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Inquiry-Based E-Module with an Ethno-STEM Approach to Develop Sustainable Environmental Literacy Skills

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Abstract

Environmental literacy is one of the keys to support the success of sustainable development goals (SDGs). This research aims to develop an inquiry e-module with an ethno-STEM approach to the concept of volatile aromatic compounds. The research subjects involved 46 students in the chemistry education study program who took the course on organic chemistry of natural substances. Data collection was carried out using an environmental literacy questionnaire covering four domains (knowledge, cognitive skills, attitudes and behavior). The results showed that the validity of e-modules in terms of material and media was 82.5% and 93.25%, respectively, which were categorized as very valid. The results of the environmental literacy test indicate that the average scores for knowledge, attitude, cognitive skills, and behavior were 45.91, 46.46, 51.32, and 53.24. All four domains fall within the high category. The inquiry e-module with an ethno-STEM approach is very suitable for developing environmental literacy skills.

Keywords: e-module, environmental literacy, volatile aromatic compound

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1. Introduction

Sustainable development goals (SDGs) include 17 goals grouped into four aspects: education, environment, economy, and social. Environmental and educational aspects are two interrelated elements (Fang et al., 2023). Environmental literacy skills are knowledge about the working mechanisms of the natural environment and the role of humans in preserving a sustainable environment (Meilinda et al., 2017). Education with the application of environmental literacy has four domains, which are knowledge, cognitive Skill, attitude, and behavior (Fetiana et al., 2022). The dynamic relationship between humans and their environment can be seen from how humans live side by side with all the components around them.

Environmental literacy has a big influence on solving environmental problems, but the lack of a good environment in practice often limits its application (Meilinda et al., 2017), the contribution of environmental problems to higher education is also still relatively slow (Coman et al., 2020). Apart from that, learning related to environmental literacy is limited to text and less emphasis is placed on special material (Solheri et al., 2022). Based on these several quotes, it can be concluded that education can play an important role in efforts to protect the environment so that in the future a good environment can be felt by the next generation.

The organic chemistry of natural substances (OCNS) course is an important course in the chemistry education curriculum because it

provides an understanding of organic compounds that come from nature and their applications in everyday life. Apart from that, this course can also increase students' understanding of the importance of maintaining biodiversity and sustainable use of natural resources (Sulistijowati et al., 2021). References for OCNS learning to provide sustainable environmental literacy are still limited. Apart from that, there has not been much research related to the integration of the inquiry learning model (MPI) with etno-STEM to provide sustainable environmental literacy.

Modules are learning materials that can be used as learning references, designed systematically based on a certain curriculum and packaged in the form of the smallest learning units and allow them to be studied independently in flexible conditions and times (Rahmi et al., 2021). According to (Puspitasari, 2019) by using modules students can learn more focused and systematic, apart from that the aim of developing modules is so that students can master the competencies taught in learning activities as well as possible (Suharto et al., 2022). This means that a module is a complete teaching unit or material and is designed to be used for learning without the presence of a teacher or lecturer.

The current era of technological progress allows students to obtain information in the form of electronic modules (e-modules) (Ersando et al., 2022). Technological advances have a positive impact on the world of education, which are being able to carry out learning flexibly, such as being able to carry out face-to-face (online) or distance learning (offline) (Rahmi et al., 2021). However, technological advances also have a negative impact on this final generation, which are cultural globalization and a lack of concern for local culture (Rahayu et al., 2022). So it is felt that a special approach is needed to be able to integrate local wisdom with knowledge simultaneously.

Etno-STEM is an approach that combines local wisdom (ethnoscience) with STEM (science, technology, engineering, and mathematics). Ethnoscience refers to an approach in science that recognizes and integrates local knowledge, practices and wisdom possessed by an ethnic or cultural group with the process of scientific inquiry (Sudarmin et al., 2020), involving collaboration between researchers from ethnic or cultural groups with researchers from outside the group (Sudarmin, 2014). In general, we can say that ethnoscience is an approach that adopts culture into science.

