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Development of socio-scientific issue based reproduction e-module to enhance critical thinking skill

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ABSTRACT

This research focuses on the development of an e-module integrating the Socio-Scientific Issues (SSI) approach in teaching human reproductive system material to enhance critical thinking skills among 11th-grade students at SMAS Cerdas Murni. The study was motivated by the low level of students' critical thinking skills, the predominance of conventional teacher-centered methods, and the lack of interactive and contextual learning materials that can connect concepts to real-life issues. The research employed a Research and Development (R&D) design with the 4D model (Define, Design, Develop, and Disseminate). The scope was limited to the development stage due to time and budget constraints. The developed SSI-based e-module was validated by subject matter experts, yielding a feasibility score of 96.43%, and by media experts, yielding a score of 95.31%, both categorized as "highly feasible." Practicality testing by biology teachers and students resulted in percentages of 96.67% and 95.33%, respectively, indicating the e-module is "very practical" for classroom use. Effectiveness was measured through an N-Gain analysis, producing a score of 0.80, which falls into the "high" category and demonstrates a significant improvement in students' critical thinking skills. These findings indicate that the SSI-based e-module is feasible, practical, and effective in supporting the development of critical thinking skills, providing an innovative and engaging alternative to conventional biology teaching on the human reproductive system. The module has potential for broader implementation in senior high school biology learning.

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Keywords
Critical thinking, E-module, Human reproductive system, Socio-scientific issues (SSI)

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INTRODUCTION

In today's era of globalization, rapid technological advancements are profoundly influencing various aspects of life, particularly the field of education (Nurmaulidina, Astuti, & Dasmo, 2022). These developments demand that education continuously adapts to change to produce graduates who are not only academically successful but also equipped with skills aligned with future workforce demands (Bayley, 2022). However, each individual has a different level of adaptability when facing such dynamic transformations. Therefore, an educational approach is needed that supports comprehensive and sustainable mastery of science and technology. One relevant and

implementable approach is 21st-century learning, which emphasizes the integration of knowledge, skills, and attitudes as a foundation for developing resilient, adaptive, and globally competitive learners (Amin et al., 2022).

According to the Partnership for 21st Century Skills (P21), four essential skills must be developed to meet the demands of the 21st century: critical thinking, communication, creativity, and collaboration. Among these, critical thinking stands out as a fundamental skill that should be emphasized, alongside the other three, because it enables students to understand, analyze, and evaluate information deeply before making decisions (Sanjaya et al., 2021; Halimah et al., 2023). Critical thinking involves a series of cognitive activities such as analyzing, evaluating, and judging information to support sound decision-making. Nevertheless, a substantial body of research indicates that Indonesian students still exhibit limited critical thinking abilities.

The 2022 Programme for International Student Assessment (PISA) revealed that Indonesian students scored 359 in literacy, which is significantly below the OECD average of 476. Although PISA focuses on literacy, the data also provides insight into students' critical thinking abilities. Rahayuni (2016) have confirmed a strong positive correlation between critical thinking skills and science literacy: the higher a student's critical thinking ability, the greater their achievement in science literacy. Consequently, low levels of science literacy can be attributed to deficiencies in critical thinking skills, underscoring the urgency for schools to prioritize the development of these abilities as a core 21st-century competency.

Classroom observations during biology lessons at SMAS Cerdas Murni, carried out in collaboration with the biology teacher, revealed that students still possess low levels of critical thinking skills. One contributing factor is the predominance of teacher-centered learning methods. Teachers tend to dominate classroom discourse without providing sufficient opportunities for students to think actively or engage meaningfully in the learning process. Additionally, the learning process lacks media or instructional materials that can support in-depth and meaningful understanding. Teachers primarily rely on textbooks and student worksheets (LKS), which are considered insufficient to address students' learning needs fully. These materials often present lengthy narrative texts with minimal visual elements, making it difficult for students to grasp the content. As a result, learning becomes monotonous, student motivation decreases, and their critical thinking skills remain underdeveloped. Therefore, there is a need for more interactive, visual, and contextually relevant teaching materials to enhance students' critical thinking.

E-modules are considered practical instructional tools for supporting the development of students' critical thinking skills (Naj'iyah et al., 2020). E-modules are digital adaptations of printed modules that integrate technology to enhance the quality and efficiency of learning (Marta, 2019). A key advantage of e-modules is their interactivity, as they incorporate multimedia elements such as images, videos, animations, and audio to support the learning process. Their interactive features also allow students to perform self-evaluations using quizzes and practice exercises (Nisa et al., 2020; Fujiarti et al., 2024). Furthermore, the ease of access provided by e-modules—available anytime and anywhere through digital devices such as smartphones, laptops, and computers—adds to their practicality (Wahyuningtyas & Sulasmono, 2020). With dynamic visuals and well-structured content, e-modules can enhance students' interest in learning, foster independent study,

and deepen their understanding of the subject matter (Lutfi et al., 2019). Thus, e-module development is seen as an effective solution to address students' weak critical thinking skills.

As digital teaching materials, e-modules offer significant benefits to students and grant educators the flexibility to implement more creative instructional methods beyond conventional approaches (Sapriyah, 2019). With interactive features and visually engaging presentations, e-modules promote active student participation during lessons, which may enhance their critical thinking skills more effectively. However, the use of e-modules has not been maximized in classroom practice. Many teachers still rely on printed textbooks and static worksheets that lack appeal and fail to sufficiently stimulate critical thinking (Susanti et al., 2021). This highlights the importance of utilizing well-designed e-modules—those that are not only rich in content but also interactive, contextual, and aligned with the characteristics of 21st-century learning. Optimally developed e-modules can serve as engaging and meaningful learning media that contribute significantly to improving students' critical thinking.

