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A Socioscientific Issue-integrated E-magazine for Supporting Students' Critical Thinking in Circulatory System

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Abstract

This study aims to develop and evaluate a Socioscientific Issue (SSI)-integrated e-magazine for supporting students' critical thinking in circulatory system material. The study employed Research and Development using the 4D model, consisting of Define, Design, Develop, and Disseminate phases. Participants were 30 eleventh-grade students. Data were collected through expert validation, teacher and student questionnaires, and pre-test and post-test assessments based on Facione's six indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation. These indicators were represented through activities involving biological interpretation, evidence analysis, inference, evaluation of claims and risks, evidence-based explanation, and reflective decision-making. Data were analyzed using descriptive statistics, n-Gain, and the Wilcoxon Signed-Ranks test. The e-magazine achieved high validity scores of 96%, 87%, and 90% from media, subject-matter, SSI experts, respectively, while practicality reached 93% from students and 96% from teachers. Students' mean critical thinking score increased from 48 to 94, with an n-Gain of 0.88 (high). The Wilcoxon test showed a significant difference between pre-test and post-test scores ($Z = -4.808$, $p < 0.001$). The findings indicate strong validity and practicality and potential to support critical thinking through integrated SSI, reasoning, CER, and reflective activities. The study contributes an integrated learning resource for circulatory system learning.

Keywords: *Circulatory system, Critical thinking, E-magazine, Socioscientific issue*

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INTRODUCTION

As the complexity of global challenges continues to increase, 21st century science education is expected to cultivate scientifically literate learners equipped with strong critical thinking skills. Critical thinking is conceptualized as reflective and rational thinking that supports decisions regarding what should be believed or done, encompassing the ability to interpret, analyze, evaluate, infer, explain, and self-regulate based on logical evidence (Ennis, 2011; Facione, 2015). Within science education, these competencies support students in analyzing authentic problems, evaluating scientific evidence, and making well-reasoned decisions (Alzate, 2025; García-Carmona, 2025). UNESCO recognizes critical thinking as essential for combating misinformation (Castelló, 2022), while the OECD (2023) emphasizes evidence-based decision-making as a key outcome of science education (Santos, 2017; Sumari & Aminatun, 2020).

Nevertheless, Indonesian students continue to demonstrate lower-than-expected critical thinking skills, particularly at the senior high school level. The results of the 2022 Programme for International Student Assessment (PISA) show that Indonesia recorded an average score of 383 in science, below the OECD average of 485 (OECD, 2023). PISA provides a broader assessment of students' science competencies, whereas this study specifically examines critical thinking based on the six indicators proposed by Facione: interpretation, analysis, inference, evaluation, explanation, and self-regulation. Therefore, the PISA results are presented here as part of a broader context regarding students' science-related competencies, rather than as a direct measure of the construct of critical thinking examined in this study. More specifically, empirical research in the field of biology

education has revealed difficulties in students' critical thinking skills. Fitriani et al. (2022) reported that students' explanation and clarification skills remained low, Sari & Yulianti (2024) found inadequate development of analysis and inference skills among 11th-grade students, and Sumari & Aminatun (2020) identified comparable difficulties in analyzing biological problems and evaluating information logically. This problem is closely linked to biology learning that continues to emphasize content memorization and teacher-centered instruction (Laksono et al., 2023).

One promising approach is the integration of SSI into biology instruction. SSI places scientific concepts within authentic social contexts, thereby encouraging students to examine the scientific, ethical, and social dimensions of various real-world issues while strengthening their analytical, reflective, and scientific reasoning skills (Arifin et al., 2025; Badeo & Duque, 2022; Viehmann et al., 2024). The pedagogical mechanisms that enable SSI to foster critical thinking can be understood from the perspective of social constructivism, in which learning occurs through students' active construction of knowledge by connecting prior understanding with new information and engaging in social interactions and discussions. In SSI-based learning, students are confronted with complex and often controversial issues that require them to interpret information, analyze evidence, compare alternative perspectives, evaluate claims, and formulate reasoned decisions. This learning process provides students with opportunities to build and refine their understanding through evidence-based reasoning and engagement with diverse viewpoints. These activities are closely aligned with the six indicators of critical thinking proposed by Facione, specifically interpretation, analysis, inference, evaluation, explanation, and self-regulation. Thus, SSI is not only used to provide contextual content but also serves as a pedagogical context that engages students in the reasoning process through which critical thinking can be developed.