STEM is becoming a trend in the current education curriculum, because of the importance of mastering STEM skills in facing global challenges. It is hoped that a STEM-based education curriculum can produce a generation that has skills relevant to the needs of the job market and future technology (Bani-Hashemi & Goodarzi, 2021). Integration between ethnoscience and STEM can enrich STEM skills and learning with cultural perspectives, traditional knowledge and social contexts that are relevant for students (Erman & Suyatno, 2022). Research conducted by Erazo also shows that using an ethno-STEM approach can provide a more enjoyable experience for students and increase their understanding of learning material. Through this integration, it is also hoped that it will be able to instill environmental literacy in students.

Drinking coffee and drinking tea are global cultures, as well as Indonesia, which is famous for its coffee and tea products. One of the regions in Indonesia as a producer of coffee and tea is Bengkulu, this is inseparable from the history of Dutch colonization which encouraged the planting of coffee and tea in the region. In addition, around coffee plantations, *Baccaurea lanceolata* (Lempaung) plants are also found growing wild and abundant and are used by the community as food ingredients (Muhammad et al., 2023).

Resetting the components of volatile compounds in the aroma of coffee and tea typical of Bengkulu has not been widely studied. Therefore, in this study, volatile compounds of coffee and tea aroma were tested. Testing of volatile compounds of coffee and tea aroma was carried out through laboratory testing and literature searches.

Laboratory testing related to volatile compounds is very important to add to the knowledge of volatile compounds and also enrich the treasures of local wisdom and culture in the region. The test results obtained from the laboratory and literature review are used as material for developing e-modules that are used as learning materials in the classroom as well as library archives on Bengkulu culture.

2. Research Method

This research is an R&D (research and development) study with the 4D model (define, design, develop, and disseminate) initiated by Thiagarajan. This research develops teaching materials in the form of e-modules that synthesize the findings from field observations, laboratory tests, and literature reviews. E-modules are compiled using Microsoft word and flipped on the PDF Corporate application. After the e-module is completed, the material and media validation test is carried out to experts (two lecturers). if the validation results show that the e-module is valid, then a small-scale test is carried out involving 24 5th semester students who take mini research courses. The results obtained from the small-scale test are the feasibility of the readability of the e-module, if it is declared feasible, then it is then applied on a large scale involving the test subject, which is chemistry education students of Unnes Academic Year 2023/2024. The large-scale trial involved 46 5th semester students from two classes taking organic chemistry of natural substances (OCNS).

2.1. Research Flow

A big picture of the flow of this research starting from conducting interviews with the community regarding coffee plants and local tea. The results of the interviews obtained community knowledge about coffee plants and local tea which was then reconstructed by scientific knowledge. Plant information is used as laboratory testing samples. Apart from that, initial observations were also carried out regarding learning in the OCNS course to find learning needs and objectives. The overall results obtained are public knowledge, scientific reconstruction, laboratory test results, and learning objectives which are the initial stages of this research.

The second stage in this research is product development by integrating the results obtained in the first stage into an e-module. The third step is to carry out a product feasibility test through a validity test and readability test, apart from that, the e-module being developed is also implemented. The final stage is the dissemination through the publication of research results.

2.2. Data Collection Technique

The instruments used in this research were observation sheets (interviews), validation sheets, small-scale response questionnaires, environmental literacy questionnaires, assessment sheets, and large-scale response questionnaires. Data collection was carried out through validation test results by material expert validators and media experts, small-scale tests to test readability, effectiveness of environmental literacy results, and student response questionnaires.

2.3. Data Analysis Techniques

2.3.1.Validation Sheet Analysis

Validation of e-modules from material and media experts using a likert scale with an assessment score scale is shown in Table 1.

Table 1. Validity Test Scale

Evaluation	Score
Very worthy	4
Worthy	3
Not worth it	2
Not feasible	1

To analyze the validation results obtained, the average score and percentage were calculated. The results obtainned are then converted into an assessment statement to determine the feasibility and quality of the product produced. The percentage scale for the assessment as shown in Table 2 (Arikunto, 2006).

