Integrated Science Education Journal
Vol. 7, No. 1, January 2026, pp. 75~85
ISSN: 2716-3725, DOI: 10.37251/isej.v7i1.2223

Research Article

Effectiveness of Inquiry Learning Model Based on Socio-Scientific Issues to Develop Students' Critical Thinking Skills

Sabrina Oktavia Irawati[1], Ria Wulandari[1,*]
[1] Department of Science Education, Faculty of Psychology and Education, Universitas Muhammadiyah Sidoarjo, Jawa Timur, Indonesia

Article Info

Article history:

Received Oct 12, 2025
Revised Nov 22, 2025
Accepted Dec 31, 2025
OnlineFirst Jan 06, 2026

Keywords:

Critical Thinking Skills
Experimental Study
Learning Model Inquiry
Science Education
Socio-Scientific Issue

ABSTRACT

Purpose of the study: This study aims to describe the effect of the socio-scientific issue-based inquiry learning model on the critical thinking skills of eighth-grade students in the subject of the digestive system.

Methodology: This study used a quantitative experimental method with a nonequivalent control group design. The population in this study was 320 eighth-grade students, with a sample size of 64 students. Data collection techniques used tests. The research instruments used pretest and posttest critical thinking skills. The data analysis technique in this study used N-gain (Normalized Gain) and inferential statistics in the form of an independent sample t-test.

Main Findings: The main findings of this study indicate that the socio-scientific issues-based inquiry learning model significantly improves students' critical thinking skills compared to conventional learning with N-gain 0,94 in high category. The test results show a sig. value (2-tailed) = 0.021 (<0.05), which indicates a significant difference between the experimental and control classes. This model is effective because it involves students in scientific investigations based on real social issues that encourage them to think reflectively, analytically, and evidence-based in their decision-making.

Novelty/Originality of this study: The novelty of this study lies in the application of a socio-scientific issues-based inquiry learning model to digestive system material to develop students' critical thinking skills. The socio-scientific issues used are obesity and GERD. The socio-scientific issues-based inquiry learning model integrates scientific investigation with contextual and evidence-based social analysis.

Corresponding Author:
Ria Wulandari,
Department of Science Education, Faculty of Psychology and Education, Universitas Muhammadiyah Sidoarjo, Raya Lebo Road, no 4, Sidoarjo, Jawa Timur, 61261, Indonesia
Email: ria.wulandari@umsida.ac.id

1. INTRODUCTION

Critical thinking skills are one of the competencies that every individual needs to master in the 21st century, in addition to communication, collaboration, and creativity [1]. Critical thinking skills enable individuals to analyze information in depth, make the right decisions, and solve complex problems effectively. 21st-century education emphasizes the importance of developing critical thinking skills as part of the curriculum, with the aim of preparing students to face increasingly complex and dynamic future challenges [2]. Critical thinking skills are skills that emerge from learning processes related to an individual's intellect. Critical thinking

skills can be developed from an early age to teach problem solving through reflective and responsible thinking [3]. In the context of natural science education, critical thinking is an important focus that is incorporated into various scientific activities such as observing, questioning, reasoning, and communicating the results of experiments. Natural science education not only teaches scientific concepts but also critical thinking skills to deal with scientific and social issues in everyday life because critical thinking skills are also considered the basis for scientific literacy, which is needed to face global challenges and the rapid development of technology [4].

The importance of developing critical thinking skills in science education is in accordance with Permendikbud No. 64 of 2013, which explains that science subjects, especially biology and physics, require critical, logical, and analytical thinking [5]. Several competencies that need to be developed in order to achieve the objectives of science learning optimally are curiosity, responsibility, honesty, creativity, and critical thinking. Critical thinking is part of higher-order thinking skills, namely the ability to think reasonably and reflectively in order to decide what to believe or do [6]. In addition, critical thinking is the process of obtaining information effectively through proof and the application of logic. This process enables a person to take responsibility for their thoughts, draw appropriate conclusions, and solve various problems systematically [7]. Several studies show that critical thinking skills are still relatively low.

At the junior high school level, several indicators of critical thinking skills, such as analysis, systematicity, and maturity, scored an average of 60% and were categorized as adequate [8]. Other studies show that 51% of students are in the low category and 14% are in the very low category for critical thinking skills [9]. Then, other research shows that students' critical thinking skills are still low with an average of 40.62 with the indicator that appears most often being Interpretation or the easiest indicator [10]. This shows that students are not yet accustomed to active learning that can train thinking skills. The low critical thinking skills of students are influenced by a learning process that is dominated by teachers and a lack of a student-centered learning environment [11]. Low critical thinking skills will cause students to have difficulty analyzing information, solving problems, and making the right decisions. This condition will hinder the development of higher-order thinking skills needed to face the challenges of the 21st century [12].

Critical thinking skills can be improved through contextual and relevant learning. Contextual learning is learning that enables students to connect the material being taught with problems in everyday life [13]. Learning is designed so that students can actively participate and gain meaningful understanding [14]. The Contextual Teaching and Learning approach can improve students' critical thinking skills and provide a positive influence in solving various problems based on real life [15]. One contextual approach that can be used is with socio-scientific issues. Through socio-scientific issues, students will be challenged to consider the scientific principles underlying certain issues and analyze scientific data that can inform discussions about these issues [16]. The socio-scientific issue approach can be used as an approach that supports the learning process in training students' critical thinking skills, because through this approach, real-life problem scenarios can be applied so that students are encouraged to analyze, evaluate, and make decisions based on scientific considerations and relevant social values [17].

