the environment involving human interaction with the environment (Rashidah, 2002).

It is believed that the current state of Chemistry education in Malaysia has little bearing on environmentally friendly behavior. When discussing concerns about the creation of sustainable education, Chemistry is a suitable field of study (Sjostrom et al., 2015). Malaysian environmental consciousness is still in its infancy, and the country's educational system has not yet been able to produce environmentally conscious students (Aminrad et al., 2013). Because noble ideals, decision-making, and problem-solving abilities related to environmental sustainability are not given as much attention, the success of EE implementation is still not clear (Aminrad et al., 2013). In addition to the lack of focus on EE, the inadequate teaching strategies of the teachers made it difficult to effectively demonstrate the use of Green Chemistry.

Malaysia still has a relatively low degree of understanding regarding Green Chemistry (Yaacob et al., 2003). Despite a number of modifications in the current trend of including environmental education into the curriculum, overall environmental sustainability practices remain at a moderate level (Hanifah et al., 2015). Even though the idea of "Green Chemistry" has been promoted for a while, it has not been generally adopted or incorporated into

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

Malaysia's educational system. Teachers' comprehension of green chemistry principles was limited due to a lack of resources, unclear implementation instructions, and poor training (Ibrahim et al., 2025). Teachers and students can gain knowledge and understanding of Green Chemistry practices that can be used in teaching and learning activities by implementing them in school laboratory activities. This could be accomplished by combining environmental awareness with subject content. Students' attitudes and awareness of the environment can be improved by changing the curriculum to incorporate Green Chemistry learning with environmental studies (Chen et al., 2020). Enhancing teacher preparation, incorporating Green Chemistry into the curriculum, and creating standardized teaching modules are all urgently needed. Its broad implementation requires institutional and policy support (Ibrahim et al., 2025).

Objectives of the Study

This study's primary objectives are to ascertain the validity and reliability of the Green Chemistry Literacy Test Questions. The specific objectives of this research are:

to determine the validity of Green Chemistry Literacy Test Questions for Secondary School Students

to determine the reliability of Green Chemistry Literacy Test Questions for Secondary School Students

LITERATURE REVIEW

Education for Sustainable Development (ESD)

Education for Sustainable Development (ESD) is introduced as an approach to teaching and learning that promotes sustainable development. According to Hopkins (2012), ESD has developed from a concept into a worldwide movement, and during the UN Decade of Education for Sustainable Development (DESD), perceptions of what it is and ought to be have changed. Education is the key to achieving all of the global development goals, according to Education for Sustainable Development (ESD). It teaches people how to alter society and save the environment by making wise decisions and acting both individually and collectively. It equips people of all ages with the knowledge, skills, values, and ability to tackle issues such as climate change, biodiversity loss, overuse of resources, and inequality that impact the well-being of people and the planet, according to UNESCO (2024). ESD promotes education that emphasizes behavioral, socioemotional, and cognitive skills. Improving our cognitive abilities is crucial for bettering our ability to think and comprehend information. While the behavioral component of ESD promotes constructive activities and behaviors, the socio-emotional component focuses on developing social skills, empathy, and emotional intelligence. ESD, which addresses what we learn, how we learn it, and the environment in which we learn it, is a potent tactic to change education. It is an essential component of a high-quality education and a process of lifelong learning (UNESCO, 2024). According to UNESCO (2014), global citizenship education is similar to development education in that it emphasizes students' active role in "facing and resolving global challenges and ultimately becoming proactive contributors to a more just, peaceful, tolerant, inclusive, secure, and sustainable world". A study conducted by Boeve-de Pauw et al. (2015) indicated that ESD can indeed impact student outcomes in terms of their sustainability consciousness. The study's findings show how important ESD is to tackling sustainable development and opening the door to a more sustainable future.

Green Chemistry

Green Chemistry has become a modern and elegant term in the last two decades, where it is widely used, especially among the Chemistry community in the United States and the United Kingdom, according to Collins (2001). Green Chemistry or sustainable chemistry is a chemical philosophy that has been designed to prevent pollution by emphasizing the use of materials, processes or practices that can reduce and eliminate the formation of pollutants or waste according to Anastas et al. (2000). Anastas and Eghbali (2009) stated that there are 12 principles in the Principles of Green Chemistry. The 12 principles of Green Chemistry are preventing waste, atom economy, less hazardous synthesis, design benign chemicals, benign solvent and auxiliaries, design for energy efficiency, use of renewable feedstocks, reduce derivatives, catalysis versus stoichiometric, design for degradation, real time analysis for pollution prevention and inherently benign chemistry for accident prevention.

Green Chemistry is also known as sustainable chemistry, which is a form of chemistry designed for the purpose of preventing environmental pollution (Karpudewan et al., 2015). Green Chemistry was introduced through the concept of environmental development and sustainable development, where it is also taught to students in the classroom apart from other basic Chemistry topics (Karpudewan et al., 2011). Green Chemistry is not a new branch of Science, but it is a responsible thinking approach related to Science, according to Karpudewan et al. (2013). Karpudewan et al. (2015) also stated that Green Chemistry is a discipline that provides opportunities for sustainable development in terms of economic, social, and environmental development.