The human reproductive system is a central topic in biology that is closely related to students' real-life experiences. This topic covers not only anatomy and physiology but also addresses health and social issues that directly affect students' development. However, the subject is often considered sensitive and challenging to discuss openly in class, leading to shallow content delivery and a lack of student engagement in critical thinking. To address this issue, a more contextual and engaging approach is needed—one that connects the material to students' real-life experiences. The Socio-Scientific Issues (SSI) approach is recognized as effective for improving students' critical thinking skills. It combines social problems with scientific concepts as the basis for learning, prompting students to think analytically and reflectively. Through SSI, students are trained to evaluate real-world issues and make decisions based on valid and accountable scientific data. The effectiveness of this approach has been demonstrated in a study by Diyyah (2022), which showed that SSI-based biology instruction significantly improved students' critical thinking skills, particularly in the topic of the human reproductive system among Grade XI students at SMAN 5 Cirebon.

The Socio-Scientific Issues (SSI) approach integrates science-based social issues into the learning process to strengthen students' intellectual, moral, and ethical competencies. SSI-based learning often involves controversial topics that generate diverse opinions in society (El Arbid & Tairab, 2020). By connecting science concepts to real-life social issues, this approach enhances students' critical thinking through activities such as analysis, evaluation, and decision-making about authentic problems (Rahmawati, 2018; Pitpiorntapin & Topcu, 2016). SSI-based instruction makes science learning more meaningful, as it is grounded in current issues relevant to students' lives (Taufik et al., 2022). Various studies have confirmed that students show improved critical thinking skills after engaging in SSI-based learning involving discussion, argumentation, and problem-solving based on scientific evidence. Other studies have also supported these findings, highlighting the significant impact of SSI in enhancing students' critical thinking (Nida et al., 2021; Pratiwi et al., 2021; Solbes et al., 2018). Therefore, combining e-modules with the Socio-Scientific Issues (SSI) approach is a relevant and effective strategy to deliver contextual, engaging learning while optimizing the development of students' critical thinking skills.

Several previous studies have explored the development of SSI-based e-modules across various learning topics. For example, Kamaruddin et al. (2021) reported that an SSI-based e-module developed using Flip PDF Corporate Edition was found to be valid and practical for classroom use. Likewise, a study by Septiningrum et al. (2021) on virus-related materials confirmed the high validity, practicality, and effectiveness of SSI-based teaching materials in enhancing high school students' critical thinking. Another study by Fadilah and Ariyanti (2024) developed an SSI-based e-module on the excretory system and found significant improvements in both cognitive and critical thinking domains. However, research specifically focusing on the development of SSI-based e-modules for the human reproductive system remains limited. This topic has strong relevance to a range of socio-scientific issues such as reproductive health, reproductive technology ethics, and social concerns like premarital sex and early marriage, all of which are ideal for SSI-based learning contexts. Through these issues, students can be trained to think critically and reflectively about real-life challenges in their environment.

Based on the problems mentioned above, this study aims to develop a Socio-Scientific Issues (SSI)-based e-module specifically on the human reproductive system material to improve the critical thinking skills of students at SMAS Cerdas Murni.

METHOD

The Research and Development (R&D) approach was employed in this study, focusing on the process of product development and the assessment of its effectiveness (Sugiyono, 2017). The e-module serves as a digital-based instructional material and constitutes the primary product designed in this research. As a framework for the development process, the study adopted the 4D model proposed by Thiagarajan et al. (1974), which consists of four main stages: define, design, develop, and disseminate. This research was conducted at SMAS Cerdas Murni, located at Jl. Beringin No. 33, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra Province, Indonesia.

The evaluation instruments in this study were designed to measure the validity, practicality, and effectiveness of the Socio-Scientific Issues (SSI)-based e-module. The validity instruments consisted of two evaluation sheets, one completed by a content expert and the other by a media expert. The content expert evaluated content feasibility, language clarity, material presentation, and the integration of SSI elements, while the media expert assessed graphic design, multimedia and language usage, and interactivity. Each instrument contained approximately 28–30 items, with 4–6 items per aspect. The practicality instruments included response questionnaires for teachers and students, focusing on visual appeal, ease of use, engagement, and contextual relevance. Effectiveness was measured using five essay questions developed based on Facione's (2015) critical thinking indicators: interpretation, analysis, evaluation, inference, and explanation. All instruments used a four-point Likert scale and were developed regarding Riduwan & Akdon (2010) and Facione (2015).

The stages of research using the 4D development model are described as follows:

1. Define Stage

The define stage aims to identify the learning process needs and gather essential information to serve as the foundation for designing the e-module. Several steps are carried out during this stage. First, a front-end analysis is conducted through interviews with biology teachers to understand the direction of e-module development, including a review of the curriculum in use, types of teaching materials applied, and the learning methods implemented in the classroom. Second, a learner analysis is conducted through student needs questionnaires to explore student preferences and the obstacles they face during the learning process. Third, a concept analysis is performed to identify challenging material and determine the key concepts to be included in the e-module systematically and in alignment with the learning topic. Fourth, a task analysis is carried out to design learning objectives and structure the learning activities in the e-module based on the Socio-Scientific Issues (SSI) approach, aiming to support the development of students' critical thinking skills. Finally, instructional goals are specified based on the results of the concept and task analyses and aligned with the Learning Outcomes (Capaian Pembelajaran/CP) as outlined in the Regulation of the Minister of Education, Culture, Research, and Technology No. 262/M/2022 on the Merdeka Curriculum.

