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Promoting SDG 15: Life on Land – Development of Socioscientific Issue-Based E-Module on Gold Mining in ESD to Facilitate Students' Critical Thinking Skill and Anticipatory Competency

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Abstract. Indonesia, with its abundant natural resources, needs to implement wise and sustainable management it line with SDG 15 to maintain ecosystem balance and support life. Education plays a crucial role in achieving sustainable development. An e-module was developed as an educational initiative to promote SDG 15 by integrating socios-scientific issues (SSI) related to gold mining, aiming to facilitate critical thinking skills (CTS) and anticipatory competency (AC). This study aims to develop and evaluate the e-module product. The research method employed is research and development (R&d) using ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. However, the implementation stage was not applied in this study. Data collection utilized e-module validation sheets as instruments. The research subjects consisted of experts validators, including 2 biology education lecturers and 2 professional biology science teachers. The results show that the validation scores from experts were as follows: material aspect with an average score of 3.71 (highly valid), content presentation aspect with an average of 3.72 (highly valid), linguistic aspect with an average of 3.77 (highly valid), and graphic design aspect with an average of 3.79 (highly valid). Overall, the developed e-mode is valid for use, though further research is still required to test its effectiveness.
Keywords: E-module, socioscientific issue, ESD, CTS, anticipatory competency

Introduction

The essence of the 2030 agenda is in the 17 sustainable development goals (SDGs), which are universal, transformative, and inclusive. These SDGs outline the key challenges humanity faces in development. The primary objective of the 17 SDGs is to create a sustainable, peaceful, prosperous, and equitable life for all people, both now and in the future. These goals address critical global challenges essential to human survival and establish environmental boundaries and critical thresholds for the utilization of natural resources (Unesco, 2017). One of the sustainable development goals is SDG 15: Life on Land. SDG 15 outlines the aim to protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and

reverse land degradation, and stop biodiversity loss (Bappenas, 2020). This is currently being pursued by the Indonesia government.

In the context of SDG 15, Indonesia possesses abundant natural resourcces, both renewable and non-renewable. To maintain ecosystem balance, these resources must be conserved and utilized wisely to sustainably support human life and other living beings, while improving the quality of life in a sustainable manner (Farisi et al., 2022). However, if these natural resources are not managed properly, they can lead to environmental degradation and irreversible changes. Examples of activities causing environmental damage include illegal natural resource exploration and exploitation. The prevalence of illegal mining, for instance, is partly driven by high economic incentives, as these activities aim to generate profit through unlawful means (Cadizza & Pratama, 2024). Such impacts directly contradict the objectives of SDG 15. Therefore, approaches are needed to promote SDG 15 goal, enabling public participation and informed decision-making in achieving sustainable development goals (Eliyawati et al., 2023; Solihat et al., 2024).

Education for sustainable development (ESD) is an educational approach aimed at supporting the transition toward sustainable development by balancing environmental, social, and economic aspects (Barth, 2016). Learning with ESD serves as an effort to integrate complex understanding in achieving the SDGs (Fadilah et al., 2024). Alongside advancements in life, particulary in technology, the challenges faced are becoming increasingly complex. Therefore, education needs to equip individuals with relevant skills to adapt to increasingly dynamic and sustainable environments (Novidsa et al., 2021). Integrating ESD principles and SDG goals into learning materials for primary and secondary schools not only provides immediate benefits but also forms a critical foundation for students' futures. This process builds environmental awareness and social responsibility, hones a sense of solidariy as citizens, and develops critical thinking and practical skills that support sustainable living. The impact ranges from changes in daily attitues to preparation for facing future global challenges (Zguir et al., 2021).

Teaching materials plays a crucial role in achieving learning objectives and are designed according to student characteristics. One strategy educators can implement is combining teaching materials with digital technology to create more interactive, innovative, and creative learning. Through the use of technology, the presentation and learning environment can be adjusted to be more modern and engaging compared to before. Technology contributes to advancements in education and can serve as a solution to address various challenges in this field. Proper utilization of technology will significantly enhance the quality of education (Pratama et al., 2017; Umar et al., 2022; Wulandari et al., 2020). The integration of teaching materials and technology can be achieved by using or developing e-modules. E-module is electronic teaching materias that not only presents content in text form but are also equipped with visual elements like images and animations, as well as audio-visual elements such as videos, making learning interactive (Pratiwi et al., 2022). Support in the learning process helps overcome various obstacles and ensures learning objectives are achieved. In this regard, e-module as a medium function as tools to deliver information from teachers to studetns, especially for material that is difficult to explain with words alone (Ferella et al., 2025). By using e-module, sustainable learning principles aligned with ESD can be implemented. These e-module can bridge the gap between field conditions and learning standards, ensuring between the two (Novianti et al., 2023). In this case, ESD integrates sustainability values to shape sustainable lifestyles in students (Pangsuma et al., 2024). Interactive module can also be integrated with ESD as learning resources in the globalization era by utilizing the latest technology, as they inherently contain sustainable development goals (Cebrián et al., 2020; Duarte et al., 2020). By integrating into education through e-modul, sustainability patterns in student can be enhanced (Bariroh et al., 2024; Umar et al., 2024).

E-modules also play a role in developing students' critical thinking skills (CTS), improving learning efficiency, and encouraging them to learn independently (Mardiah et al., 2021). This is also needed because critical thinking skills are included in the integrated 21st century skills of 4C, namely, collaboration, communication, creativity, and critical thinking. Students need to have CTS to understand the changes in the modern era that continue to develop. Thinking is the mental process of asking questions and connecting information appropriately. In the field of biology, this ability includes analytic, inductive, and deductive thinking that helps solve problems related to natural phenomena around us (Adinda et al., 2022). However, case studies, show that students' CTS are still low due to several factors, such as minimal student involvement in learning due to monotonous learning models, less varied teacher teaching methods, and dependence on textbooks as the only source of learning. In addition, the subject matter does not reflect the local reality of students, so it needs to be reviewed in order to increase students' participation and interest in learning to deepen their understanding in the local context (Hermayani et al., 2015; Ula et al., 2025). However, the level pf CTS of high school students in Indonesia is still low (Putri et al., 2022; Sonia et al., 2023; Yulianis & Suryanti, 2023). This is reinforced in the research of Husnita et al. (2019) that the reluts of students' CTS are at a score of 32.56%, this is due to several internal and external factors and the student learning process.