Previous Studies of Green Chemistry Among Students

A previous study conducted by Ma and Shengli (2020) showed that secondary school students' understanding of Green Chemistry concepts and Green Chemistry terms is still at a low level, with emphasis on the principles of raw materials, solvents, and atomic economy. Hence, the researcher suggested that teachers should better examine the knowledge mastered by students in addition to assessing their learning progress in Green Chemistry learning. Sajeena (2021) stated that the level of students' awareness of the concept of Green Chemistry and the application of Green Chemistry in daily life is still at a moderate level. Integration of Green Chemistry principles for the purpose of preventing waste, using less hazardous chemicals, and conducting safer experiments can be implemented in the practical Chemistry subject at school, according to Listrayani et al. (2019). Teachers can change the way a Chemistry topic is taught for the purpose of preparing students to solve global challenges while contributing to sustainable development, namely through Green Chemistry and systems thinking (Aubrecht et al., 2019). Practical activities in the laboratory through the implementation of Green Chemistry can increase students' awareness and practices regarding environmental sustainability (Patah et al., 2015)

In the Malaysian context, a study conducted by Kanapathy et al. (2019) on students at the pre-university level showed that the students had a good level of knowledge and attitude towards the concept of sustainable development. Their knowledge, attitude, and behavior were more focused on the environmental dimension compared to other dimensions of sustainable development. Another study also showed that the level of knowledge, awareness, and practice of Green Chemistry among university students in Malaysia was at a high level (Ghazali & Yahaya, 2022). Green Chemistry is also seen to be able to increase the level of self-efficacy and task value among secondary school students in addition to making them more interested in studying the subject of Chemistry (Karpudewan et al., 2013). In the context of environmental education, especially in Malaysia, Green Chemistry experiments are seen to increase students' understanding of Science learning, especially through experiences in daily life, according to Akashah et al. (2019). Taha et al. (2021) also stated that students involved in designing Green Chemistry experiments are seen to have a higher level of Green Chemistry awareness compared to students who conduct experiments conventionally.

METHODOLOGY

In this study, the researcher focused on the development of Green Chemistry Literacy Test Questions specifically for secondary school students. The test questions were adopted and adapted from a previous study, and a few changes were made based on the suitability of the test questions for the Malaysian secondary school context. The validity and reliability tests were also done on the newly adapted instrument.

Sample of Research

The simple random sampling (SRS) technique was used to select the sample for this research. Using the simple random sample approach, 30 students in total were selected at random for the study test questions trial. The respondents have 45 minutes to finish answering the test questions. The responses were 30 in total, of which 17 were female students and 13 were male students. The 30 respondents also comprised 14 Malay students, 14 Indian students, and 2 Chinese students. Despite the unequal gender and racial distribution of the samples, the study's objectives were to validate and evaluate the test questions' reliability; hence, the limitations were acknowledged but not addressed due to the pilot nature of the study.

The validity test of the Green Chemistry Literacy Test Questions was conducted by three (3) experts. The three (3) experts who participated in the validity test were from the fields of Science and Chemistry Education, as well as Malay language education, since the test questions that were distributed were written in Malay. The validity test was conducted on the Green Chemistry Literacy Test Questions in order to ensure the test questions' content validity.

Development of Green Chemistry Literacy Test Questions for Secondary School Students

The Green Chemistry Literacy Test Questions were adopted and adapted from the Green Chemistry High School Test Questions (American Chemical Society, 2019). There was a total of 50 questions in the Green Chemistry High School Test Questions developed by the American Chemical Society (2019). The instrument was selected since it may gauge the Green Chemistry literacy among the secondary school students. The adaptation process was completed following multiple discussions with a Subject Matter Expert (SME) with specialized knowledge in teaching Chemistry Education in the Science, Technology, Engineering, and Mathematics (STEM) discipline. The Subject Matter Expert was responsible for verifying that all of the updated test questions were suitable for the intended research samples.

The first check of the test questions was essential to ensure that the newly modified test questions aligned with the original test questions, the Green Chemistry High School Test Questions (American Chemical Society, 2019). It is necessary for the test questions to go through the steps of adaptation and modification to ensure that the updated test questions are appropriate for the most recent study. The original questions must be modified and reworded to adhere to the necessary standard Malay sentences since the distributed test questions were written in both English and Malay.

The newly modified test questions had 43 questions. Seven (7) questions were removed from the original test questions since they were not fit for the study in the Malaysian context. All of the 43 questions were translated into the Malay language as well. After translation, most of the elements were reworded to fit more comprehensible Malay language sentences. Modifications were also made to the diagrams involved in the test questions, where the researcher provided diagrams in both English and Malay. The newly adopted and adapted Green Chemistry Literacy Test Questions for Secondary School Students contained 43 multiple-choice questions. All the answers for the test questions were based on the original test questions provided in the Green Chemistry High School Test Questions by the American Chemical Society (2019).