2. Design Stage

The design stage is a crucial process focused on drafting the product based on the analysis results from the previous phase. Several core activities are undertaken during this stage. First, assessment instruments are developed to evaluate the quality of the e-module, covering aspects of validity, practicality, and effectiveness. In this study, the instruments used include evaluation sheets completed by experts (validators), response questionnaires from teachers and students, as well as test blueprints to measure product effectiveness. Second, appropriate instructional media are selected by considering their alignment with learning objectives and student characteristics to support the creation of an effective and optimal learning process. Third, the format of the e-module is determined, including visual design, content structure, and material presentation that is engaging and communicative. The final step involves designing the initial prototype of the e-module, which includes core components such as learning objectives, material explanations, summaries, evaluation questions, a glossary, and a bibliography.

3. Development Stage

The development stage aims to create and refine the e-module. This stage includes several activities, beginning with expert validation to assess the feasibility of the e-module in terms of both content and media aspects. Following validation, data are collected through response questionnaires completed by teachers and students to evaluate the practicality of the e-module in the learning process. Additionally, students are administered a pre-test and a post-test as instruments to measure the effectiveness of the e-module in enhancing critical thinking skills.

4. Dissemination Stage

The dissemination stage is intended to introduce and implement the revised e-module on a broader scale to evaluate its usage effectiveness. However, this study is limited to the development stage due to time and budget constraints.

This research was conducted at SMA Cerdas Murni, involving 27 students from Class XI IPAS-2 as the research subjects. The instruments used in the study comprise several parts. During the needs analysis stage, interview sheets for teachers and questionnaires for students were used to identify instructional needs. To assess the validity of the e-module, evaluation sheets were completed by content and media experts to determine its feasibility in terms of content and presentation. Meanwhile, to measure the practicality of the e-module, response questionnaires were distributed to teachers and students as direct users of the developed e-module. The effectiveness of the e-module was assessed using critical thinking essay questions. These essay questions, designed to assess critical thinking skills, were developed based on the indicators proposed by Facione (2015) and completed individually by students.

All data obtained from validation sheets and response questionnaires completed by teachers and students were analyzed using a four-point Likert scale to assess the feasibility and practicality of the developed e-module. The assessment of the e-module's quality was also conducted using the Likert scale, with the rating criteria presented in Table 1 below:

Table 1. Guidelines for likert scale assessment

Score	Assessment Criteria
1	Very Poor
2	Poor
3	Good
4	Verry Good

(Sugiyono, 2017)

The validity of the e-module was quantitatively assessed based on scores provided by experts using a Likert scale ranging from 1 to 4, which reflects the quality of the e-module from "very poor" to "very good". The validation process involved two expert evaluators with respective competencies in instructional content and media development, who assessed the appropriateness and feasibility of the developed e-module. The average score was calculated from all assessments provided by the two validators. Subsequently, the score was analyzed to determine the validity level of the e-module using Formula 1 as a reference for calculating the percentage of feasibility.

$$\text{Percentage of Material/Media Validation} = \frac{\sum \text{obtained score}}{\sum \text{maximum score}} \text{ x } 100\% \quad \text{(Formula 1)}$$

After the calculation was carried out using the predetermined formula, the resulting percentage of validation was then matched against the feasibility criteria presented in Table 2. These criteria serve as a reference for interpreting the validity level of the e-module, based on evaluations provided by the validators. Through this comparison, it can be determined whether the developed e-module meets the classification of being *very valid*, *valid*, *fairly valid*, or *not valid* for instructional use.

The analysis of the practicality of the Socio-Scientific Issues (SSI)-based e-module was conducted by referring to the responses of both teachers and student Scientific names of species (incl. subspecies, variety, etc.) should be written in italic, except for italic sentence. Scientific name (genera, species, author), and cultivar or strain should be mentioned completely for the first time mentioning it in the body text, especially for taxonomic manuscripts. Name of genera can be

shortened after first mentioning, except generating confusion. Name of the author can be eliminated after first mentioning. For example, *Rhizopus oryzae* L. UICC 524, hereinafter can be written as *R. oryzae* UICC 524. Using trivial name should be avoided, otherwise generating confusion. s after using the developed e-module. The collected response data were analyzed and calculated using Formula 2 to obtain the total score. Subsequently, the results were converted into a percentage using Formula 1 to determine the level of practicality of the e-module. The obtained percentage was then compared with predetermined practicality criteria to assess the appropriateness of the e-module for use in learning activities.

Table 2. Criteria for validity assessment results

Percentage (%)	Criteria
00-49	Not Valid
50-59	Fairly Valid
60-79	Valid
80-100	Highly valid

(source: Riduwan & Akdon, 2010)

$$S = \frac{\Sigma p}{\Sigma n} \text{ (Formula 2)}$$

Where S is the score per aspect, ΣP is the total score for each element, and Σn is the number of students.

After calculation using the predetermined formula, the practicality percentage of the e-module is obtained. This percentage is then matched against the practicality criteria in Table 3, which serves to evaluate the extent to which the Socio-Scientific Issues (SSI)-based e-module meets the practicality categories namely, very practical, practical, fairly practical, or impractical for use in the learning process.