The limitations in students' CTS and the unoptimal utilization of learning media indicate the need for the development of appropriate and effective learning media. Learning media itself includes everything that can be used by teachers to convey material from teaching materials to students (Puspitarini & Hanif, 2019). Therefore, e-modules that are able to facilitate students' CTS are also needed. Biology learning must be contextual because it is directly related to everyday life and involves knowledge and skills in solving problems. Therefore, the right learning approach needs to emphasize contextual aspects so that students not only gain knowledge, but also values, attitudes, and decision-making skills for the problems faced. One approach that supports this is socioscientific-issues (SSI) (Ummah, 2025). The content in SSI is generally controversial, but also requires moral reasoning and evaluation of the issues and ethics in determining appropriate solutions. In addition, its open nature allows learners to think critically and discuss with other students who have different views on the issue (Zeidler & Nichols, 2009). SSI cover a wide range of environmental, social, ethical, economic, political and scientific issues that involve conflicting interests. Issues such as environmental challenges and genetic engineering fall into this category as they are often contentious and require moral as well as scientific considerations in finding solutions. (Hsu & Lin, 2017; Sadler & Zeidler, 2004).

In addition, awareness of disaster anticipation in Indonesia is still relatively low, coupled with the lack of school involvement in controlling disaster preparedness education (Seddighi et al., 2022). Disaster anticipation activities aim to increase community preparedness, reduce the risk of disasters in the long term, and reduce the number of victims by minimizing their impact. However, anticipation competence is still low, and research on students' anticipation competence is limite (Hasanah, 2021). So that this needs to be addressed, using e-modules with socioscientific gold mining issues in ESD is expected to facilitate students' anticipatory competency (AC).

In this research, an issue that contradicts sustainable practices with SDG goal 15, namely life on land, is used. The issue used is the issue of illegal gold mining in Bolaang Mongondow, North Sulawesi Province. In practice, illegal mining often uses methods that damage the environment without considering the sustainability of natural resources. In addition, the perpetrators always ignore the principles of environmentally responsible mining (Cadizza & Pratama, 2024). Illegal mining activities in Indonesia, from tropical forests to coasts, cause multidimensional damage. Land clearing by illegal logging triggers massive deforestation, destroys endemic animal habitats, disrupts ecosystem balance, and

exacerbates the climate crisis. In addition, the use of mercury and cyanide pollutes rivers and groundwater, endangering aquatic life and the health of people who depend on these water sources. Toxic waste carelessly dumped into ditches, gullies or rivers contaminates agricultural land, drinking water and animal feed, threatening the lives of local residents. This practice not only destroys nature, but also systematically erodes ecological and social sustainability (Cadizza & Pratama, 2024; Farisi et al., 2022; Trimiska et al., 2018). Therefore, the issue of illegal gold mining (SSI) is integrated with ESD through the validity of e-module content to promote SDG 15.

This research aims to develop an e-module with socioscientific content on gold mining issues in education for sustainable development to improve students' CTS and AC on ecosystem material in phase E of the independent curriculum. This e-module covers fundamental concepts, issues surrounding illegal gold mining, and data on environmental pollution caused by this activity. It is hoped that by presenting environmental issues and data relevant to where students live, students can understand the material, improve students' CTS, AC, and can facilitate students to oppose unsustainable mining practices and damage the environment.

Methods

This research method is research and development which is often called R&D. The chosen model is ADDIE, which consists of stages; analysis, design, development, implementation, and evaluation. The ADDIE model is a process framework designed to guide the resolution of complex situations, making it very effective in the development of education-based learning products and resources (Branch, 2010). In this study, the stages of analysis, design, development, and evaluation were implemented, while the implementation stage was excluded because the research was limited to producing product. So the researcher modified the development stage by cutting one stage of the ADDIE method.

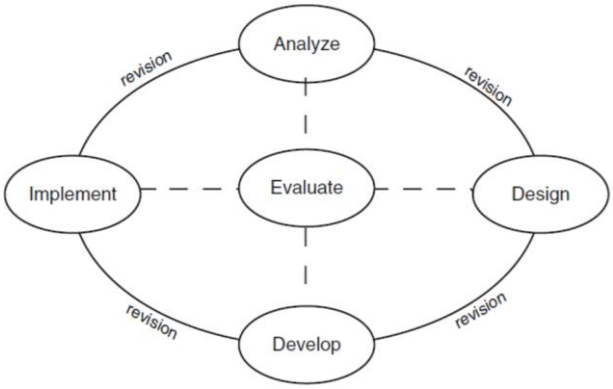


Figure 1. Stages of the ADDIE development model (Branch, 2010)

The data collection technique in this study uses descriptive qualitative. Qualitative research is a method that focuses on describing and understanding phenomena based on what is observed, heard, felt, and expressed (Elita et al., 2025; Sugiyono, 2016). In this study, qualitative descriptive data were collected based on respondents' responses to assess the socioscientific e-module on gold mining issues in ESD. The purpose of this research is to produce an E-module product with socioscientific content on gold mining issues in education for sustainable development which is seen in various aspects, namely: material aspect, material presentation aspect, linguistic aspect, and graphical aspect. This research was conducted at schools in public high schools in Kotamobagu City. The subjects of this study consisted of 4 experts, namely, 2 biology education lecturers and 2 biology

science teachers with at least a master's degree. Meanwhile, the object of the research is an e-module with socioscientific content on gold mining issues in ESD to facilitate CTS and AC. The assessments used in this study were expert validation sheets and student responses on the material aspect consisting of 15 items; the material presentation aspect consisting of 12 items; the linguistic aspect consisting of 8 items; and the graphical aspect consisting of 15 items. In total, there were 50 assessment statements which were compiled and developed based on the same indicators of the e-module (Kemdikbud, 2017).