FINDINGS AND DISCUSSION

The newly adapted Green Chemistry Literacy Test Questions for Secondary School Students was validated by three (3) experts in the fields of Science and Chemistry Education, as well as Malay language education. A Content Validity Index (CVI) analysis was conducted to determine the S-CVI/Average of the items included in the test questions. The validity process was also important for the researcher to review the items and make the necessary modifications to the newly adapted test questions. Then, a reliability test was conducted in order to ensure the trustworthiness of the Green Chemistry Literacy Test Questions for Secondary School Students.

Validation of Green Chemistry Literacy Test Questions for Secondary School Students

Validation and reliability testing of an instrument are important to make sure that it is dependable and valid for use in actual research. Validity is the extent to which an instrument measures something that must be measured with a certain level of accuracy and truth. The main steps of the validity procedure done by the researcher are listed below in Table 2.

The Green Chemistry Literacy Test Questions for Secondary School Students was validated by three (3) experts specialized in Science Education, Chemistry Education, and Malay language studies. All the experts are actively involved in their fields of expertise by authoring several articles on their areas of knowledge as well as publishing educational resources about Science, Technology, Engineering, and Mathematics (STEM). Table 1 shows the list of experts involved in the validation process of these newly adapted test questions.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

Table 1: List of Experts for the Validation Process

Experts	Areas of Expertise	Academic Qualifications	Years of Service
1.	Science Education, Curriculum Development	PhD (Associate Professor)	More than 10 years
2.	Chemistry Education	Bachelor Degree (Chemistry Teacher)	More than 10 years
3.	Malay Language Education	PhD (Dr)	More than 5 years

Yusoff (2019) suggested several steps that can be taken during the validity procedure of an instrument. There were six (6) steps of the content validity recommended by Yusoff (2019). Table 2 shows the listed content validity steps of these test questions that were performed by the researcher based on the suggested procedures.

Table 2: Content Validity Steps

Steps	Explanation
1.	The researcher prepared the content validity form and test questions for the experts
2.	The researcher selected the panel of experts to review the test questions
3.	Experts carried out the procedure for the content validation
4.	Experts reviewed the items involved in the test questions
5.	Experts gave the score to each of the items in the test questions
6.	The researcher conducted the content validity index analysis

The Green Chemistry Literacy Test Questions for Secondary School Students were subjected to the content validation process. The content validation form for the experts in this study comprised 43 items with a 10-point rating scale. The scale started from scale 1, which indicates strong disagreement, to scale 10, which indicates strong agreement. Each expert received a content validation form with a 10-point rating for each item in the test questions to be reviewed.

The relevance scale to calculate the Content Validity Index (CVI) was either 1 or 0. The relevance scale was 0 for items rated between scales 1 and 5, and 1 for items rated between scales 6 and 10. Yusoff (2019) stated that items scored 1 or 2 should have a relevance score of 0, while items scored 3 or 4 should have a relevance score of 1. In this validation process of the newly adapted test questions, items scored 1 or 2 correspond with items scored 1 to 5 in this study, while items scored 3 or 4 correspond with items scored 6 to 10 in this study.

Content Validity Index (CVI) was calculated by dividing the number of experts in agreement by the total number of experts involved in the validation process. If all three experts agreed with the items, the universal agreement (UA) score was 1, and if only one or two experts agreed, the score was 0. A Content Validity Index (CVI) value of one (1) is appropriate for three (3) to five (5) experts according to Polit et al. (2007). The Content Validity Index (CVI) analysis is displayed in Table 3.

Table 3: Content Validity Index (CVI) Analysis

Items	Expert 1	Expert 2	Expert 3	Experts in Agreement	I-CVI	UA
1	1	1	1	3	1.00	1
2	1	1	1	3	1.00	1
3	1	1	1	3	1.00	1
4	1	1	1	3	1.00	1
5	1	1	1	3	1.00	1
6	1	1	1	3	1.00	1
7	1	1	1	3	1.00	1
8	1	1	1	3	1.00	1
9	1	1	1	3	1.00	1

10	1	1	1	3	1.00	1
11	1	1	1	3	1.00	1
12	1	1	1	3	1.00	1
13	1	1	1	3	1.00	1
14	1	1	1	3	1.00	1
15	1	1	1	3	1.00	1
16	1	1	1	3	1.00	1
17	1	1	1	3	1.00	1
18	1	1	1	3	1.00	1
19	1	1	1	3	1.00	1
20	1	1	1	3	1.00	1
21	1	1	1	3	1.00	1
22	1	1	1	3	1.00	1
23	1	1	1	3	1.00	1
24	1	1	1	3	1.00	1
25	1	1	1	3	1.00	1
26	1	1	1	3	1.00	1
27	1	1	1	3	1.00	1
28	1	1	1	3	1.00	1
29	1	1	1	3	1.00	1
30	1	1	1	3	1.00	1
31	1	1	1	3	1.00	1
32	1	1	1	3	1.00	1
33	1	1	1	3	1.00	1
34	1	1	1	3	1.00	1
35	1	1	1	3	1.00	1
36	1	1	1	3	1.00	1
37	1	1	1	3	1.00	1
38	1	0	1	2	0.70	0
39	1	1	1	3	1.00	1
40	1	1	1	3	1.00	1
41	1	1	1	3	1.00	1
42	1	1	1	3	1.00	1
43	1	1	1	3	1.00	1