Table 2. Percentage Rating Scale Validation

Percentage Rate (%)	Criteria
0-19	Invalid
20-39	Not valid
40-59	Fairly valid
60-79	Valid
80-100	Very valid

2.3.2. Small Scale Trials

A small-scale test was carried out to test the readability of products that had been developed using a likert scale as in Table 3.

Table 3. Likert Scale for Small Scale Trials

Evaluation	Score
Strongly Agree (SS)	4
Agree (S)	3
Disagree (KS)	2
Disagree (TS)	1

The assessment scores obtained from the results of the small-scale trial questionnaire were calculated by the average value and percentage for each criterion. The percentage obtained is then converted into assessment criteria to determine the readability of the e-module product being developed. If it is found that there are parts of the e-module that do not meet the criteria, the e-module will be revised. The percentage scale for the assessment can be seen in Table 4 (Arikunto, 2006).

Table 4. Criteria for Small Scale Trial Results

Percentage Rate (%)	Criteria
0-19	Not attractive
20-39	Less attractive
40-59	Quite interesting
60-79	Interesting
80-100	Very interesting

2.3.3. Analysis of Student Environmental Literacy

Environmental Literacy Analysis uses the score transformation used by NELA (2011), with score ranges and categories as Table 5.

Table 5. Environmental Literacy Score Scale

Domain	Value Range	Score	Criteria
Knowledge	0-60	0-20	Low
		21-40	Medium
		41-60	High
Competitive skills	0-60	0-20	Low
		21-40	Medium
		41-60	High
Attitude	15-60	15-30	Low
		31-45	Medium
		46-60	High
Behaviour	12-60	12-17	Low
		28-44	Medium
		45-60	High

2.3.4. Student Response Questionnaire Sheet

After the product was tested on a large scale, a questionnaire was distributed to students regarding the e-module used in the learning process of organic chemistry of natural substances. Analysis of student response questionnaires to the e-modules distributed using a likert scale. The Likert scale for student response questionnaires can be seen in Table 6 (Arikunto, 2010);

Table 6. Likert Scale for Student Response Questionnaires

Evaluation	Score
Strongly Agree (SS)	4
Agree (S)	3
Disagree (KS)	2
Disagree (TS)	1

The assessment scores are obtained from the results of the student response questionnaire, then the average value is calculated and the percentage of student responses for each criterion is calculated. The percentage of student responses obtained is then converted into an assessment statement to determine student responses to the e-module product being developed. The percentage scale for the assessment can be seen in Table 7 (Arikunto, 2006).

Table 7. Criteria for Student Response Results

Percentage Rate (%)	Criteria
0-19	Not attractive
20-39	Less attractive
40-59	Quite interesting
60-79	Interesting
80-100	Very interesting

3. Result and Discussion

This research focuses on developing an integrated inquiry e-module with ethno-STEM content on learning material of volatile organic compound local coffee and tea to provide sustainable environmental literacy. The development process involves four stages, which are define, design, develop, and disseminate with the following explanation.

Define, The initial stage of research is conducting a learning needs analysis and determining learning objectives. Analysis of learning needs through interviews with course lecturers resulted in the OCNS course requiring the development of teaching materials in the form of e-modules with material discussing volatile tea aroma compounds. Next, carrying out an analysis of objectives by looking at the university's vision and mission, analysis of previous research, and course achievements, the results obtained were the need to develop an e-module with learning material of volatile coffee aromatic compounds and integrated herbal inquiry and ethno-STEM.

Design, The design stage is the second stage in e-module development. At this stage, media is selected to be included in the e-module. Media selection includes videos, images, links, and QR. Apart from that, at this stage format selection is also carried out, such as writing, font size, module arrangement scheme, and module design. An example of a module design as shown in Figure 1.

Figure 1. E-Module Cover

The initial part of the e-module that has been developed is the cover which can be seen in Figure 1. The initial chart consists of information on the e-module title, module identity via logo, author, and agency where the author comes from.