Table 1. Likert scale on product assessment

Likert Scale	Category	Information
4	Strongly Agree	STS
3	Agree	S
2	Disagree	TS
1	Strongly Disagree	STS

Likert scale scoring of each statement into four graded categories with no neutral option is shown in Table 1. This aims to prevent experts and students from continuously choosing neutral answers, thus reducing the possibility of undecided answers (Puspitasari & Sari, 2024). The data on the expert validation sheet instrument was analyzed by calculating the average value based on the validator's assessment. Furthermore, the results of the average calculation were analyzed and interpreted in accordance with the predetermined criteria according to (Mardapi, 2017), The following are the criteria for expert assessment and student response in Table 2.

Table 2. E-module assessment criteria based on expert

Score Interval	Criteria
$x \geq 3.00$	Highly valid/ highly appropriate/ highly feasible; can be used without revision
$3.00 > x \geq 2.50$	Valid/appropriate/feasible; can be used with minor revisions
$2.50 > x \geq 2.00$	Less valid/ less appropriate/ less feasible; can be used with major revisions
$x < 2.00$	Not valid/ not suitable/ not feasible; cannot be used

(Source: Mardapi, 2017)

Results and Discussion

The research and development carried out in this study was carried out to produce e-modules with socioscientific content on the issue of gold mining in ESD to facilitate students' CTS and AC, which can be accessed using mobile phones on iOS and Android systems as well as on personal computers of teachers and students. The following are the detailed stages of the development process.

Analysis

At the analysis stage, a needs analysis was conducted among biology teachers. Needs analysis is carried out to identify problems in the learning process in order to develop relevant e-modules (Setiawan et al., 2024). The teachers conducted interview sessions to find out the characteristics and learning strategies carried out on students. The results found in learning are often done by lecturing and assignment methods, besides that the use of media is also used by teachers either in the form of powerpoints or taking from internet sources. The availability of learning media itself is classified as less varied by teachers, so teachers only use existing media. This is in line with the findings by Ula et al (2025) who explained that the teacher's challenges are in: learning methods that are still

conventional, the utilization of school facilities is not optimal, the difficulty of teachers in choosing media or methods, to the low motivation of students due to the monotony of the learning process. The lack of technology integration and learning activities that support the development of CTS contribute to this. In addition, the lack of motivation to learn, as well as limitations in the learning resources used, have an impact on student learning outcomes which are still below the standard (Suryani & Herman, 2024).

In addition, curriculum analysis is also carried out, this step is carried out to identify the type of curriculum applied at school. This is the basis for determining relevant and appropriate material to be developed into learning e-modules (Mahrawi et al., 2021; Suryani & Herman, 2024). The curriculum used in 4 high schools in Kotamobagu City refers to the latest learning outcomes No. 032 in phase E. The following information on the latest learning outcomes is presented in Table 3.

Tabel 3. Latest learning outcome phase E

Phase E common learning outcomes	
By the end of Phase E, students are equipped to comprehend systems of measurement, alternative energy, ecosystems, biotechnolology, biodiversity, atomic structure, chemical reactions, fundamental laws of chemistry, and climate change, thereby enabling them to be responsive and actively contribute to addressing issues within local and global contexts. All these efforts are directed toward achieving the objectives of SDGs	
Element	Learning outcome
Science Comprehension	Students understand the classification process of living things; the role of viruses, bacteria, and fungi in life; ecosystems and interactions between components and influencing factors; and the use of biotechnology in various fields of life. Students apply their understanding of science to solve problems related to climate change.

(Source: Kemendikbudristek, 2024)

The curriculum shows that the learning outcomes of students must play an active role in solving local and global issues, and these efforts are directed towards achieving SDGs, but teachers have not implemented ESD-based learning or directed towards sustainable development goals. Based on the curriculum analysis, ecosystem material is suitable material to be provided to students in the context of local to global environmental issues, and direct them to the achievement of sustainable development goals, namely SDG 15. The development of ESD-laden e-modules on ecosystem and environmental materials is needed to be carried out because the socialization of ESD is still limited in schools, and the training pattern also applied is not optimal to disseminate ESD understanding and practice to teachers. (Ardelia et al., 2022; Kusumawati et al., 2023). The results of this analysis form the basis for proceeding to the next stage, which is design.

Design

The e-module design stage is carried out based on the data obtained from the analysis results. The design process begins with the collection of key concepts, followed by making an initial design of the module display and application interface, including media selection, presentation format, and fonts to be used (Salsabila et al., 2024). The design of e-modules with socioscientific content on gold mining issues in ESD begins with the first step of preparing the concept of material and determining learning objectives, secondly determining the platform and designing the layout of the e-module being developed to make the e-module look more attractive, and thirdly determining the assessment used in the e-module.

First, the material concept used in this e-module is ecosystem material and also environmental changes. After analyzing the latest learning outcomes curriculum, it is found that ecosystem material and environmental changes become one domain of material taught looking at the elements of science understanding, namely factors that affect the ecosystem. So that the concept of material contained in this e-module consists of: 1) Ecosystem components and interactions between components, 2) energy flow in ecosystems, 3) biogeochemical cycles, and 4) environmental change and ecological restoration. This material is essential material that will facilitate students' critical thinking skills and anticipation abilities. After determining the material concept, the researcher created a total of 19 learning objectives based on general learning outcomes, ESD SDG 15 learning objectives according to (Unesco, 2017), and made material concept propositions based on Campbell 12th edition book references.

Second, determining the platform for developing e-modules and designing the e-module layout. The platform used to develop e-modules in this study is using Canva with the link www.canva.com. Canva can be used to design various needs with an attractive appearance and easily converted into pdf, png, jpg and other formats (Puspita et al., 2021). The development of e-modules using Canva in the study provides valid, interesting, and interactive results, while motivating students to be actively involved in the learning process, so it is worthy of being used as an alternative in developing e-module (Ayuardini, 2023; Kadir et al., 2024; Sahil et al., 2023). The front cover and back cover of the e-module with socioscientific issue on gold mining in ESD using Canva are presented in Figure 2 and 3.