Facione's framework was chosen because its six cognitive skills interpretation, analysis, inference, evaluation, explanation, and self-regulation provide a comprehensive and operational structure for examining critical thinking in science learning. These indicators are highly relevant to SSI-based biology learning because students are required to understand information, examine scientific evidence, draw logical conclusions, evaluate conflicting claims, justify their reasoning, and reflect on decisions related to real-world issues. In this e-magazine, these six indicators are operationalized through structured SSI learning activities and evidence-based reasoning tasks. Interpretation is developed through activities that require students to interpret biological phenomena, analysis through the comparison of biological mechanisms and scientific evidence, inference through drawing logical conclusions from SSI information, evaluation through weighing scientific evidence, benefits, risks, and alternative claims and explanation through the formulation of scientifically supported explanations. Self-regulation is developed through reflection on and justification of evidence-based health decisions. Thus, Facione's framework serves not only as a theoretical foundation for defining critical thinking, but also as an instructional and assessment framework that guides the design of e-magazine activities and the development of critical thinking tests.

To facilitate the effective implementation of SSI, biology learning requires interactive and contextual instructional media (Karomah et al., 2023). Among various digital media, e-magazines offer considerable potential by integrating text, images, and interactive visual elements that increase students' engagement while supporting contextual learning and making complex biological processes visually clear (Herman et al., 2021; Prastiwi et al., 2024). Previous research has demonstrated the potential of SSI and technology-supported learning resources in fostering students' critical thinking and scientific literacy. Integrating SSI into learning activities can encourage students to examine evidence, consider alternative perspectives, and make reasoned decisions (Oktaviyanti et al., 2025). Digital learning resources, including e-modules and mobile learning, have also been shown to provide contextual and interactive learning experiences that support critical thinking and independent learning (Arfianti et al., 2025; Sumari & Aminatun, 2020). Other digital media, such as video-based learning resources, have also demonstrated similar potential in supporting biology learning (Wati & Fikri, 2023). These findings suggest that the integration of contextual issues, digital media, and structured

learning activities can provide opportunities to develop students' higher-order thinking skills.

Although SSI-based learning media have been developed in various formats, including leaflets, instructional materials, e-worksheets, and web-based media (Chomsun et al., 2024; Puspita & Subiantoro, 2022), SSI-based e-magazines specifically addressing the circulatory system remain limited. In this study, "comprehensive" refers to the integration of learning outcomes and objectives, circulatory system concepts, authentic SSI, structured Scientific Reasoning and Claim-Evidence-Reasoning (CER) activities, educational comics, and interactive assessments within a single e-magazine. These components are designed to engage Facione's six critical thinking indicators: SSI provides the context, scientific reasoning and CER support interpretation, analysis, inference, evaluation, and explanation, while reflective decision-making promotes self-regulation. Thus, the e-magazine not only presents contextual biology content but also enables students to analyze evidence, construct scientific reasoning, evaluate information, and make evidence-based decisions. This integrated structure distinguishes it from media that merely present SSI content without structured reasoning and evaluation activities. Such media are particularly relevant to the circulatory system, which involves contemporary health issues requiring evidence-based decisions (Fitra et al., 2025), while conventional media offer limited opportunities to explore complex physiological processes (Oktaviyanti et al., 2025).