The second part of this module is the e-module learning material of volatile organic compound which discusses volatile compounds related to the aromatic of coffee and local tea. Material was obtained from interviews and laboratory test results. Interviews were conducted with the Rejang tribe community in Bengkulu province about local plants. Based on the results of the interviews, information was obtained related to coffee and tea plants and the local culture that consumes coffee and tea at various events and in their daily lives. For example, coffee and tea drinks are an appetizer when welcoming guests, weddings, or enjoyed as a drink on the beach. According to the local community, consuming coffee and the can provide stamina to work and fight sleepiness, while the distinctive aroma and taste of coffee and the can provide relaxation. In addition to coffee plants, there are many other specialty plants that can be used as herbal teas, one of which is the lempaung plant.

The interview results obtained were subjected to scientific reconstruction. Like coffee It has a distinctive and strong fragrant aroma, this aroma comes from several compounds such as furan, caffeine, and palmitic acid (Apriliya et al., 2023; Yu et al., 2021; Saud et al., 2021; Uner & Macit., 2023). The tea also has a distinctive aroma according to its composition, such as camellia sinensis tea leaves have aroma-giving compounds, which are catechins, while other teas such as clove tea have a distinctive fragrant aroma, which are eugenol (Wang et al., 2020). This means that we can say that each tea has different aroma-giving compounds that cause different aromas.

Coffee and the can reduce drowsiness due to the presence of caffeine which is included in the alkaloid compound class (Fibrianto et al., 2023), this compound is able to suppress neurotransmitters that work to give drowsiness. Caffeine compounds in coffee are also able to stimulate the central nervous system to increase the production of the hormone adrenaline and accelerate metabolism (Taib, 2023), this results in an increase in energy so as to increase the fitness and work stamina of the consumer. The distinctive aroma of coffee and tea and there are various herbal teas, such as lavender, jasmine, and Rose (Wang et al., 2020), so it is widely used as aroma therapy, this fragrant and soothing aroma provides relaxation to the nerves (Guo et al., 2023) So that the body feels a relaxed sensation.

According to the community to maintain the aroma when drinking coffee and tea by covering the drink with a glass cover or container. This can be explained scientifically that aroma is a volatile compound. Brewing using hot water is able to provide heat that can vaporize these compounds to create a fragrant aroma (Kath et al., 2020). The act of closing the container traps the aroma compounds in the container. This causes the aroma to last longer in the container. To maintain the aroma of coffee and tea, it can be stored in cool conditions and in a closed container (Moldevaer, 2021). Also, when brewing, you should use hot water, this can give the fragrant aroma of coffee and tea a stronger flavor (Kath et al., 2020). Meanwhile, when using cold water, coffee and tea do not give a strong aroma. In addition, the amount of coffee and tea for consumption depends on taste. However, the amount of use does not change the aroma, it is just that when brewed in larger quantities coffee and tea can give a thicker aroma (Fibrianto et al., 2023).

The results of scientific reconstruction of community knowledge related to coffee and tea found that there are many compounds that play a role in giving aroma to coffee and tea. This reconstruction is used as a study material in learning using the ethno-STEM approach. Chemical materials in this approach include (S) knowledge about coffee and tea, especially the volatile compounds of coffee and tea, (T) tools used in producing the aroma of coffee and tea, (E) engineering used to maintain the aroma of coffee and tea, (M) Measurements used to produce the aroma of coffee and tea. Proving the existence of volatile aroma compounds is done by trapping volatile compounds using an arduino sensor and Sudarmin design distillation. Bioa sengok coffee plants, Kabawetan tea, and Lempaung are local plants selected as laboratory testing samples. The results of laboratory testing obtained information on secondary metabolite compounds and volatile compounds from each sample. In addition, this section also explains how to test and analyze the test samples.

Secondary metabolite compounds contained in the sample are alkaloids, flavonoids, tannins, saponins, terpenoids, and steroids. volatile aroma compounds contained in the sample are characterized by the presence of several compounds such as CO and CO_2. The amount of compound concentration detected in each sample showed significant differences. The test results show that not all components of the detected compounds are volatile compounds, such as carbon monoxide (CO) and carbon dioxide (CO_2) compounds. This study uses a gas sensor that is not intended to detect volatile aroma compounds but rather detects compounds resulting from combustion reactions or degraded

compounds, resulting in the presence of non-volatile compounds being detected.