Content Validity Index (CVI) analysis demonstrated that one (1) item has an I-CVI value of 0.7, and 42 items have an I-CVI value of 1.00. This also shows that all of the items have a score of 1 for Universal Agreement (UA) except for item number 38, which has a score of 0. The Content Validity Index (CVI) analysis in Table 3 allows for the calculation of the scale-level content validity index based on the average method (S-CVI/Ave) and scale-level content validity index based on the universal agreement method (S-CVI/UA). For the 43 items that were included, the S-CVI/Ave acquired value was 0.99, and S-CVI/UA was 0.98.

According to Rodrigues et al. (2017), the results of the analysis for items (I-CVI) that are more than 0.79 are relevant, while I-CVI values between 0.70 and 0.79 require re-evaluation. Any items that have an I-CVI value of less than 0.70 should be eliminated. The I-CVI values of all items are 1.00, except item 38, which has the I-CVI value of 0.70. Hence, item number 38 should be re-evaluated so that it can be included in the test questions. The experts' recommendations served as the basis for the re-evaluation procedure for item number 38. According to the expert's suggestions, item number 38 needs to be reworded using more scientific and English-friendly terminology. Using appropriate scientific terminology in English is crucial to preventing students from misinterpreting the questions. An S-CVI/Ave score of 0.99 was obtained from the Content Validity Index (CVI) analysis, indicating that this instrument can be used for real research in the future. Thus, these validated Green Chemistry Literacy Test Questions for Secondary School Students will be tested for reliability.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

Reliability of Green Chemistry Literacy Test Questions for Secondary School Students

Reliability pertains to two conditions, which are measuring consistency and its stability over time, according to Creswell and Creswell (2018). A reliability test was done through a pilot test in order to measure the test questions' reliability. 30 secondary school students in Science classes participated in the pilot study of the Green Chemistry Literacy Test Questions for Secondary School Students. A sample size of between 10 and 30 people is necessary for the pilot study's objectives (Isaac & Michael, 1982). Hence, 30 secondary school students were adequate for the pilot study. Besides, Tsang et al. (2017) also stated that 30 to 50 samples of respondents are required for the pilot test in order to get a high-reliability value for every item in the instrument.

The researcher utilized the Kuder-Richardson 20 (KR-20) analysis in order to calculate the reliability of the instrument. The data collected from the pilot test were dichotomous. A more appropriate method that can be used to assess the internal consistency of a measure for dichotomous data is Kuder-Richardson 20 (KR-20), according to Kempf-Leonard (2005). KR-20 is the dichotomous equivalent to the coefficient alpha, and the coefficient alpha is based on the variance of the item scores (Kempf-Leonard, 2005). Figure 1 shows the formula for the KR-20 used by the researcher in this reliability test.

$$rKR20=k/k-11-\sum pq/\sigma y2$$

Figure 1: KR-20 Formula

Source: Kempf-Leonard (2005)

Based on the formula above, here is the explanation of the formula:

k = number of samples

p = proportion of respondents passing the item

q = proportion of respondents failing the item

$\sum pq$ = summation for each item of the proportion of respondents who pass the item times the proportion of respondents who do not pass the item

Scores for KR-20 are 0 and 1, where 0 was given to the wrong answers and 1 was given to the right answers. The value obtained from the KR-20 analysis of this instrument was 0.95. KR-20 coefficient values that are close to 1.00 are categorized as coefficient values that have a strong correlation, while coefficient values that are close to 0 are weak. Hence, the results of the KR-20 analysis of the Green Chemistry Literacy Test Questions for Secondary School Students showed that this instrument was very reliable and can be used in a real study. The correlation coefficient that has been acquired for this instrument was 0.95, which indicates a very strong correlation according to Nugroho et al. (2019). KR-20 analysis was conducted using Microsoft Excel software, where the calculation to obtain the KR-20 coefficient value is by using a specific formula. Table 4 below shows the interpretation of the KR-20 coefficient value referring to Nugroho et al. (2019).