The circulatory system provides a relevant context for SSI-based learning because its biological mechanisms are closely connected to health practices, medical interventions, and societal beliefs involving scientific, social, and ethical considerations. Issues such as cupping and scraping therapy can be explored through blood flow, blood vessels, capillary responses, and local circulation; leech therapy through blood clotting and anticoagulant mechanisms; and heart xenotransplantation through circulation, oxygen distribution, immune responses, and organ rejection. These issues require students to understand physiological mechanisms, examine scientific evidence, weigh benefits and risks, and consider multiple perspectives before reaching evidence-based conclusions. Thus, the circulatory system extends beyond conceptual understanding by providing a meaningful context for applying biological knowledge to real-world SSI and developing evidence-based reasoning.

A similar condition was identified at a public Islamic senior high school in Medan, where SSI implementation remains inconsistent and dependent on textbooks. Therefore, this study developed and evaluated an integrated SSI-based e-magazine on the circulatory system that combines curriculum-aligned content, authentic SSI, structured reasoning activities, and interactive assessments to foster critical thinking skills among 11th-grade students, based on its validity, practicality, and instructional effectiveness.

METHOD

This study employs a Research and Development (R&D) approach to develop an SSI-based e-magazine to support students' critical thinking skills in learning about the circulatory system. This study adopts the 4D development model. The 4D model was chosen because it provides a systematic framework for developing and evaluating learning products (Pratama & Sari, 2025).

The define phase comprises five activities: preliminary, learner, concept, and task analyses, followed by the formulation of learning objectives. Preliminary analysis identifies existing learning conditions and the need for SSI integration, while learner analysis examines students' characteristics, interests, and understanding of circulatory system issues. Concept analysis identifies key circulatory system concepts and their connections to relevant SSI, whereas task analysis determines activities supporting concept application, evidence analysis, evaluation, and decision-making. Based on these analyses, learning objectives are formulated according to students' needs and characteristics and the Phase F biology learning outcomes.

The design phase focuses on developing the structure, visual appearance, organization, and research instruments for the SSI-based e-magazine. Activities include developing storyboards, interfaces, navigation, and SSI-based content aligned with the learning objectives and student needs identified in the define phase. Instruments for evaluating the e-magazine and assessing students' critical thinking skills are also developed during this phase.

The development phase focuses on validating and refining the e-magazine and

research instruments. The e-magazine was validated by subject matter, media, and SSI experts, while the critical thinking test was validated by an assessment expert to ensure alignment with the learning objectives and assessment criteria. Based on expert feedback, revisions were made to improve the product and instruments before a limited pilot test was conducted to assess the e-magazine's validity, practicality, and effectiveness.

The dissemination phase involved implementing the revised SSI-based e-magazine after expert validation and product refinement. The e-magazine was introduced and used in biology lessons with 11th-grade students, while teacher and student feedback was collected to assess its practicality and feasibility as a learning resource. This phase also provided user feedback and evaluated the e-magazine's suitability for supporting biology learning and students' critical thinking skills.

The participants were 30 eleventh-grade Natural Sciences students purposively selected based on biology teachers' recommendations and their suitability for SSI-based learning. For the initial feasibility evaluation, 10 students and one biology teacher participated to assess the e-magazine's clarity, accessibility, and suitability. Participants were selected based on the teacher's knowledge of students' learning characteristics and their relevance to the planned learning activities. This purposive sampling ensured that participants were appropriate for the SSI-based e-magazine implementation. Research permission was obtained from the school, and all activities followed the school's established procedures. The participating students were informed of the study's objectives and procedures, and their participation in the study was voluntary. Student information and research data were kept confidential.

Data were collected through interviews, questionnaires, expert validation, and critical thinking tests. Teacher interviews identified existing biology learning conditions and the need for an SSI-based e-magazine, while student questionnaires examined their characteristics, learning interests, and understanding of circulatory system issues. Expert validation assessed the e-magazine's media, content, and SSI integration, while teacher and student questionnaires evaluated its practicality. Critical thinking skills were measured using six essay questions based on Facione's indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation, administered as pre-test and post-test. The test instrument design is presented in Table 1.