The test results show that there are more compounds in kabawetan tea than compounds in lempaung. The highest concentrations in each scample were CO, CO_2, and Alcohol (-OH). CO and CO_2 may come from the degradation of organic compounds due to heating, the heating method is one of the most commonly used methods to degrade organic compounds into simpler compounds, one of which is CO and CO_2 (Zhang et al., 2023). In tea samples CO and CO_2 may come from carbohydrates, fats, and volatile compounds (Pokharel et al., 2021 & Shi et al., 2021). While (-OH) is possible from the solvent because in this study using 25% ethanol solvent.

The results of interviews and laboratory tests become learning materials that are announced into e-modules as study materials. Another stage in the e-module that has been developed is learning activities. This section is a student activity after understanding the learning material of volatile organic compound. At this stage, students are invited to explore herbal tea plants around their residences and conduct research regarding the volatile compounds found in these tea plants and their benefits for humans.

Develop, the development stage is the third stage in this research stage which includes validation stages by material experts, validation by media experts, small-scale trials, and large-scale trials. Validation aims to evaluate the module that has been developed. In this study, validation involved two chemistry education master lecturers with the results of material validation as shown in in Figure 2.

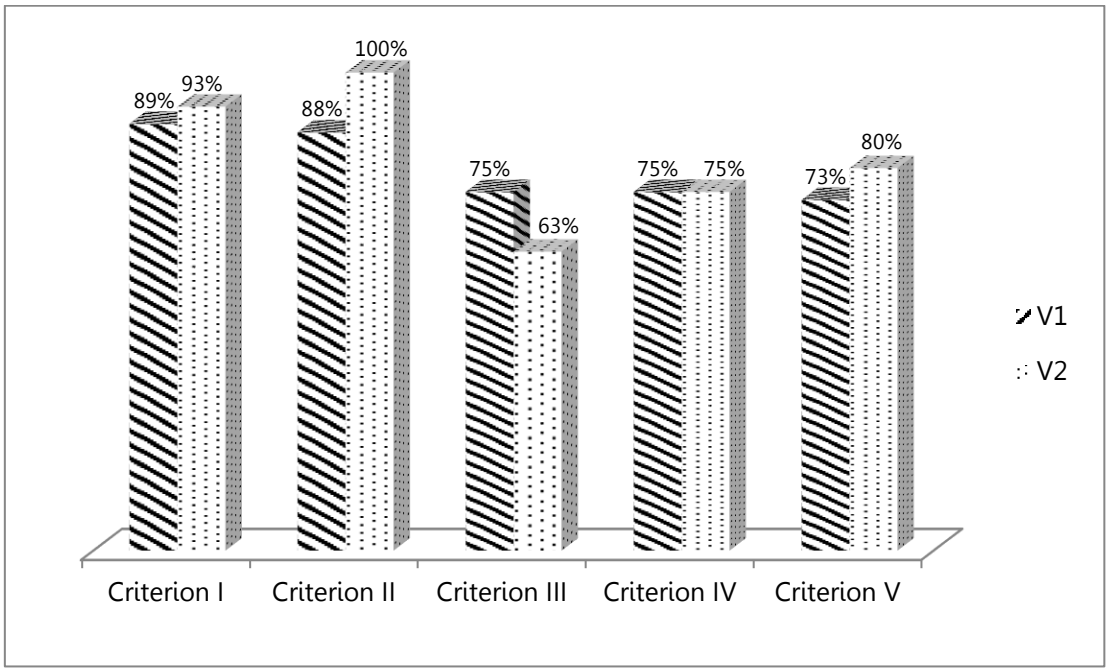

Figure 2. Results of E-Module Validation by Material Experts

The assessment criteria by experts involve five aspects of criteria, which are content appropriateness (Criterion I), material presentation aspect (criterion II), language appropriateness aspect (criterion III), ethno-STEM based (IV), and environmental literacy ability (V). The validation results for each validator can be seen in Figure 2. The percentage of validity results for each criterion from the two validators shows that in Criterion I and Criterion II the category is very valid, while in Criterion II and III, it is categorized as valid, and in Criterion V it is in the valid category from Validator 1 (V1) and the very