Table 4: Interpretation of Correlation Coefficient Value

Correlation Coefficient	Interpretation
0.00 – 0.10	Negligible Correlation
0.11 – 0.39	Weak Correlation
0.40 – 0.69	Moderate Correlation
0.70 – 0.89	Strong Correlation
0.90 – 1.00	Very Strong Correlation

Source: Nugroho et al. (2019)

DISCUSSION

The main objectives of this study were to adopt and adapt an instrument in order to measure the green chemistry literacy among secondary school students. The newly adopted Green Chemistry Literacy Test Questions for Secondary School Students were adopted and adapted from the previous test questions prepared by the American Chemical Society (2019). Seven (7) items were removed from the original test questions that consisted of 50 items to fit the Malaysian secondary school context after several discussion sessions with the Subject Matter Expert (SME). The test questions that consisted of 43 items were validated by three (3) experts in Science, Chemistry, and Malay language education, respectively. This is due to the test questions were prepared in both Malay and English. Escobar-Pérez and Cuervo-Martínez (2008) in Fernández-Gómez et al. (2020) stated that selecting experts who are recognized in the community, have professional experience, or have an educational background is essential for instruments' validation process. According to DeVellis (2016), the primary purpose of the expert review process is to maximize the measure's content validity by obtaining feedback from a panel of experts regarding how relevant they think each item is to what you intend to measure. Thus, the test questions must be validated by the experts in the specialized areas.

The Content Validity Index (CVI) analysis of the items in the test question demonstrated that this newly adapted instrument was valid to be used in the real study. Based on the CVI analysis, the S-CVI/Ave of this instrument was 0.99, and the S-CVI/UA was 0.98. All of the items in this newly adapted test have I-CVI values of 1.00, except for item number 38, which has an I-CVI value of 0.70. Thus, this item must be re-evaluated by the researcher before it can be included in the real study, and the modifications must be made based on the suggestions from the experts in the validation process. The CVI analysis results for items that are more than 0.79 are meaningful, while the I-CVI values between 0.70 and 0.79 demand re-evaluation according to Rodrigues et al. (2017). The researcher re-evaluated and modified item number 38 based on the recommendations from the appointed experts. The Content Validity Index (CVI) helps in making decisions on items such as eliminating, modifying, or conserving them, and it is the most widely reported approach for content validity of an instrument, according to Hadzaman et al. (2018).

A pilot study was conducted for the reliability testing of the instrument after the validation procedure. The pilot study was conducted among 30 secondary school students enrolled in science classes. All of the students were in the same grade. Permission was granted by the chosen school for the pilot study to be conducted among the students. A science teacher at the school assisted in briefing and distributing the instrument since it was distributed online to all of the respondents. According to Naah et al. (2018), calculating dichotomous numbers or test results, such as 0 or 1, can be accomplished using the Kuder Richardson either KR-20 or KR-21 formula. Using the Kuder-Richardson 20 (KR-20), the reliability test of the newly modified test questions revealed a correlation coefficient of 0.95. Nugroho et al. (2019) stated that coefficient correlation values ranging from 0.90 to 1.00 are very strong and suitable for employment as a research instrument. This suggests that this instrument can be used to gather actual data for research in the future.

This newly modified instrument, which consisted of 43 items, can be used to test the secondary school students regarding their Green Chemistry literacy. As suggested by the expert, the time taken for the students to answer these test questions was 45 minutes. This is important so that the students can spend adequate time thinking critically before answering all those questions. According to a study by Kreepala et al. (2023), the suitable number of questions in one (1) one-hour examination that consists of intermediate-level questions should contain approximately 41.4 ± 15.62 questions, which is a minimum of 20 questions and a maximum of 120 questions. Five (5) factors in determining the time allocation by students in answering multiple-choice questions are the total word count of tests, non-native English examiners, test difficulty, images in tests, and the atmosphere of the examination affecting the testing time (Kreepala et al., 2023). Thus, the students will spend 45 minutes answering 43 test questions in this newly adapted test prepared by the researcher in the real study. Multiple-choice questions (MCQs) are a well-established, reliable method of assessing knowledge according to Tangianu et al. (2018).

The recently modified instrument can also be used by teachers to assess secondary school students' Green Chemistry literacy, particularly in science classes. Science teachers in science classrooms will receive information from the assessment regarding how to integrate Green Chemistry in designing courses and teaching materials based on the students' literacy and readiness in learning about the Green Chemistry concepts.

CONCLUSION

This study's primary contribution was the validation and reliability testing of recently modified test questions designed to measure secondary school students in Malaysia's understanding of Green Chemistry concepts. The study successfully adopted and adapted the Green Chemistry High School Test Questions to effectively assess the literacy of Green Chemistry among secondary school students in Malaysia. Following a number of revision processes, the test questions were improved to ensure their application and relevance in the local educational setting. The validation process conducted by three (3) experts towards this instrument showed a result of S-CVI Ave of 0.99. The Coefficient Correlation value of 0.95 obtained from the KR-20 analysis showed that this instrument is reliable and can be used in further research.

This adapted test not only contributes to the field of educational research but also provides a valuable instrument for teachers to assess and enhance their students' understanding of Green Chemistry, ultimately improving their awareness regarding environmental sustainability in their daily life. The findings from this study can inform teachers about the level of Green Chemistry comprehension among the students and enabling them to develop more effective teaching strategies that cater to these needs.