Table 1. Test instrument

SSI Issue	Indicator	Question Indicator	Item
Traditional scraping therapy (kerokan)	Interpretation	Interpret the physiological causes of skin redness and bruising after scraping based on the circulatory system concept, capillary structure, and peripheral blood flow	1
Cupping therapy	Analysis	Analyze differences in the circulatory system before and after cupping therapy by relating changes in blood pressure and blood flow to blood volume, vessel function, and circulation mechanisms	2
Heart xenotransplantation	Inference	Draw logical conclusions regarding the potential effects of heart xenotransplantation on blood circulation and oxygen distribution if immune-mediated organ rejection occurs	3
Hirudotherapy	Evaluation	Evaluate whether hirudotherapy can be considered a safe and effective method for improving blood circulation by weighing its biological benefits against associated medical risks	4
Blood type and personality	Explanation	Explain scientifically why blood groups cannot serve as a basis for determining personality	5
Routine cupping therapy	Self-regulation	Determine and justify a personal healthcare decision regarding routine cupping therapy based on circulatory concepts, physiological consequences, risks, and benefits	6

The collected data were analyzed using qualitative and quantitative techniques. The analysis method was selected based on the type and purpose of the data. The data analysis procedures are presented in Table 2.

Table 2. Data analysis techniques

Data	Analysis Technique	Purpose
Teacher interview data	Qualitative descriptive analysis	To identify existing learning conditions, students' learning needs, and the need for SSI-based e-magazine development
Student needs analysis questionnaire	Descriptive analysis	To identify students' characteristics, learning interests, and learning needs
Expert validation data	Descriptive percentage analysis	To determine the validity of the SSI-based e-magazine
Teacher response questionnaire	Descriptive percentage analysis	To determine the practicality of the SSI-based e-magazine from the teacher's perspective
Student response questionnaire	Descriptive percentage analysis	To determine the practicality of the SSI-based e-magazine from the students' perspective
Pre-test and post-test	Shapiro-Wilk test	To examine the normality of the data
Pre-test and post-test	Wilcoxon signed-ranks test	To determine a significant difference between students' pre-test and post-test scores
Pre-test and post-test	Effect size	To determine the magnitude of the difference between pre-test and post-test scores
Pre-test and post-test	n-Gain	To determine the level of improvement in students' critical thinking skills

Pre-test and post-test scores were first assessed for normality using the Shapiro-Wilk test (Pratama et al., 2026). Because the data were not normally distributed, the Wilcoxon signed-ranks test was used. Effect size was calculated to determine the magnitude of the difference, with values of 0.10, 0.30, and 0.50 indicating small, moderate, and large effects, respectively. Learning improvement was assessed using n-Gain, with values <0.30, 0.30–0.69, and ≥0.70 indicating low, moderate, and high improvement, respectively.

RESULTS AND DISCUSSION

The define phase identifies learning conditions, student characteristics, and learning needs as the foundation for developing the e-magazine. Initial analysis shows that biology instruction is still dominated by a textbook-based, teacher-centered approach, with limited integration of SSI and critical thinking activities. Analysis of the students revealed that they are more interested in biology when concepts are linked to everyday phenomena. However, their understanding of issues such as cupping therapy and beliefs related to blood types is still largely based on common knowledge rather than scientific evidence. These findings highlight the need for interactive learning resources that connect biological concepts with SSI.

The design phase produced the initial structure and visual framework of the e-magazine based on the needs identified in the define phase. The e-magazine connects circulatory system concepts with real-world SSI and provides activities that guide students to observe phenomena, analyze information, evaluate evidence, formulate scientific arguments, and make evidence-based decisions. This phase also produced the learning activity framework and research instruments, including expert validation sheets, teacher and student feedback questionnaires, and a six-item critical thinking test based on Facione's indicators and contextualized through relevant circulatory system SSI. The e-magazine design framework is presented in Figure 1.