Table 3. Criteria for assessing practicality results

Precentage (%)	Criteria
21-40	Not Practical
41-60	Fairly Practical
61-80	Practical
81-100	Highly Partical

(source: Riduwan & Akdon, 2010)

Meanwhile, the effectiveness of the e-module was evaluated based on students' test scores, specifically targeting indicators of critical thinking skills measured using a previously developed assessment instrument. The collected data were analyzed using the N-Gain formula (Formula 3), and the results were interpreted according to the criteria outlined in Table 4. This interpretation process aimed to determine whether there was any improvement or change in students' critical thinking abilities following the implementation of the e-module during the learning process.

$$\text{N-gain (\%)} = \frac{\text{(Postest Score} - \text{Pretest Score)}}{\text{(Maximum Score} - \text{Pretest Score)}} \text{ (Formula 3)}$$

Based on the N-Gain criteria, an N-Gain score greater than 0.7 indicates that the effectiveness of the e-module is categorized as high, suggesting that the e-module is highly effective

when applied in the learning process. Conversely, suppose the N-Gain score is less than 0.3. In that case, the effectiveness of the e-module is considered low, implying that revisions or improvements are necessary to enhance the module's ability to support the achievement of learning objectives more optimally.

Table 4. N-gain interpretation criteria

N-Gain	Criteria
g<0,3	Low
0,3<g<0,7	Moderate
g>0,7	High

(source: Nasution & Rasyidah, 2022)

RESULTS AND DISCUSSION

This research was conducted with a focus on developing an e-module based on Socio-Scientific Issues (SSI), particularly concerning the topic of the human reproductive system. The e-module was designed to be accessible through various digital devices such as smartphones, laptops, and desktop computers, thereby offering ease and flexibility in its use. The primary objective of this development was to support the improvement of students' critical thinking skills. The design of the e-module referred to the 4D development model, which includes the following stages: The initial stage of the research began with the definition phase. This phase aimed to identify the needs within the learning process and to gather the necessary information to inform product design. Activities carried out in this stage included problem analysis, analysis of student characteristics, learning materials, assigned tasks, and the formulation of learning objectives. Interviews with biology teachers revealed that although the school had implemented the Merdeka Curriculum, the learning process was still dominated by lecture methods with minimal use of discussion. While this method is considered efficient and easy to understand, it tends to reduce student engagement. Moreover, existing teaching materials were limited to worksheets and textbooks purchased individually by students. The topic of the human reproductive system is considered challenging for students due to its abstract, complex, and sensitive nature, making it difficult to discuss openly. This situation poses a challenge for teachers to deliver the content engagingly and effectively. The lack of variation in teaching methods and materials also contributed to low levels of student participation and critical thinking skills.

The subsequent stage involved analyzing the characteristics of the students. Based on the results of the needs questionnaire distributed to students, it was found that most of them lacked motivation to participate in biology lessons. This limitation was attributed to the scarcity of instructional materials, which were predominantly textbooks and worksheets presented in a theoretical manner, with minimal connection to real-life contexts. Furthermore, students' ability to comprehend and respond to the material varied, ultimately affecting their interest, attention, and enthusiasm during learning. This situation negatively impacted classroom participation and students' critical thinking abilities. Given these circumstances, the researchers developed an SSI-based e-module to link biology content to relevant social issues. Through this approach, it was expected that student engagement would increase, thereby fostering the development of critical thinking skills to their fullest potential.

Furthermore, the definition phase incorporated concept analysis, task analysis, and a comprehensive formulation of the learning objectives. The instructional content focused on the human reproductive system, covering six major subtopics: reproductive organs and their functions, reproductive hormones, the process of gametogenesis, the menstrual cycle, reproductive disorders, and reproductive technology. The learning objectives were formulated based on the learning outcomes outlined for Phase F in the Merdeka Curriculum. At this level, equivalent to Grade 11 in senior high school, students are expected to understand the structure and function of the human reproductive system, explain reproductive processes, and apply this knowledge in maintaining reproductive health responsibly. These outcomes reflect an orientation not only toward conceptual understanding but also contextual relevance, particularly in addressing adolescent challenges related to reproductive health (Permendikbudristek No. 262/M/2022).

The tasks presented in the e-module were designed to stimulate students' critical thinking through real-world contexts. For example, students were encouraged to analyze issues such as early marriage, adolescent obesity concerning polycystic ovary syndrome (PCOS), and to discuss reproductive technologies such as in vitro fertilization. All learning activities were designed to be carried out individually or in groups, with an emphasis on developing critical thinking skills. These activities included exploring various issues, constructing scientific arguments, and reflecting on the problems studied. Based on this analysis, the learning objectives of the e-module were formulated as follows: 1) Students can identify the structure and function of the organs that comprise the human reproductive system; 2) Students can explain the process of gametogenesis and the role of hormones in regulating the human reproductive system; 3) Students can analyze disorders or diseases of the reproductive system as well as the role of reproductive technology; and 4) Students can evaluate social and technological issues related to the reproductive system critically and responsibly.

In the design phase, the development of the e-module involved several key steps, including the preparation of assessment tools, media selection, format determination, and the creation of an initial draft. The assessment tools developed included validation questionnaires provided to experts to evaluate the content and design of the e-module. Additionally, response questionnaires were used to gather feedback from teachers and students regarding the module's practicality. To assess the effectiveness of the e-module in improving students' critical thinking skills, test blueprints were created for both pre-tests and post-tests. The e-module was chosen for development due to its flexible accessibility via various digital devices such as smartphones, laptops, or desktop computers. It provided content on the human reproductive system, supplemented with theoretical explanations, practice questions, and reflective assignments to facilitate comprehension and promote critical thinking development. At this stage, the module's design was also supported with a flowchart that served as a guide in the development process, as illustrated in Figure 2 (Syabrina & Sulistyowati, 2020).