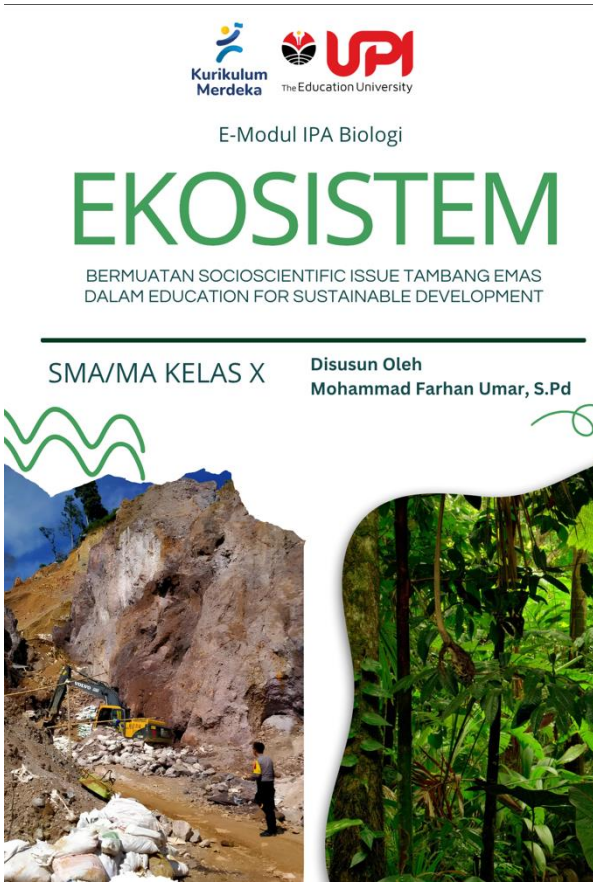


Figure 2. Front Cover

Figure 3. Back Cover

The layout design chosen in the e-module development is B5 size, which is 17.6 x 25 cm, according to the book in the form of a binder. After that, determining the green and white colors as the dominant colors of the use of colors in this e-module but varied in the type of green color to give an attractive and motivating impression to students is presented in Figure 4. Choosing the right color can improve short-term memory, thus helping students remember the material more easily (Febrianto & Puspitaningsih, 2020). In order to display a neat e-module, a ruler is given to the canvas in Canva presented in Figure 5.

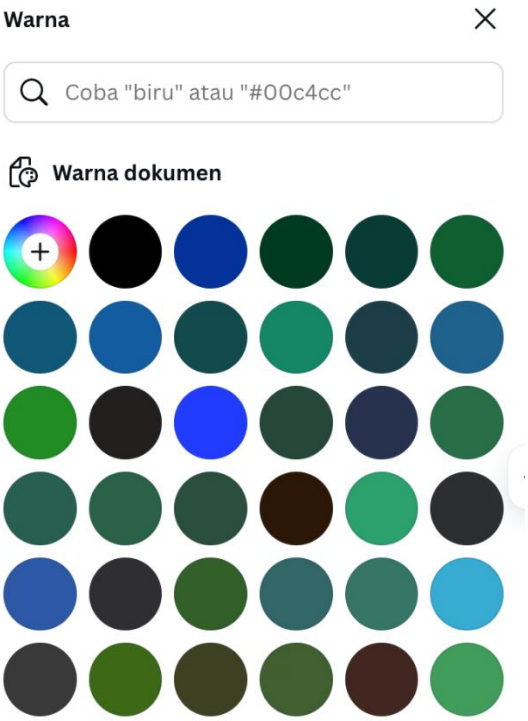


Figure 4. Color selection

Figure 5. Ruler on canvas

Finally, determining the assessment used in the e-module. Researchers designed to use formative assessments in the e-module in order to monitor the progress of student learning during the learners. In addition to the assignments given, researchers provide competency tests to students, and reflection spaces so that teachers who use this e-module can get feedback on the achievement of learning objectives in each material. Technology integrated in this assessment using google form to assess the ability and reflection space contained in the e-module being developed is presented in Figure 6 and Figure 7. In the e-module design, buttons and hyperlink features are given so that if students press the hyperlink button, they will be directed to google form to do the assessment. Google form is more practical because it can be accessed through Android phones or smartphones that are easy to carry anywhere, its use is also more flexible as long as there is an internet network available. In addition, free services can be obtained by providing online survey features with a variety of question types, such as short text, long paragraphs, multiple choice, dropdown lists, tick contacts, rating scales, and grids (Alwiyah et al., 2013).

Figure 6. E-Module display

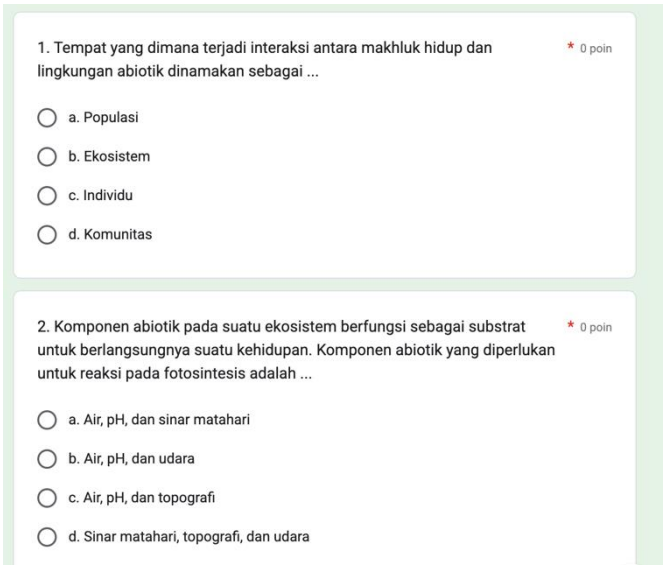


Figure 7. Google form display

Development

The development stage involves a series of stages to implement the product development that has been designed in the previous design stage, with the aim of producing learning resources that have been selected as well as validating their feasibility (Asrifaturofingah & Zamhari, 2024; Branch, 2010). At this stage, the researcher first compiled the ecosystem and environmental change materials based on the material concept, material preposition, ESD learning objectives and the latest learning outcomes. In this research, the ecosystem and environmental change materials are combined, which have implemented the new curriculum. The material presented contains socioscientific gold mining issues related to the ecosystem around students and contains tasks that must be done with the aim of mastering concepts, as well as facilitating CTS, and students' AC. In addition to the material, researchers also provide interesting icons that are in harmony with the colors and themes of ecosystem material, provide hyperlinks to news information sources contained in the e-module feature, hyperlink youtube videos containing gold mining environmental issues related to the material being taught, and complete the e-module opening, material content, and closing sections. After being developed, researchers converted the finished e-module design results to flipbook mode using an application that was integrated with Canva, namely heyzine flipbook. Heyzine Flipbook is a web platform that allows the conversion of PDF files into interactive digital forms such as magazines, flip books, or brochures. E-modules are developed through Canva to design learning materials, then uploaded to Heyzine Flipbook for dynamic access. Teachers can design e-modules independently by utilizing Heyzine's interface features that mimic the experience of opening a physical book page. The platform also provides music, video and animation integration to enhance interactivity. Students can access the e-modules at any time through a link shared by the teacher, free of charge and compatible with mobile devices (Auwaliyah et al., 2023; Putri & Annas, 2024).