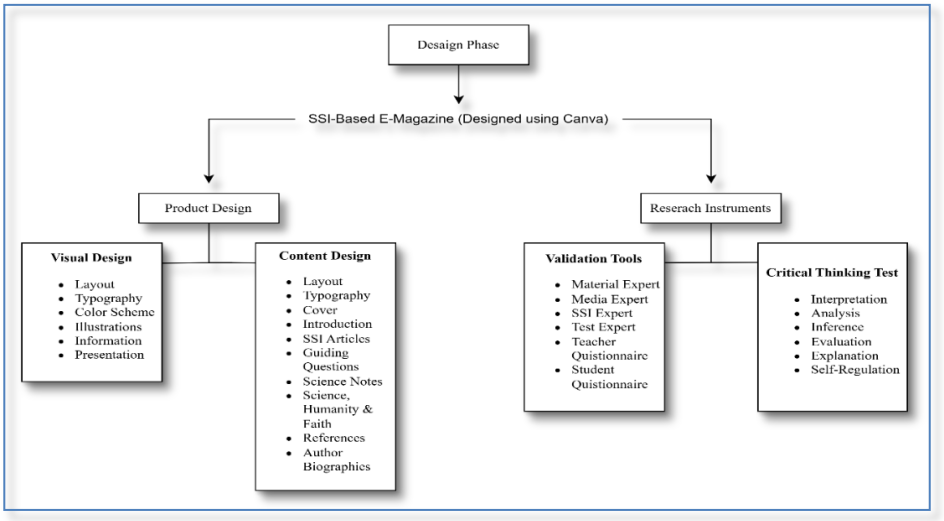

Figure 1. Design framework of the e-magazine

The development phase began with expert validation of the e-magazine and critical thinking tests. The e-magazine has been validated by four experts, consisting of one media expert, one subject-matter expert, one SSI expert, and one evaluation expert. The validators were selected based on their academic and professional expertise relevant to the aspects being evaluated, including educational media, biology content, SSI, and educational assessment. Selection criteria included relevant academic qualifications, teaching or professional experience, and expertise in their respective fields. The critical thinking test was also reviewed by an assessment expert to ensure that the test items accurately represented the six indicators of critical thinking according to Facione. Based on the validation results and the experts' recommendations, revisions were made to improve the content, visual presentation, navigation, and SSI integration before the product was implemented with students. The validation results for the SSI-based e-magazine and the critical thinking test are presented in Table 3.

Table 3. Expert validation results

Validator	Aspect	Score	Maximal Score	Percentage (%)	Criteria
Media	Visual Design	30	32	94	Highly Valid
	Graphic Elements	30	32	94	Highly Valid
	Navigation	8	8	100	Highly Valid
Subject Matter	Content	23	24	96	Highly Valid
	Language	27	32	84	Highly Valid
	Presentation	13	16	81	Highly Valid
SSI	Content	12	12	100	Highly Valid
	Construction	12	12	100	Highly Valid
	Language	10	12	83	Highly Valid
	Format and Presentation	3	4	75	Valid

As shown in Table 3, the e-magazine received high validity scores from all three validators, covering the aspects of media, subject matter, and SSI. The media expert evaluation yielded an average score of 96%, categorized as "Highly Valid," indicating that the e-magazine's visual design, graphic elements, and navigation are appropriate. The subject matter expert evaluation yielded an average score of 87%, also categorized as "Highly Valid," indicating that the content, language, and presentation of the biology material are suitable for learning. Meanwhile, the SSI expert evaluation yielded an average score of 90%, categorized as "Highly Valid," indicating that the content, structure, language, format, and presentation of the SSI components are appropriate. Overall, the validation results

show that the SSI-based e-magazine that was developed has met the validity criteria and is suitable for further testing after implementing the validators' recommendations. After a validation process by experts and product revisions, the e-magazine was evaluated for its practicality based on feedback from teachers and students. The results of practicality test are presented in Table 4.