The initial design was created as the first step in developing the e-module prototype. The design process made use of the *Canva* application, chosen for its diverse features and visually engaging templates that can be readily adapted to align with students' needs and characteristics. The e-module design refers to the previously constructed flowchart, emphasizing a balanced

composition of text, images, and interactive elements. Each page of the e-module is equipped with hyperlinks to facilitate navigation and enhance students' understanding of the material.

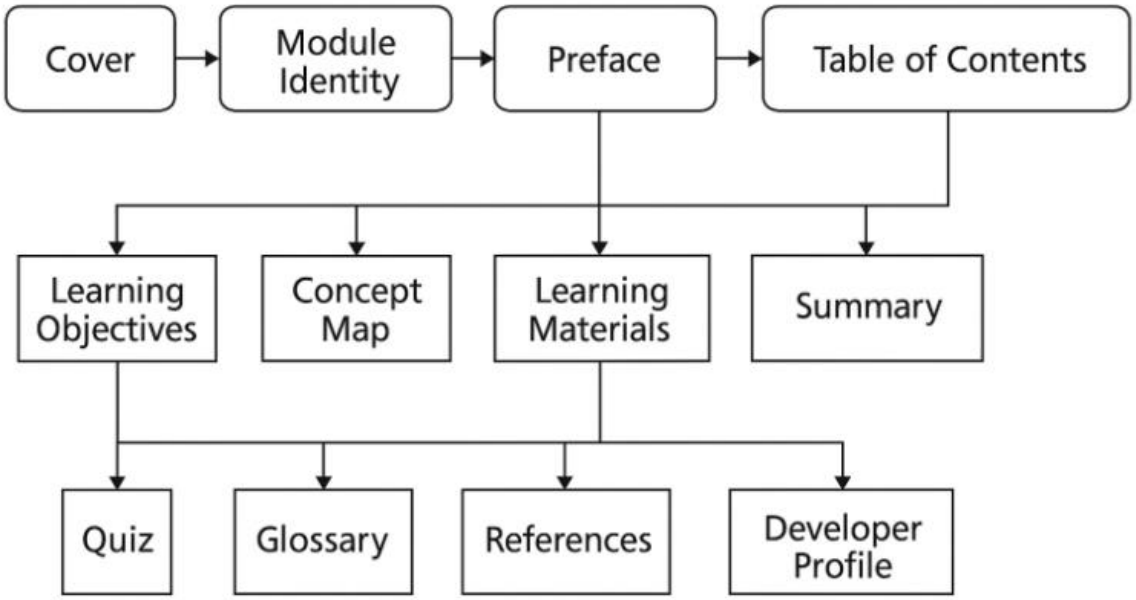


Figure 1. Flowchart of the e-module workflow

Upon completion of the design process, the e-module was transformed into an interactive digital format using the *Heyzine* platform. This platform was chosen because it supports cross-device accessibility, including computers, laptops, and smartphones (Humairah, 2022). By using *Heyzine*, the e-module was enriched with several interactive features, such as full screen display mode, zoom functionality for clarifying small content areas, embedded instructional videos for each sub-topic, and background audio to improve interactivity and student engagement. In addition, the page transition animation that resembles flipping a printed book provides a more engaging and realistic reading experience for students (Sari et al., 2023).

After the e-module was successfully developed, the next step was further refinement. At this stage, the validity and feasibility of the e-module were assessed by expert validators in both content and media presentation. The validation process aimed to evaluate whether the e-module met quality standards in terms of learning content and visual presentation. The assessment was carried out using a questionnaire instrument that covered several aspects, including content relevance, language clarity, presentation quality, and graphical elements.

The results of this process served as a reference for improving the e-module before its implementation in learning activities. The validation involved two validators, each representing content and media expertise. The detailed results of this validation process are presented in Table 5 and Ta Based on the data presented in Table 5, the subject matter expert validator assigned a score of 108 out of a maximum of 112, which corresponds to a percentage of 96.43%. This places the e-module in the "highly feasible" category, indicating a very high level of validity. The learning material has been comprehensively designed and is well integrated with the predetermined learning outcomes and objectives. This statement aligns with the perspective of Munandar and

Ahmad (2022), who emphasized that in the development of e-modules, the content should be structured sequentially, thoroughly, and aligned with the applicable curriculum standards. The e-module is also equipped with various visual elements such as images and videos, which serve to clarify concepts and simultaneously enhance students' critical thinking skills. The language used is communicative and easy to understand, thus facilitating active student engagement in the learning process.ble 6, which display the assessments for content and media validation, respectively.

Table 5. Results of content expert validation

Aspect	Score Obtained	Maximum Score	Precentage (%)	Criteria
Content Feasibility	42	44	95,45%	Highly Feasible
Material Presentation	0	20	100%	Highly Feasible
Language Usage	19	20	95%	Highly Feasible
Socio-scientific Issues (ssi)	27	28	96,43%	Highly Feasible
Avarage	**108**	**112**	**96,43%**	**Highly Feasible**

Furthermore, referring to the data in Table 6, the media expert validator assigned a score of 62 out of a maximum of 64, which is equivalent to a percentage of 95.31%. This also places the e-module in the "highly feasible" category and reflects a very high level of validity in supporting learning activities. This assessment indicates that the e-module interface has been attractively designed, with well-considered layout arrangements of each element, and possesses characteristics of flexibility and ease of use for users. These findings are supported by Amiyah and Hardiana (2024), who stated that students prefer e-modules that include interactive features such as videos and animations, as well as a high level of accessibility—being available anytime and anywhere. The validation results show that the e-module is highly feasible in terms of both content and media aspects; however, the experts have also provided improvement suggestions to enhance further the quality of the Socio-Scientific Issues (SSI)-based e-module, as illustrated in Figures 2, 3, 4, and 5.