After that, the e-module that has been designed and developed then goes through a validation process to ensure and assess the quality of content and design. The validation

process involves expert lecturers through an instrument of expert validation sheet, where the validation test is carried out by experts to obtain input, recommendations, and assess the product. The results of the validation are the basis for determining whether the product needs to be revised or has met the eligibility criteria (Alfatia et al., 2025; Puspita et al., 2021). In this section, researchers divide the results and discussion of validation based on aspect criteria, namely; material aspects are presented in Table 4, material presentation aspects are presented in Table 6, linguistic aspects are presented in Table 8, and graphical aspects are presented in Table 9. The following are the results and explanations of the e-module validation.

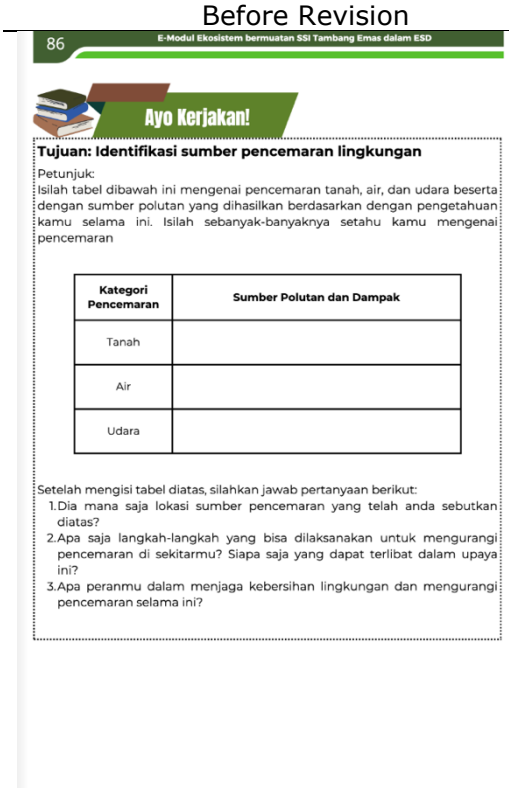
Tabel 4. Validation results on material aspects

No	Indicator	VA1	VA2	VA3	VA4	Maximum Value
1.	Suitability of learning material	30	30	31	31	32
2.	Independence in learning	10	11	11	11	12
3.	Suitability of the material with ESD concept	15	13	15	14	16
Total		56	54	57	56	60
Percentage		93.33	90	95	93.33	100
Average		3.73	3.6	3.8	3.73	4
Average Number				3.71		
Category				Highly valid		

Based on Table 4. Shows that there are 3 assessment indicators to validate the e-module on the material aspect, these indicators consist of; suitability of learning material, independence in learning, and suitability of material with ESD concepts contained in the e-module. The results of validation based on material aspects using 15 assessments obtained an average result of 3.71 with a highly valid category. This shows that in terms of the material contained in the e-module developed is good and in accordance with the existing curriculum. In terms of material, this e-module product has presented complete and informative content, is able to achieve learning objectives without causing misperceptions, interesting presentation, easy to understand, and relevant to the learning context (Ferella et al., 2025)

Although the e-module was validated as highly valid, the validators provided input suggestions to add content on the differences between legal and illegal gold mining. This aims to give students a clear understanding of the main distinctions and foster critical thinking. The key difference between illegal and legal mining lies in licensing status and legal compliance. Illegal mining operates without official permits from the central or local government, thus failing to meet environmental standards (Mambi et al., 2023). Improvement suggestions regarding the design before and after revisions were implemented and labeled with ESD pillars (environmental, economic, and social) due to their interrelation. The results of the e-module development based on the material aspect are presented in Table 5.

Table 5. The results of e-module development based on suggestions and input from validators on material aspects

Before Revision	After Revision
	
Before discussing in more detail about the types of environmental pollution, students are asked to do the task of identifying the types of pollution along with the sources of pollutants and their impacts.	Before discussing details about types of environmental pollution, after students work on the task of identifying types of pollution along with the sources of pollutants and their impacts, students are provided with additional information through the ecoscope feature regarding the differences between legal and illegal mining.

Then, the results of validation on the aspect of presentation of material based on the validator's assessment in Table 6 show an average amount of 3.72 in highly valid category, this is assessed based on 3 indicators, namely, systematic presentation, presentation of material, and supporting presentation with 12 assessments. E-modules are considered feasible in presentation because the material is arranged in stages from easy to difficult, as well as encouraging student learning independence through tasks or questions designed to be completed independently (Manzil et al., 2022). In addition to assignments that can be accessed to provide further understanding, and facilitate CTS and the ability to anticipate learners. The researcher provided youtube hyperlinks to provide learners with additional materials and visualizations that are relevant to the issue at hand. The use of videos in learning is proven to be effective in increasing students' interest and motivation to learn, as well as creating a fun learning atmosphere. The presence of visual content in videos facilitates student understanding because concepts can be illustrated concretely, and strengthens interactivity. e-modules need to be equipped with a combination of multimedia such as video, audio, and animation that complement each