This research implies that this study provides a well-verified and trustworthy instrument for evaluating secondary school students' comprehension of Green Chemistry in Malaysia with a high S-CVI Ave (0.99) and KR-20 reliability (0.95). This suggests that the instrument is accurate and consistent. Additionally, by using this instrument to pinpoint students' knowledge gaps in Green Chemistry, teachers can modify their pedagogical approaches and foster more successful environmental science instruction. The instrument's usefulness in various educational contexts is increased by indirectly promoting environmental sustainability through education by assisting students in understanding Green Chemistry concepts.

For future recommendations, the modified instrument can be used with students from different grades and classes, since this study was limited to 16-year-old students enrolled in science classes at school. This adaptability increases the instrument's usefulness for researchers and educators by enabling a wider applicability across fields. In order to ensure the instrument's efficacy and generalizability, more research might also examine how it is used in various cultural and educational contexts. Future studies can apply the instrument in diverse cultural and educational contexts to assess its generalizability, enhancing its global relevance in Green Chemistry education.

ACKNOWLEDGEMENT

The researchers would like to thank all the experts, respondents, and relevant parties who have contributed greatly to this research.

REFERENCES

1. Akashah, F.N.M., Nadzri, N.S.M., & Taha, H. (2019). Secondary school students' green chemistry experiment, knowledge, attitude, and practice: instrument development and an exploratory study in Malaysia. Jurnal Pendidikan Sains Dan Matematik Malaysia, 9(1), 13-17.
2. American Chemical Society. (2019). American Chemical Society. https://www.acs.org
3. Aminrad, Z., Zakariya, S.Z.B.S., Hadi, A. S., & Sakari, M. (2013). Relationship between awareness, knowledge and attitudes towards environmental education among secondary school students in Malaysia. World Applied Sciences Journal, 22(9), 1326-1333. http://dx.doi.org/10.5829/idosi.wasj.2013.22.09.275
4. Anastas, P., & Eghbali, N. (2009). Green Chemistry: Principles and Practice. Chem. Soc. Rev., 39(1), 301–312. https://doi.org/10.1039/b918763b
5. Anastas, P. & Eghbali, N. (2010). Green chemistry: Principles and practice. Chemical Society Reviews, 30(1), 301–312. doi: 10.1039/b918763b.
6. Anastas, P. T., Heine, L. G., & Williamson, T. C. (2000). Green Chemical Syntheses and Processes.

7. Aubrecht, K. B., Bourgeois, M., Brush, E. J., MacKellar, J., & Wissinger, J. E. (2019). Integrating Green Chemistry in the Curriculum: Building Student Skills in Systems Thinking, Safety, and Sustainability. Journal of Chemical Education, 96(12), 2872– 2880. https://doi.org/10.1021/acs.jchemed.9b00354
8. Boeve-de Pauw, J., Gericke, N., Olsson, D., & Berglund, T. (2015). The Effectiveness of Education for Sustainable Development. Sustainability, 7(11), 15693–15717. https://doi.org/10.3390/su71115693
9. Chen, M., Jeronen, E., & Wang, A. (2020). What lies behind teaching and learning green chemistry to promote sustainability education? A literature review. International Journal of Environmental Research and Public Health, 17(21), 1-24. doi:10.3390/ijerph17217876.
10. Collins, T. (2001). Green chemistry through the mill. Nature, 414(6860), 161–163. https://doi.org/10.1038/35102662
11. Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and Mixed Methods Approaches (5th ed.). SAGE Publications.
12. DeVellis, R. F. (2016). Scale development (4th ed.). Sage.
13. Environment, U. N. (2019, March 11). Global Chemicals Outlook II: From Legacies to Innovative Solutions. UNEP - UN Environment Programme. https://www.unep.org/resources/report/global-chemicals-outlook-ii-legacies-innovative-solutions
14. EPA. (2021). U.S. Environmental Protection Agency | US EPA. https://www.epa.gov/home
15. Escobar-Pérez, J., & Cuervo-Martínez, A. (2008). Validez De Contenido Y Juicio De Expertos: Una Aproximacion A Su Utilizacion. Avances en Medición, 6, 27–36.
16. Fernández-Gómez, E., Martín-Salvador, A., Luque-Vara, T., Sánchez-Ojeda, M. A., Navarro- Prado, S., & Enrique-Mirón, C. (2020). Content Validation through Expert Judgement of an Instrument on the Nutritional Knowledge, Beliefs, and Habits of Pregnant Women. Nutrients, 12(4), 1136. https://doi.org/10.3390/nu12041136
17. Ghazali, M. Z., & Yahaya, A. (2022). Analysis of Green Chemistry Knowledge, Awareness and Practice Among the University Students. Journal of Science and Mathematics Letters, 10(1), 79-90. https://doi.org/10.37134/jsml.vol10.1.8.2022
18. Hadzaman, N. A. H., Takim, R., Nawawi, A. H., & Mohamad Yusuwan, N. (2018). Content validity of governing in Building Information Modelling (BIM) implementation assessment instrument. IOP Conference Series: Earth and Environmental Science, 140, 012105. https://doi.org/10.1088/1755-1315/140/1/012105
19. Hanifah, M., Shaharudin, I., Mohmadisa, H., Nasir, N., & Yazid, S. (2015). Transforming sustainability development education in Malaysian schools through greening activities. Review of International Geographical Education Online, 5(1), 78 – 94.
20. Harliza, A. R. (2017). Usaha dan cabaran dalam mengaplikasikan pendidikan alam sekitar dalam sistem persekolahan Di Malaysia. Asian Journal of Environment, History and Heritage, 61-70.
21. Hopkins, C. (2012). Twenty Years of Education for Sustainable Development. J. Educ. Sustain. Dev. 6, 1–4.
22. Ibrahim, M. M., Abas, A., Asmayati Yahaya, Taha, H., Ahmad, & Rozita Yahaya. (2025). Exploring Environmental Sustainability Awareness: Perspectives of Rural and Urban School Students and Teachers on Green Chemistry and Strategies for Achieving Sustainable Development Goals. Journal of Lifestyle and SDGs Review, 5(3), e04946–e04946. https://doi.org/10.47172/2965-730x.sdgsreview.v5.n03.pe04946
23. Isaac, S., & Michael, W. B. (1982). Handbook in research and evaluation: a collection of principles, methods, and strategies useful in the planning, design, and evaluation of studies in education and the behavioral sciences. Edits Publishers.
24. Ithnin, R., Teratani, S., & Matsubara, S. (2015). Green Chemistry and Sustainable Development Teaching Materials from ECoS In Japan. Jurnal Bahasa Dan Budaya Jepun, 5, 171-190. https://ejournal.um.edu.my/index.php/JBBJ/article/view/11491.
25. Kanapathy, S., Lee, K. E., Mokhtar, M., Syed Zakaria, S. Z., Sivapalan, S., & Mohd Zahidi, A. (2019). Sustainable chemistry teaching at the pre-university level. International Journal of Sustainability in Higher Education, 20(4), 784–802. https://doi.org/10.1108/ijshe-10-2018-0186
26. Karpudewan, M., Hj Ismail, Z., & Mohamed, N. (2011). Greening a Chemistry Teaching Methods Course at the School of Educational Studies, Universiti Sains Malaysia. Journal of Education for Sustainable Development, 5(2), 197–214. https://doi.org/10.1177/097340821100500210