Table 6. Results of media expert validation

Aspect	Score Obtained	Maximum Score	Precentage (%)	Criiteria
Graphics	26	28	92,86%	Very Appropriate
Multimedia and Language	23	24	95,83 %	Very Appropriate
Practicality & Usability	12	12	100 %	Very Appropriate
Average	**61**	**64**	**95,31%**	**Very Appropriate**



Figure 2. Display of the e-module cover page before revision (left) and after revision (right)

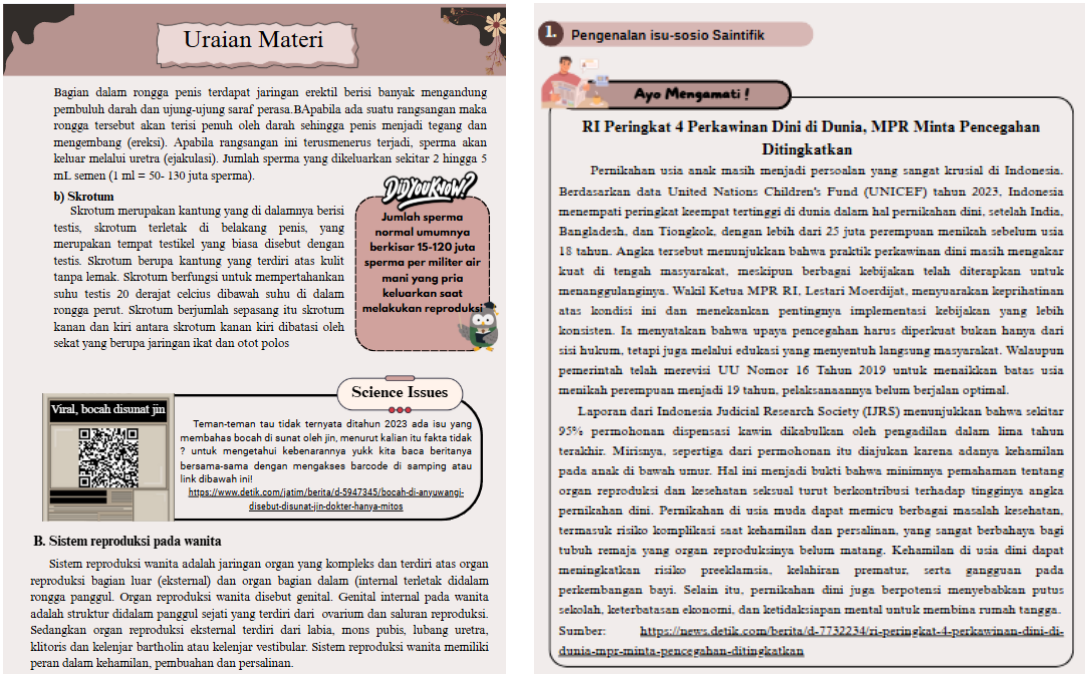


Figure 3. Display the image on the left shows the presentation of social issues in the e-module as a stimulus to build students' critical thinking skills through a biological context, while the image on the right is the "Let's Observe" activity which directs students to examine current issues such as early marriage as an introduction to socio-biological studies.

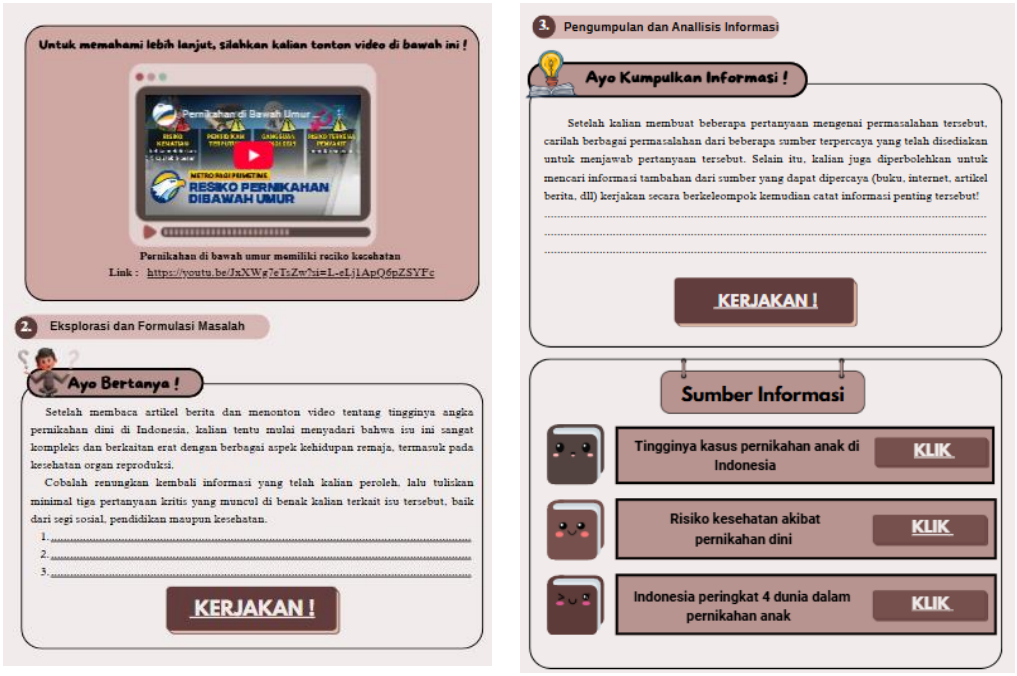


Figure 4. Display The image on the left is . The use of educational videos to strengthen students' understanding of social issues and their relationship to biology material, while the image on the right is . The "Let's Explore" activity encourages students to seek scientific information to deepen their understanding of the issues discussed.