Table 4. Practicality test results

Respondent	Score	Maximal Score	Percentage (%)	Criteria
Students	59.4	64	93	Highly Practical
Teacher	50	52	96	Highly Practical

As shown in Table 4, the SSI-based e-magazine received a practicality score of 93% from students and 96% from teachers. These results indicate that the e-magazine is considered easy to use and suitable for supporting biology learning from both the students' and teachers' perspectives. The high practicality scores also indicate that the content, presentation, and interactive features of the e-magazine were well-received by the intended users. After assessing practicality, the effectiveness of the SSI-based e-magazine was tested by comparing students' critical thinking performance before and after its implementation. The results of this effectiveness assessment are presented in Table 5.

Table 5. Effectiveness test results

Test	Mean	Maximal Score	n-Gain	Criteria
Pre-test	48	100	0.88	Effective
Post-test	94	100		

As shown in Table 5, students' average scores increased from 48 on the pre-test to 94 on the post-test after using the developed SSI-based e-magazine. An n-Gain of 0.88 is categorized as high, indicating a significant improvement in students' learning outcomes following the implementation of the e-magazine. These results demonstrate that the developed e-magazine is effective in supporting student learning and improving their performance in the learning process. The effectiveness of the e-magazine was further verified using the Wilcoxon signed-ranks test because normality tests indicated a non-normal distribution ($p < 0.05$). The Wilcoxon signed-rank test yielded a Z value of -4.808 with a significance level of <0.001 ($p < 0.05$), demonstrating a significant difference between the students' pre-test and post-test scores after using the e-magazine. This result is in line with the n-Gain analysis, which generated a high average score of 0.88, indicating a substantial improvement in students' critical thinking skills. The consistency between the Wilcoxon test and the n-Gain findings suggests that the implementation of the SSI-based e-magazine was associated with the observed enhancement in students' critical thinking performance.

The magnitude of the difference between the pre-test and post-test scores was then further analyzed using the effect size (r) obtained from the Wilcoxon signed-rank test. The effect size was 0.878, indicating a large effect according to Cohen's (1988) criteria. These results indicate that SSI-based e-magazines are associated with a significant improvement in students' critical thinking skills. Similarly, Amalia and Manalu (2025) found that SSI-based electronic modules effectively improve students' critical thinking skills, thereby supporting the potential of SSI-based digital media to foster meaningful critical thinking development.

The dissemination phase was carried out after the SSI-based e-magazine had undergone validation by experts, revisions, feasibility testing, and effectiveness testing. The final product was introduced and distributed to biology teachers and students as an alternative learning resource on the circulatory system. This dissemination activity focused on introducing the content, SSI-based learning activities, and the e-magazine's interactive features to potential users. Feedback gathered during this activity was used to assess the product's suitability for wider use and to provide input for further improvements.

The final outcome of this project is an e-magazine titled "BIOSPHERE". This e-magazine is available in PDF format with A4 page size and consists of 28 pages. Access to

this e-magazine is provided via a QR code that directs users to the Heyzine platform, allowing the product to be accessed via laptops, tablets, and smartphones. The e-magazine contains learning objectives, material on the circulatory system, SSI, science reasoning lab activities, CER assignments, educational comics, and interactive assessment activities. These components are integrated to support the six indicators of critical thinking according to Facione, interpretation, analysis, inference, evaluation, explanation, and self-regulation. An example of an e-magazine that has been developed is shown in Figure 2-4. The selected components represent the main features of the final product, including the cover, the learning orientation, and the integration of SSI with structured critical thinking activities.