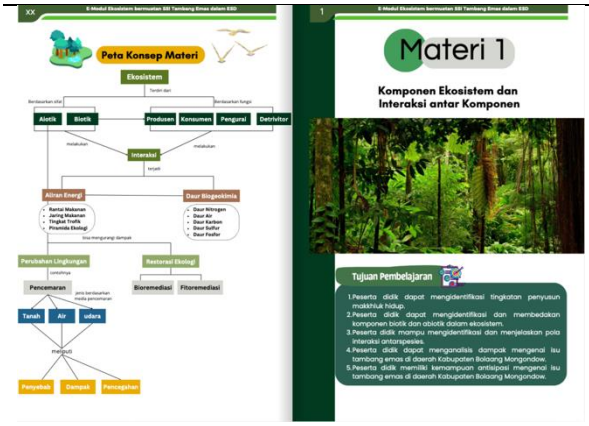
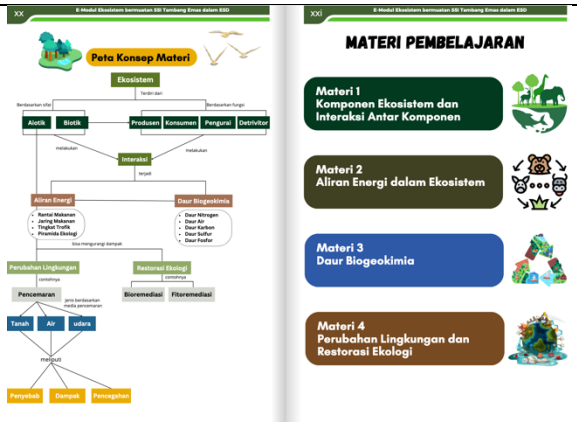
other, so that the learning experience of students becomes more dynamic and holistic (Fadilla et al., 2023; Sania, Yeni, 2021).

Table 6. Validation results on materia presentation aspects

No	Indicator	VA1	VA2	VA3	VA4	Maximum Value
1.	Systematics of presentation	15	14	16	16	16
2.	Material Presentation	15	14	15	14	16
3.	Presentation Support	16	15	14	15	16
Total		46	43	45	45	48
Percentage		95.83	89.58	93.75	93.75	100
Average		3.83	3.58	3.75	3.75	4
Average Number				3.72		
Category				Sangat Valid		

The validators provided input and suggestions on the material presentation aspect, spesifically recommending the addition of hyperlinks button divided according to the number of learning sessions or materials in the e-module. This allows students in subsequent sessions or material to directly click these hyperlink buttons, facilitationg navigation to the content they need to study. In addition to navigation, the validators suggested that the presentation of image sources should include the web domain of images taken from the internet and properly cites these sources. Below, Table 7 presents the e-modul development result for the material presentation aspect based on the validators' feedback.

Table 7. Results of e-module development based on validators' suggestion for the material presentation aspect

Before Revision	After Revision
	
A concept map included, which directly links to material 1.	A concept map provided, along with an added material menu that functions as a hyperlink for navigating to the target material.


127 E-Modul Ekosistem bermuatan SSI Tambang Emas dalam ESD

C. Restorasi Ekologi dan Penanggulangan

a.) Restorasi Ekologi

Kalian sudah tahu bahwa penggundulan hutan merupakan salah satu aktivitas manusia yang sangat merugikan dengan berbagai peruntukkan salah satunya tambang. Perhaatikan gambar 4.30 (a) dan (b), hutan taman nasional di Bolaang Mongondow yaitu Taman Nasional Bogani Nani Wartabone (TNBNW) telah rusak atau terdegradasi karena aktivitas PETI. Hal ini mempengaruhi terhadap ekosistem yang disana. Di tengah tantangan besar yang dihadapi lingkungan kita, seperti pencemaran yang diakibatkan oleh aktivitas industri dan pertambangan, restorasi muncul sebagai solusi penting untuk memulihkan keseimbangan alam. Sebagai generasi muda, kita memiliki tanggung jawab untuk memahami bagaimana proses ini dapat membantu mengatasi kerusakan yang telah terjadi dan melindungi ekosistem yang masih ada. Mari kita eksplorasi bersama konsep restorasi ekologi dan bagaimana upaya ini dapat menjadi langkah yang bisa kita lakukan dalam mengurangi dampak pencemaran lingkungan, serta menciptakan masa depan yang lebih berkelanjutan bagi lingkungan dan Bumi kita.

Sumber: PPID.MenLHK
Gambar 4.31 (a) Kerusakan Kawasan TNBNW Akibat PETI

Sumber: PPID.MenLHK
Gambar 4.31 (b) Kerusakan Kawasan TNBNW Akibat PETI

In the image, image sources taken from the internet do not include the web domain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a.) Restorasi Ekologi

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Sumber: PPID.MenLHK (ppid.menlhk.go.id)
Gambar 4.32 (a) Kerusakan Kawasan TNBNW Akibat PETI

Gambar 4.32 (b) Kerusakan Kawasan TNBNW Akibat PETI

In the image, image sources taken from the internet include the basic web domain, so the full web domain can be accessed through the image source section in the e-module

The electronic module is equipped with interactive links (hyperlink) and structured navigation to facilitate users in exploring learning materials, whether currently being studied, upacoming materials, or reviewing previous content. This feature not only enhances the efficiency of module usage but also facilitates quick access and distribution of research material to students or respondents without technical constraints (Laksita et al., 2024; Lastari et al., 2021). This is emphasized by Qotimah dan Mulyadi (2021), stating that the ideal e-module should be designed to spark student interest, facilitate understanding of material according to learning difficulty levels, and be equipped with an intuitive navigation system so user can explore content easily and in a guided manner.

Additionally, based on Table 8, the expert validation results for the linguistic aspect show an average score of 3.77, categorized as highly valid. The assessment is based on language use and user interaction, with a total of 8 assessment criteria. The linguistic aspect of this e-module refers to the appropriateness of font usage, proper Indonesian grammar, and sentence effectiveness. This relates to the use of language in interacting with students through the e-module, encouraging and inviting them to think and reason, especially in the context of daily life. The language adheres to linguistic rules, is logically structured, and is communicative. The communicative aspect is realized through the selection of words and sentence structures that align with language communication functions, ensuring the material is easily understood by readers (Asri & Dwiningsih, 2022; Yulianti et al., 2018)

Table 8. Validation results on the linguistic aspect

No	Indicator	VA1	VA2	VA3	VA4	Maximum Value
1.	Language use	16	15	16	14	16
2.	Interaction with users	15	14	16	15	16
Total		31	29	32	29	32
Percentage		96.87	90.62	100	3.62	100
Average		3.87	3.62	4	3.62	4
Average Number				3.77		
Category				Highly valid		

Finally, the e-module assessment is based on the graphical aspect. The expert validation results in Table 9 show an average assessment score of 3.79, categorized as highly valid. The assessment indicators for the graphical aspect include the e-module's size, cover design, and content design, with a total of 15 validator assessments. According to Kemdikbud (2017) the graphical aspect refers to visual design that balances aesthetics and functionality to enhance material clarity and appeal, covering book size, layout, color selection, typography (font type and size), and illustrations presented in the book. By incorporating these elements in the graphical aspect, the e-module not only becomes more visually appealing but also improves readability, information clarity, and suitability for readers' psychological and educational needs.