27. Karpudewan, M., Roth, W.-M., & Ismail, Z. (2013). The Effects of "Green Chemistry" on Secondary School Students' Understanding and Motivation.The Asia-Pacific Education Researcher, 24(1), 35–43. https://doi.org/10.1007/s40299-013-0156-z
28. Karpudewan, M., Roth, W.-M., & Ismail, Z. (2015). Education in Green Chemistry: Incorporating Green Chemistry into Chemistry Teaching Methods Courses at the Universiti Sains Malaysia.The Royal Society of Chemistry EBooks, 248–265. https://doi.org/10.1039/9781782621942-00248
29. Kempf-Leonard, K. (2005). Encyclopedia of Social Measurement | ScienceDirect. Sciencedirect.com.https://www.sciencedirect.com/referencework/9780123693983/encyclopedia-of-social-measurement
30. KPM (Ministry of Education Malaysia). (2016), Buku Penerangan KSSM. Putrajaya, Malaysia: Bahagian Pembangunan Kurikulum (Putrajaya, Malaysia: Curriculum Development Department, Ministry of Education Malaysia).
31. Kreepala, C., Thongsombat, S., Wattanavaekin, K., Danjittrong, T., Keeratibharat, N., & Juntararuangtong, T. (2023). Factors Determining Time Allocation of a Multiple-Choice Question Examination: The Students' Perspective. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-3019852/v1
32. Listyarini, R, V., Pamenang, F, D, N., Harta, J., Wijayanti, L, W., Asy'ari, M., & Lee, W. (2019). The Integration of Green Chemistry Principles into Small Scale Chemistry Practicum for Senior High School Students. Jurnal Pendidikan IPA Indonesia, 8(3). https://doi.org/10.15294/jpii.v8i3.19250
33. Mahat, H., Ahmad, S., Mohamad, & Ali, N. (2025). Pendidikan Pembangunan Lestari - Hubungan kesedaran antara ibu bapa dengan pelajar (Education for Sustainable Development (ESD) - The awareness connection between parents and students). Geografia-Malaysian Journal of Society and Space, 10(5). https://ejournal.ukm.my/gmjss/article/view/18653.
34. Ma, J., & Shengli, H. (2020). Evaluating Chinese Secondary School Students' Understanding of Green Chemistry. Science Education International, 31(2), 209–219. https://doi.org/10.33828/sei.v31.i2.11
35. Moroye, C. (2005). Common ground: An ecological perspective on teaching and learning. Curriculum and teaching dialogue, 7(1/2), 123-139.
36. Naah, A. M., Peter Mayeem, B., Adjei, A., & Ossei-Anto, A. (2018). Assessing Senior High School Science Students' Planning Skills In Selected Topics From The Integrated Science Syllabus. International Journal of Scientific Research and Management, 6(11). https://doi.org/10.18535/ijsrm/v6i11.el01
37. Nugroho, A., Hendric, L., Heriyadi, Y., & Tanutama, L. (2019). Measure The Level Of Success In Using Google Drive with the Kuder Richardson (KR) Reliability Method. https://doi.org/10.1109/ait49014.2019.9144915
38. OECD. (2019). Sustainable Chemistry. http://www.oecd.org/chemicalsafety/riskmanagement/sustainablechemistry.htm.
39. Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. Research in Nursing & Health, 30(4), 459– 467. https://doi.org/10.1002/nur.20199
40. Ramakrishna, V., Malleswari, B., & Ramagundam, R. (2020). Green Chemistry Plays Key Role in Eco-Friendly, Sustainable Development. International Research Journal of Engineering and Technology (IRJET), 7(4), 4024-4028.
41. Rashidah, B.G. (2002). Effectiveness of the 1st level natural hero project on knowledge among students in Selangor on pollution and environmental protection. Unpublished bachelor's thesis, Universiti Malaya, Kuala Lumpur.
42. Rodrigues, I. B., Adachi, J. D., Beattie, K. A., & MacDermid, J. C. (2017). Development and validation of a new tool to measure the facilitators, barriers and preferences to exercise in people with osteoporosis. BMC Musculoskeletal Disorders, 18(1). https://doi.org/10.1186/s12891-017-1914-5
43. Sajeena, S. (2021). A Study on the Role of Green Chemistry in Daily Life of Secondary School Students. International Journal of Engineering Applied Sciences and Technology, 6(3). https://doi.org/10.33564/ijeast.2021.v06i03.053
44. Salgado-Chavarría, D., & Palacios-Alquisira, J. (2021). Problem-Based Learning Approach to Review the Principles of Green Chemistry Applied to a Polycondensation Reaction. Science Education International, 32(2), 107–113. https://doi.org/10.33828/sei.v32.i2.3