valid category from Validator II (V2). In general., the e-modules that have been developed show a high percentage, which are V1 and V2, respectively 82% - 83%. If the percentage of e-module material validation from the two validators is averaged, a value of 82.5% is obtained, the value obtained is quite high and is categorized as very valid.

The smallest percentage of validation results is category III which is related to language. From the notes of the two validators, there are still many spelling errors in the writing. Apart from that, criterion IV related to ethno-STEM also includes the smallest validation results, with improvements noted, which is the need for confirmation of the "STEM" section. So that the e-module that is developed is revised according to the input from the validator, which are improving materials (typo) and explaining the STEM content in the e-module which is placed in the introduction section. Apart from that, there was a suggestion from V1 to develop an e-module for the lecture material as a whole (16 meetings). However, this suggestion cannot be fulfilled considering the existence of other learning objectives and outcomes and limited research time. The results of media validation can be seen in Figure 3.

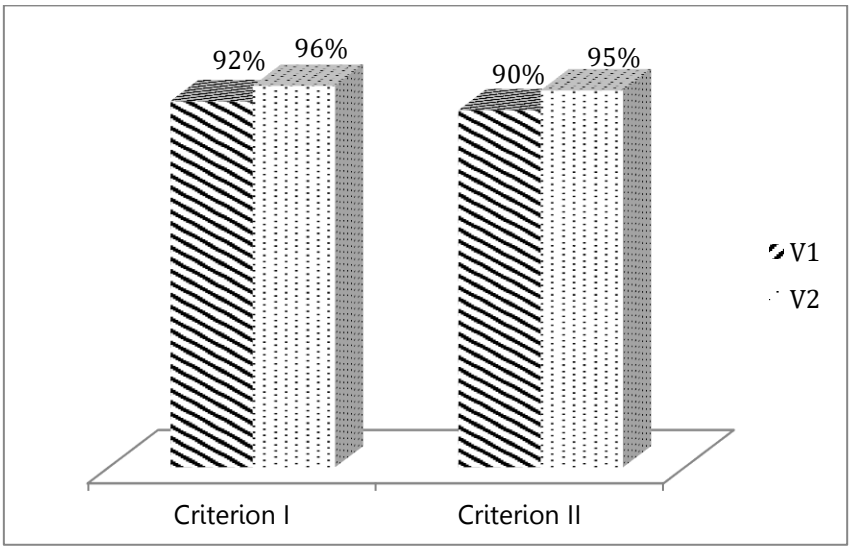

Figure 3. Results of E-Module Validation by Media Experts

Media validation is an evaluation process that aims to assess the quality, effectiveness, and relevance of the product being developed. Validity in this media assessment is the same validator as the material validator. There are two aspects of this validation assessment, which are appearance (criterion I) and physicality (criterion II). Both criteria obtained a high percentage as shown in Figure 3. In criteria I and II, the percentage of assessments from validator I (V1) and validator II (V2) were categorized as very valid, apart from that, in this validation there were also no records of improvement. If we calculate the average media validation results from the two validators, we get a percentage value of 93.25%. The percentage obtained is a very high value and is included in the very valid category. After the e-module developed is declared valid, the next stage is the Readability Test. Results of small scale trials can bes seen in Figure 4.