Table 9. Validation results on the graphical aspect

No	Indicator	VA1	VA2	VA3	VA4	Maximum Value
1.	E-module size	8	8	7	7	8
2.	E-module cover design	19	19	20	19	20
3.	E-modul content design	30	30	31	30	32
Total		57	57	58	56	60
Percentage		95	95	96.66	93.33	100
Average		3.8	3.8	3.86	3.73	4
Average Number				3.79		
Category				Highly valid		

In general, the development stage has been implemented by validating the e-module product with expert validators for assessment. The validators provided suggestions and inputs to help improve the developed e-module based on content aspects, presentation of content, linguistic aspects, and graphical aspects. The results indicate that all aspects meet the criteria and are positive with a highly valid category. Thus, the developed e-module can be declared suitable for use in the next stage to measure the effectiveness of utilizing this e-module properly.

Implementation

The implementation phase in the ADDIE model aims to ensure the learning environment is ready for use and students are actively engaged in the learning process. At this stage, the ADDIE model typically integrates summative evaluation to measure learning achievements while applying learning strategies that encourage practical application of the material (Branch, 2010). In this study, the implementation phase was not conducted because the objective of this research is to produce an e-module product containing socio-scientific issues of gold mining in ESD and to test the content validity of the developed e-module.

Evaluation

The evaluation stage in this research includes assessments of the product development process, conducted through formative evaluation (during development) and summative evaluation (after development is completed) (Agitsna et al., 2019). The evaluation is integrated into each phase of the ADDIE model – Analysis, design, development, and implementation as illustrated in Figure 1. This comprehensive evaluation at every stage ensures the final product aligns with the development process and achieves optimal results (Adesfiana et al., 2022). In the ADDIE framework, evaluation serves as a quality control mechanism to bridge the gap between planning (design) and the final product. This ensures that the learning resources developed are not only engaging but also relevant and functional (Branch, 2010). The validation results of the socio scientific issue based e-module on gold mining within ESD are categorized as highly valid and appropriate, based on the development process and validation by expert lectures. The learning media, designied by linking teaching materials to real-world problem contexts, not only enhances students' contextual understanding but also trains their ability to connect theory with actual situations. Additionaly, the integration of technology in the learning media enables the presentation of complex material in a more visual and interactive manner, facilitating comprehension and stimulating constructive feedback from students. Another advantage of technology-based media is its flexible accessibility, particularly for students unable to attend in-person classes (Maziyah & Pangestuti, 2021).

Final Product Description

This development research produced a product in the form of an e-module containing socio-scientific issues of gold mining in ESD, generated using the Canva application and converted into a heyzine flipbook. The final product output can be accessed via the following link: https://heyzine.com/flip-book/d3f132f949.html . In general, the e-module comprises components presented in Table.

Table 10. E-Module components

E-Module components	
Beginning	Front cover, cover page, preface, learning outcome, pancasila student profile, learning objectives, table of contents, list of figures, list of videos. E-module description, e-module usage guidelines, e-module features, introduction (regarding ESD and SDG 15), critical thinking skills variable and aniticpatory competency, concept map of the material, learning material navigation.
Content	Maerials 1 to 4 (includes tasks, ecoscope feature, T.R.A.C.E [facilitation CTS], AnEcSight [facilitation AC], Bolmong info, competency test for each material, and reflection space)
End	Glossary, bibliography, image sources, authors' biodata, supervising lecturer's biodata, back cover page, and back cover.

This e-module contains socio-scientific issues of gold mining in ESD, presenting environmental issues caused by gold mining operations, particularly illegal gold mining. The e-module includes features designed to facilitate students' CTS and AC. One feature is **T.R.A.C.E (Think, Reflecting, and Acting for the Change Ecosystem)**, which provides information, news, and questions for students to solve, aiming to foster CTS. The indicators used to facilitate critical thinking skills, based on Ennis (1986) on (Costa, 1986) consist of 5 indicators: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. These indicators are embedded in the questions within the T.R.A.C.E feature Another feature, **AnEcSight (Anticipatory Ecosystem**

Insight), presents information and a questionnaire test to assess students' AC. Each feature includes an ESD label that categorizes the information content according to the pillars of ESD: environment, social, and economy. Students' AC are facilitated through this feature using Unesco (2017) indicators, which comprise 5 indicators: the abilities to (1) understand and evaluate multiple futures—possible, probable, and desirable, (2) create one's own visions for the future, (3) apply the precautionary principle, (4) assess the consequences of actions, and (5) deal with risks and changes. The finalized layout of the developed e-module is displayed in Figure 8 to Figure 12.