45. Sjostrom, J., Rauch, F., & Eilks, I. (2015). Chemistry education for sustainability. In Relevant Chemistry Education. Brill-Sense.
46. Taha, H., Zahari, N. L., Tien Tien, L., & Muhammad Damanhuri, M. I. (2021). An Exploratory Study on Green Chemistry Practices and Experiments in Malaysian Secondary Schools. Journal of Science and Mathematics Letters, 9(2), 9-21. https://doi.org/10.37134/jsml.vol9.2.2.2021
47. Tangianu, F., Mazzone, A., Berti, F., Pinna, G., Bortolotti, I., Colombo, F., Nozzoli, C., La Regina, M., Greco, A., Filannino, C., Silingardi, M., & Nardi, R. (2018). Are multiple-choice questions a good tool for the assessment of clinical competence in Internal Medicine? Italian Journal of Medicine, 12(2), 88. https://doi.org/10.4081/itjm.2018.980
48. Tawok, S. G., & Saidin, S. (2025). Student's Knowledge, Attitudes, and Practice towards Sustainable Development Goals at the Sultan Idris Education University. International Journal of Research and Innovation in Social Science, IX(II), 3743–3753. https://doi.org/10.47772/ijriss.2025.9020291
49. Tsang, S., Royse, C., & Terkawi, A. (2017). Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine. Saudi Journal of Anaesthesia, 11(5), 80. https://doi.org/10.4103/sja.sja_203_17
50. Tuğçe, G., Nalan, A. & Şenol, A. (2017). Understanding Green Chemistry and Sustainability: An Example of Problem- Based Learning (PBL). Research in Science & Technological Education, 35(4), 500-520.
51. UNESCO. (2009). United Nations Decade of Education for Sustainable Development, "Review of contexts and structures for education for sustainable development: Key findings & ways forward."
52. UNESCO. (2014). Global citizenship education: preparing learners for the challenges of the 21st century. Unesco.org. https://unesdoc.unesco.org/ark:/48223/pf0000227729
53. UNESCO. (2024). What you need to know about education for sustainable development. Unesco.org. https://www.unesco.org/en/sustainable-development/education/need-know
54. Vladova, I. (2023). Towards a More Sustainable Future: The Importance of Environmental Education in Developing Attitudes towards Environmental Protection. SHS Web of Conferences, 176, 01009. https://doi.org/10.1051/shsconf/202317601009
55. Yaacob, M. R., Hameed, R.S., & Ismail, N.R.N. (2003). Perceptions of Educated Consumers on Environmentally Friendly Products in the East Coast of Peninsular Malaysia. Malaysian Journal of Consumer and Family Economics, 6(1), 42-49.
56. Yusoff, M. S. B. (2019). ABC of Content Validation and Content Validity Index Calculation. Education in Medicine Journal, 11(2), 49–54. https://doi.org/10.21315/eimj2019.11.2.6
57. Zuin, V. G., Eilks, I., Elschami, M., & Kümmerer, K. (2021). Education in green chemistry and in sustainable chemistry: perspectives towards sustainability. Green Chemistry, 23(4), 1594–1608. https://pubs.rsc.org/en/content/articlepdf/2021/gc/d0gc03313h