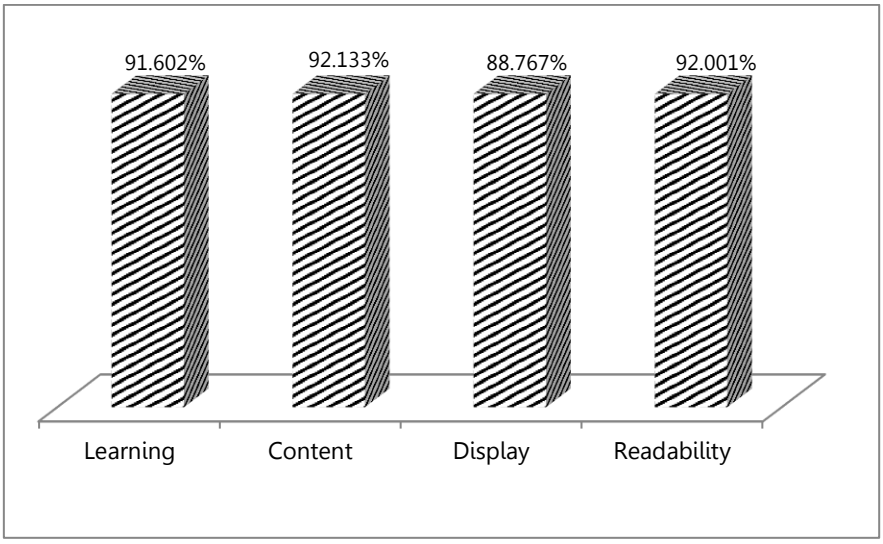

Figure 4. Results of Small-Scale Trials

Small-scale trials are carried out after the e-module developed is declared valid based on the results of the assessment by the validator. There are four assessment criteria in this trial., which are learning aspects, content aspects, display aspects, and readability aspects. The results of small-scale trials can be seen in Figure 4, where each aspect obtained a very high percentage. The Learning Aspect received a percentage of 91.602% which was categorized as very interesting, the Content Aspect received a percentage of 92.133% which was categorized as very interesting, the Display Aspect received the smallest points compared to other aspects, which is 88.767%, but this aspect is still included in the very interesting category, and finally the readability aspect obtained a percentage of 92.001% in the very interesting category.

If averaged, the percentage of e-modules gets a score of 91.3% which is included in the very interesting category. Based on the results of small-scale trials which showed very high results, apart from that the e-module was also declared valid based on validation results, and the e-module developed was declared suitable for use as teaching material. Environmental literacy results can be seen in figure 5.

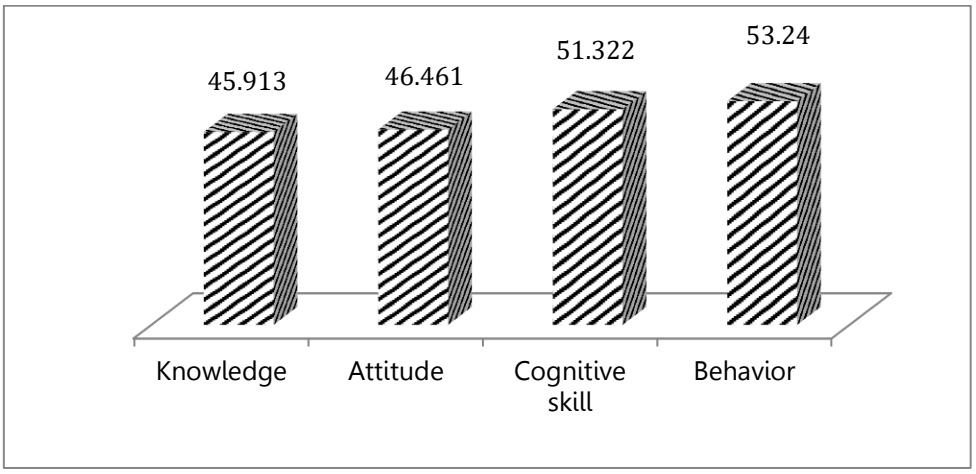

Figure 5. Environmental Literacy Results

The next stage is large-scale trials or the use of e-modules in learning. The e-module was used for four meetings. At the first meeting, the topic of volatile aroma compounds of coffee and tea was discussed. The second meeting continued the activities of the first meeting by conducting group exploration and looking for herbal tea plants from the areas where each lived. The third meeting held environmental literacy and designed a group search results report. At the fourth meeting, which was the last meeting, there was a presentation and discussion of the results obtained by each group. The environmental literacy results obtained can be seen in Figure 6 which shows that students' environmental literacy is in the high category of the four domains, which means that the e-module has been developed can provide environmental literacy.