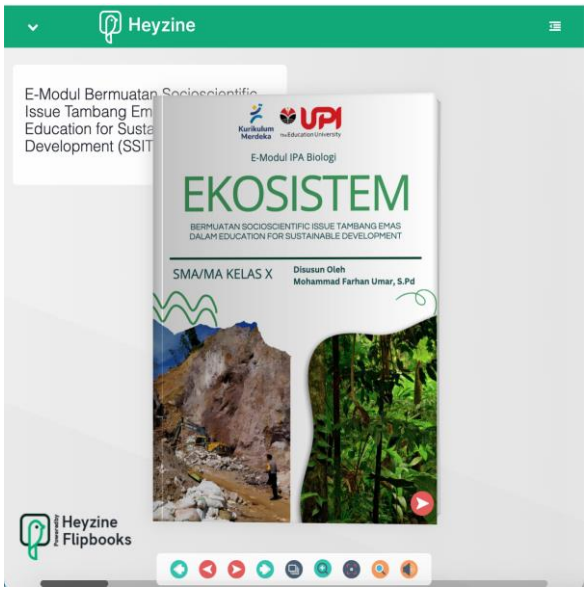

Figure 8. E-module display on the heyzine flipbook platform

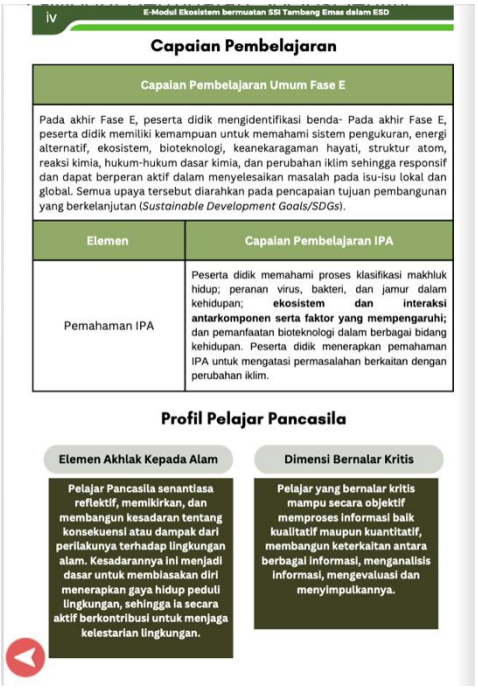

Figure 9. Learning outcomes and pancasila student profile

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Pendahuluan

Mengenai ESD

Agenda 2030 untuk Pembangunan Berkelanjutan (the 2030 Agenda *for Sustainable Development* atau SDGs) adalah kesepakatan pembangunan baru yang mendorong perubahan-perubahan yang bergeser ke arah pembangunan berkelanjutan yang berdasarkan hak asasi manusia dan kesetaraan untuk mendorong pembangunan sosial, ekonomi dan lingkungan hidup. SDGs akan dilaksanakan berdasarkan prinsip universal, yang menyeluruh dan terdiri dari 17 tujuan yang bisa kalian lihat pada gambar dibawah:

Sumber: Bappenas, 2020

Pendidikan untuk pembangunan berkelanjutan atau education for sustainable development (ESD), adalah cara untuk mendapatkan pendidikan berkualitas tinggi yang memungkinkan transisi menuju pembangunan berkelanjutan dengan menyeimbangkan aspek, sosial, dan ekonomi Pembangunan (Barth, 2016). Ketika kehidupan berkembang, terutama dalam hal teknologi, masalah yang kita hadapi semakin kompleks. Oleh karena itu, dunia pendidikan harus mempelajari kemampuan yang penting dalam lingkungan yang kompleks dan berkelanjutan (Novidsa et al., 2021).

Figure 9. Display of ESD explanation

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SDGs 15: *Life on Land* (Ekosistem Darat)

PPB memungkinkan semua individu untuk berkontribusi dalam mencapai SDGs dengan membekali mereka dengan pengetahuan dan kompetensi yang mereka butuhkan, tidak hanya untuk memahami apa yang dimaksud dengan SDGs, tetapi juga untuk terlibat sebagai warga negara yang terinformasi dalam mewujudkan perubahan yang diperlukan (UNESCO, 2017). Pada e-modul ini menekankan pada SDG'15 yaitu ekosistem darat. materi atau topik bahasan yang bisa dikaitkan pada pembelajaran yang berhubungan dengan SDG-15 menurut (UNESCO, 2017) adalah sebagai berikut:

- Ekologi: kompetisi, mangsa-pemangsa, dinamika komunitas, aliran energi melalui jaring-jaring makanan, penyebaran dan jelajah. Ekosistem spesifik - ekosistem asli lokal dan global serta ekosistem buatan manusia, misalnya hutan tanaman industri yang dikelola.
- Ancaman terhadap keanekaragaman hayati: hilangnya habitat, deforestasi, fragmentasi, spesies invasif, dan eksploitasi berlebihan (yang disebabkan oleh praktik produksi dan konsumsi yang tidak berkelanjutan, teknologi yang tidak berkelanjutan, dan lain-lain)
- Perubahan iklim dan keanekaragaman hayati, ekosistem sebagai penyerap karbon, pengurangan risiko bencana dan ekosistem (ekosistem sebagai penghalang alami terhadap bahaya alam)
- Tanah dan pembentukan serta strukturnya
- Penggurunan, deforestasi dan upaya untuk menanggulanginya.

Berikut ini *learning obejctives* menurut (UNESCO, 2017) yang diharapkan ketika peserta didik belajar menggunakan e-modul bermuatan ESD ini terkait dengan SDG-15 berikut:

Cognitive learning objectives	1. Peserta didik memahami ekologi dasar dengan mengacu pada ekosistem lokal dan global. 2. Peserta didik memahami berbagai ancaman yang mengancam keanekaragaman hayati, termasuk hilangnya habitat, deforestasi, fragmentasi, eksploitasi berlebihan, dan spesies invasif, serta dapat mengaitkan ancaman-ancaman tersebut dengan keanekaragaman hayati setempat. 3. Peserta didik memahami lambatnya regenerasi tanah dan berbagai ancaman yang merusak dan menghilangkan tanah lebih cepat daripada kemampuannya untuk memulihkan diri, seperti praktik pertanian atau kehutanan yang buruk.

Figure 10. Display of SDG 15 explanation and learning objectives

Figure 11. Display of the T.R.A.C.E feature to facilitate CTS

Figure 12. Display of the AnEcSight feature to facilitate AC

Conclusion

Based on the research and discussion, the e-module containing SSI of gold mining in ESD has been validated as an effective and valid electronic teaching material to facilitate students' CTS and AC. This validation is based on assessments of the material aspects, material presentation, linguistic aspects, and graphical aspects. The development model in this research uses ADDIE, focusing on the development stage, with the implementation phase not conducted. The development process utilizes the Canva application as the e-module design platform and heyzine flipbook to convert the Canva design results into a digital book accessible to both students and teachers. The expert validation results show material aspect with an average of 3.71 (highly valid), material presentation aspect with an average score of 3.72 (highly valid), linguistic aspect with an average score 3.77 (highly valid), and graphical aspect with an average score of 3.79 (highly valid). Overall, the developed e-module is valid for use. Further research is required to test the effectiveness of the e-module.

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