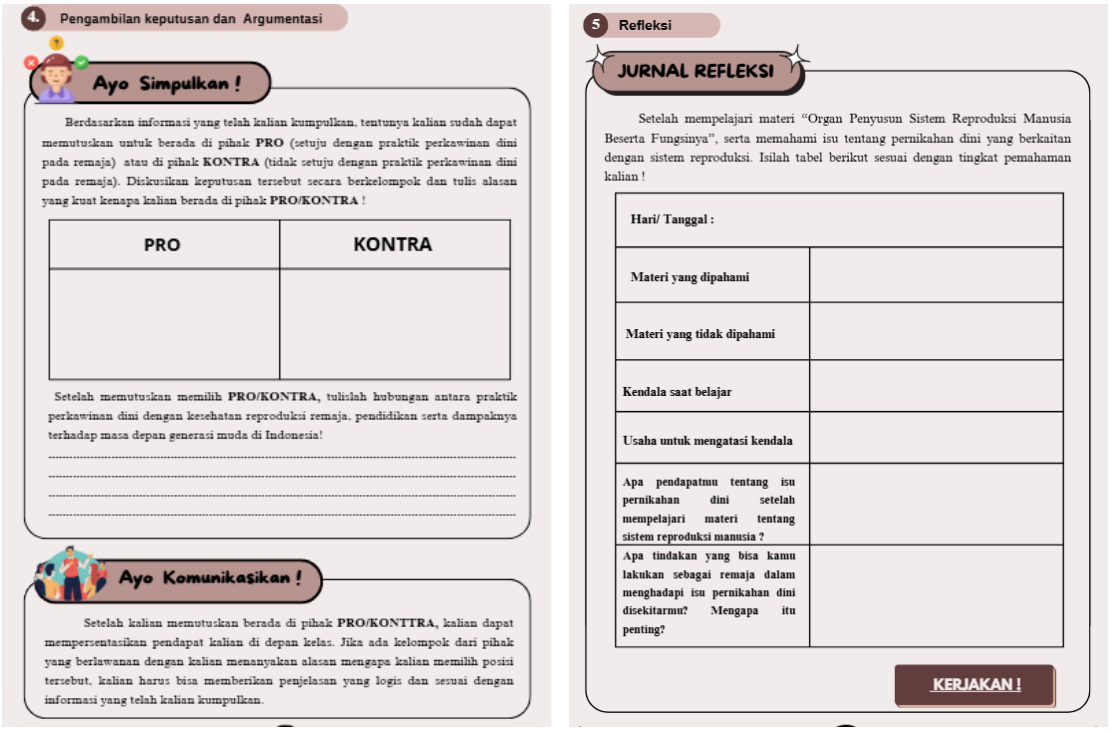


Figure 5. Display The image on the left is the "Let's Discuss" activity, which trains critical thinking skills by presenting pro and con arguments based on scientific data, while the image on the right is a display of student reflection journals as a means of evaluating understanding and critical thinking after studying social-issue-based material.

After receiving input from material and media experts, the next stage in the e-module development process was the implementation of a practicality test. This test involved a biology teacher and Grade XI Science students at SMA Cerdas Murni as respondents, using instruments in the form of teacher and student response questionnaires. The purpose of this practicality test was to obtain information regarding the ease of use and the appropriateness of the e-module content for classroom learning. The results of the practicality assessment from the teacher response questionnaire are presented in Table 7 below:

Table 7. Results of teacher response questionnaire

Aspect	Score Obtained	Maximum Score	Precentage(%)	Criteria
Attractiveness	23	24	95,83%	Very Practical
Material	19	20	95%	Very Practical
Language	16	16	100%	Very Practical
Average	**58**	**60**	**96,67%**	**Very Practical**

Referring to the data presented in Table 7, the teacher assigned a score of 58 out of a maximum of 60, which is equivalent to a percentage of 96.67%. This achievement places the e-module in the "very practical" category. These findings reflect a highly positive response from the teacher toward the implementation of the Socio-Scientific Issues (SSI)-based e-module in biology learning, particularly in the topic of the human reproductive system. Furthermore, the e-module was trialed on 27 students of class XI-MIPA 2 at SMA Cerdas Murni. The practicality test also involved students as respondents, who provided their assessments through a questionnaire focusing on aspects such as ease of use and interest in the e-module. The summary of student responses is presented in Table 8.

Table 8. Results of student response questionnaire

No	Aspect	Score Obtained	Maximum Score	Precentage (%)	Criteria
1.	Feasibility	920	972	94,65%	Very Practical
2.	Language	618	648	95,37%	Very Practical
3.	Graphics	830	864	95,60%	Very Practical
	Avarage	**2368**	**2484**	**95,33%**	**Very Practical**

Referring to the data presented in Table 8, students' responses to the e-module showed a total score of 2368 out of a maximum of 2484, equivalent to a percentage of 95.33%. This places the e-module in the “very practical” category. This level of practicality is supported by the presence of illustrative images, instructional videos, and interactive elements that enhance student engagement and active participation during the learning process. Both teacher and student responses indicated very positive feedback. Students felt enthusiastic and excited, as the presentation of the material in the e-module was designed to be engaging, interactive, and easy to understand. These findings are in line with Suastrawan et al. (2021), who stated that the ease of access and use of the learning media greatly influences the practicality of a learning material. A comprehensive analysis of users’ responses to the e-module is illustrated in Figure 7 below.