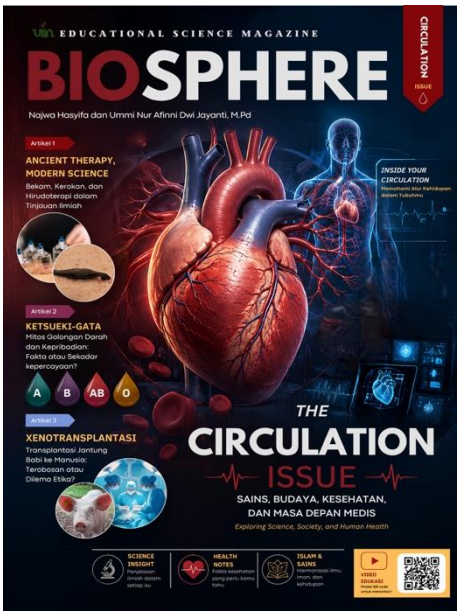

Figure 2. Cover of the e-magazine

Figure 3. Learning orientation section

Figure 4. Example activity

The improvement in students' critical thinking skills indicates that integrating SSI into the e-magazine supported contextual learning on the circulatory system. Through authentic SSI contexts, students interpreted information, analyzed scientific evidence, and formulated evidence-based judgments, thereby promoting scientific reasoning while connecting biological concepts to everyday issues. Similar findings were reported by Tazkia & Subiantoro (2025)

and Amalia & Manalu (2025), who found that SSI-based digital learning media effectively foster critical thinking through contextual scientific problems.

This improvement can be explained by the cognitive processes activated through engagement with authentic social science issues. SSI requires students to connect prior knowledge with new information, analyze evidence, evaluate conflicting claims, and formulate evidence-based conclusions. The integration of science reasoning lab and CER activities further supports argument construction and evidence evaluation, while reflective decision-making promotes metacognitive regulation. These higher-order cognitive processes are central to critical thinking and may account for the observed improvement (Badeo & Duque, 2022; Viehmann et al., 2024; García-Carmona, 2025). Thus, the improvement was likely attributable not merely to exposure to SSI content but to structured engagement with evidence, argumentation, evaluation, and reflection.

High n-Gain scores were obtained across all six critical thinking indicators proposed by Facione, although the magnitude of improvement varied. Interpretation showed the highest increase, likely due to the contextual and authentic SSI presented in the e-magazine. Students identified biological phenomena and connected them with prior concepts, while the science reasoning lab provided structured support for understanding relevant information before engaging in complex reasoning. This contextualization may have facilitated interpretation by linking new information to familiar real-world phenomena. In contrast, evaluation showed the lowest improvement, although it remained in the high category. This indicator required students to assess the safety and effectiveness of hirudotherapy by weighing biological benefits against medical risks, comparing evidence, considering alternative claims, and providing justified assessments. Such processes require more complex reasoning than information interpretation, suggesting that evaluative reasoning may require sustained practice and repeated opportunities to assess conflicting evidence. This finding is consistent with Nora'in et al. (2025), who reported that SSI-based learning supports critical thinking through scientific argumentation and evidence-based reasoning.

The present findings extend previous research by applying an SSI-based e-magazine to the circulatory system while explicitly incorporating Facione's (2015) six critical thinking indicators into learning activities. The results are consistent with Janand et al. (2026), who also reported significant improvements in critical thinking based on n-Gain and Wilcoxon signed-ranks test analyses. These findings highlight the potential of SSI-based e-magazines as alternative digital resources for biology instruction.

Several limitations should be acknowledged. First, the study involved only 30 11th-grade students from one school, limiting generalizability. Second, critical thinking was assessed using only six essay questions, with each representing one of Facione's six indicators. Some activities also relied on external platforms, such as YouTube and Wordwall, requiring internet access. Future research should involve larger and more diverse samples, employ more comprehensive assessment instruments, and develop a more integrated digital platform.

CONCLUSION

An SSI-integrated e-magazine for the circulatory system was successfully developed and demonstrated high validity and practicality, while related to improving students' critical thinking skills, as indicated by the high n-Gain and significant Wilcoxon signed-ranks test results. The e-magazine integrates SSI with science reasoning lab, CER, and reflective activities to support interpretation, analysis, inference, evaluation, explanation, and self-regulation. However, this study was conducted in only one school with 30 students, and several learning activities remained dependent on external digital platforms requiring internet access, which may limit the generalizability and implementation of the findings. Future research should involve larger and more diverse samples, use more comprehensive assessment instruments, and develop a more integrated digital platform for broader application in biology learning.

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