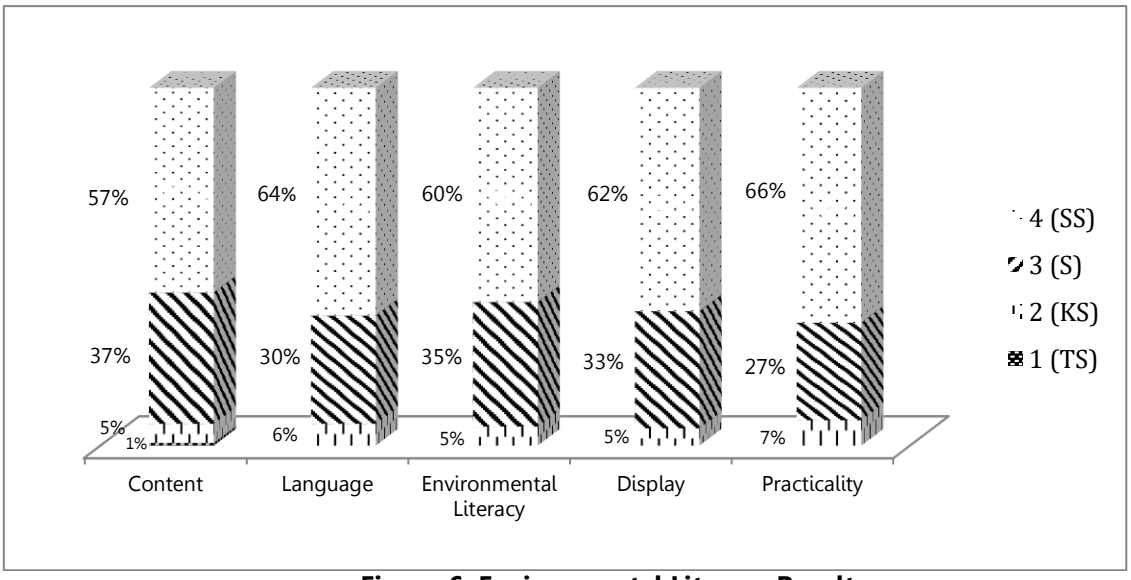

Figure 6. Environmental Literacy Results

At the end of the learning activity, a student response questionnaire was given regarding the use of e-modules in learning activities. The results of student responses to using the module can be seen in Figure 6. The module assessment category includes five aspects, which are material., language, environmental literacy, appearance, and practicality. Each aspect of student responses received an average percentage of 88%, 89%, 89%, 89%, and 90% respectively. The response results show that each criterion has a very interesting category. At this stage, you are also allowed to provide criticism, suggestions, and experiences while taking part in learning using the e-module that has been developed.

Some points of suggestion in this e-module include adding learning material for aroma volatile compounds from other plants originating from Indonesia and the world, as well as providing locations in the form of a map of the origin of these plants. Apart from that, it is recommended to add material related to anti-cancer or anti-diabetes. The e-module that has been developed is limited to three local plants and focuses on aroma volatile compound material. The suggestions and input obtained as in Figure 6 can be used as evaluation material in developing e-modules and can be used as a reference for future researchers. The experiences conveyed by students are also very positive in terms of ease of access, completeness of material., use of simple language, and attractive and varied e-module design.

4. Conclusion

Teaching materials in the form of e-modules which are integrated with inquiry and ethno-STEM in the study of volatile compounds of aroma of local coffee and tea are suitable for use as teaching materials seen from the results

of e-module validation from material experts and media experts respectively with an average of 82.5% and 93.25%, both of which are categorized as very valid and able to provide environmental literacy by looking at the results of the environmental literacy trial with a knowledge score of 45.913, attitude 46.461, cognitive skills 51.322, and behavior 53.24, all of which are categorized as high.

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