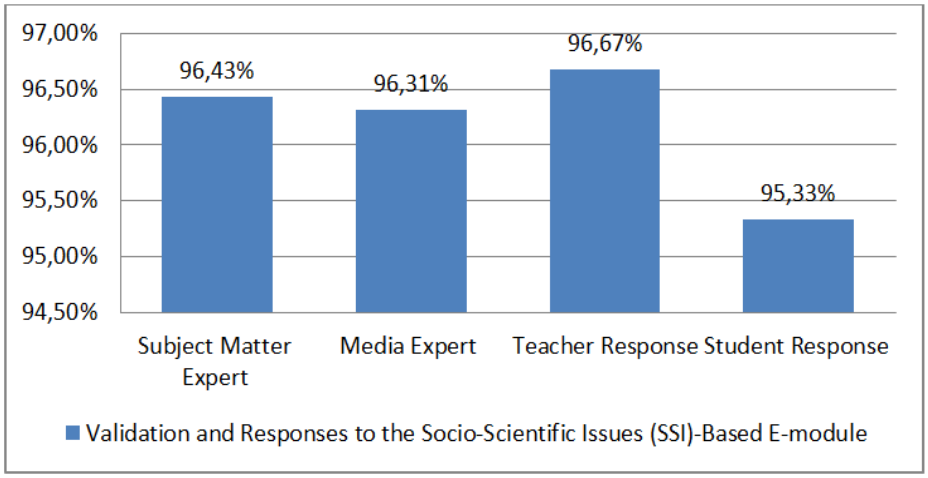


Figure 7. Diagram of data analysis results

Based on the data analysis diagram presented in Figure 7, it can be concluded that the developed e-module has fully met the feasibility criteria and is suitable for implementation in biology learning, particularly on the topic of the human reproductive system. This level of feasibility was obtained through validation results by subject matter experts, which reached 96.43%, and media experts, who provided a score of 95.31%. In addition, the limited-scale trial conducted in a school setting showed very positive responses—96.67% from teachers and 95.33% from students—indicating that the e-module is highly practical and user-friendly. This trial activity also served to evaluate the effectiveness of the e-module in enhancing students' critical thinking skills. The data on students' critical thinking ability after using the e-module is presented in Table 9.

Table 9. Students' critical thinking skills

Pre-test	Post-test	N-gain	Percentage	Criteria
56,51	91,37	0,80	80%	High

Based on the data presented in Table 9, the effectiveness test demonstrates that the e-module developed with the Socio-Scientific Issues (SSI) approach effectively enhances students' critical thinking skills. There was a significant improvement between the pre-test and post-test results, reflecting the positive impact of the developed e-module. The average post-test scores showed a notable increase compared to the pre-test scores. The N-gain value obtained was 0.80, which falls into the high category, indicating that the developed e-module significantly contributes to improving students' critical thinking abilities. These findings are consistent with the study by Septiningrum et al. (2021), which stated that the use of biology teaching materials based on Socio-Scientific Issues (SSI) can encourage the development of students' critical thinking skills. In line with this, Pratiwi (2021) also revealed that learning using SSI-based teaching materials not only contributes to a significant improvement in critical thinking skills but also shows a high level of learning mastery and received positive responses from 92% of students.

The e-module designed using the Socio-Scientific Issues (SSI) approach significantly contributes to strengthening conceptual understanding and improving students' critical thinking skills. By integrating current social and scientific issues, the learning process encourages students

to actively engage in discussions, explore multiple perspectives, and analyze data and arguments rationally. In the topic of the human reproductive system, the SSI approach enables students to relate biological theories to real-world problems, such as early marriage, infertility, and reproductive technology innovations. This collaboration between science and social issues serves as an effective medium to develop students' critical thinking patterns. Therefore, SSI-based e-modules not only strengthen students' understanding of the human reproductive system but also contribute to the development of contextual and relevant critical thinking skills that apply to real-life issues.

The development of this e-module encountered several limitations, including its reliance on external platforms such as Google Forms for accessing exercises and YouTube for video content, which require a stable internet connection. Additionally, the scope of the material in this e-module is still limited to the topic of the human reproductive system. Hence, it is recommended that future research develop similar e-modules covering a broader range of biology topics for grade XI and consider integrating interactive features directly into the e-module without depending on external platforms.

CONCLUSION

Discussion of the research findings indicates that the developed e-module has met the criteria of feasibility, practicality, and effectiveness as a learning material. These results suggest that the e-module can be implemented in biology learning at the senior high school level. The validation process also revealed that the feasibility level of the e-module was in the "very high" category, with a score of 96.43% from the material validator and 95.31% from the media validator. Meanwhile, the practicality of the e-module was proven through teacher responses with a percentage of 96.67% and student responses of 95.33%, indicating that the e-module is considered very practical in its use. The effectiveness test also showed a significant improvement in students' critical thinking skills, with an N-gain score of 0.80, which falls into the high category. These findings indicate that the e-module with a Socio-Scientific Issues (SSI) approach has significant potential to enhance students' critical thinking abilities in a logical and in-depth manner within the context of scientific learning. However, there are several limitations to this finding, including restricted access to practice questions that are still hosted on Google Forms, and the need to access video materials via YouTube. Additionally, the scope of the e-module is still limited to the human reproductive system. Therefore, it is recommended that future development expands the e-module content to cover other materials in Grade XI biology curriculum.

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