In general, cases that are classified as socio-scientific issues are controversial and generate much debate, thereby enabling students to develop certain skills, including critical thinking skills. For example, some topics that are closely related to everyday life and contain socio-scientific issues are: 1) global warming. This topic is often used to teach students about the impacts of climate change. Related issues such as Antarctic ice melt and greenhouse gas emissions from transportation can be integrated into the lesson. Students can be encouraged to analyze data and discuss possible solutions to reduce the impact of global warming, thereby encouraging them to think critically [17]. 2) Environmental pollution. This material discusses the impact of pollution caused by industrial and household waste. Students can analyze how pollution affects human health and ecosystems, and discuss possible solutions to reduce these impacts [18], 3) biotechnology. This material covers issues related to biotechnology, such as the use of genetically modified organisms in agriculture, which can be used as discussion material for students. Students can explore the pros and cons of biotechnology application, as well as its impact on food safety and the environment [19], 4) The human respiratory system. Students can learn how air pollution affects the human respiratory system. This discussion can cover the long-term effects of exposure to pollution on health and steps that can be taken to protect oneself from pollution [18]. The Socioscientific Issues-based Inquiry Model plays an important role in improving students' science learning abilities, including scientific thinking habits and scientific literacy, conceptual understanding, critical thinking skills, scientific explanations, interests and learning achievements [20]. So in its implementation, the socio-scientific issues approach can be integrated with the inquiry learning model to improve students' critical thinking skills.

The inquiry learning model places students as active subjects in the learning process through investigation activities, asking questions, collecting data, and drawing conclusions based on scientific evidence [21]. The inquiry learning model provides opportunities for students to learn how to discover facts, concepts, and principles through their direct experiences. Inquiry helps develop critical, analytical, and reflective thinking skills that are essential in solving various scientific problems in real life [22]. To make inquiry activities more

contextual and meaningful, their application can be linked to social issues rooted in the context of science. The socio-scientific issue-based inquiry learning model combines scientific thinking processes with analysis of social issues that have scientific, ethical, and moral dimensions. In this model, students are invited to examine, discuss, and make decisions on real issues such as climate change, the use of biotechnology, or environmental pollution by considering scientific perspectives and social values.

Research results show that the socio-scientific issue-based inquiry learning model can improve critical thinking skills and learning motivation [23] [24]. In addition, students are actively involved in small groups, building concepts independently through inquiry activities, evaluating scientific information, and participating in decision-making related to socio-scientific issues [25]. This study aims to describe the effect of the socio-scientific issue-based inquiry learning model on improving students' critical thinking skills. The critical thinking skill indicators used are: 1) recognition of assumptions, 2) analyzing arguments, 3) deduction, 4) information, and 5) conclusion and shown in Table 1 [26].

2. RESEARCH METHOD

This study used a quantitative experimental method with a nonequivalent control group design. In this design, participants came from two pre-formed classes. One class was the experimental class that received treatment, and one class was the control class that did not receive treatment. Critical thinking skills were measured twice, before the treatment (pretest) and after the treatment (posttest), to determine the effect of the socio-scientific issue-based inquiry learning model in science learning on the digestive system material. This design has three main characteristics: 1) participants are not randomly assigned to groups, 2) both classes receive the same learning conditions except for the treatment, and 3) critical thinking skills are measured at the same time, namely pretest and posttest [27]. The research design is shown in Figure 1 [28].

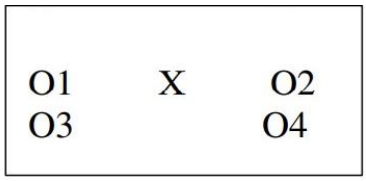

Figure 1. Research design

The treatment given to the experimental class was a socio-scientific issue-based inquiry learning model, while the control class used the learning model commonly used by teachers, namely direct learning. The population in this study was 320 eighth-grade students, with a sample size of 64 students. The sampling technique used is simple random sampling where each member of the population has the same opportunity to be selected randomly [29]. Data collection techniques used tests. The research instruments used pretest and posttest critical thinking skills. The instrument used consisted of 10 questions adapted from research [30] and modified according to the indicators used. Pretests and posttests were conducted to measure changes that occurred before and after the treatment was given. The data analysis technique in this study used N-gain (Normalized Gain) and inferential statistics in the form of an independent sample t-test. N-gain is an analysis method used to measure the effectiveness of learning by comparing the increase in scores between the pretest (before learning) and posttest (after learning) [31]. N-gain shows the extent of improvement in critical thinking skills after receiving treatment, namely the socio-scientific issue-based inquiry learning model. N-gain values range from -1 to 1, where positive values indicate an increase in critical thinking skills, while negative values indicate a decrease. The next analysis technique is the independent sample t-test to test the difference in means between two classes. This test compares the means of two independent groups from the same population where members in one group are not related to members of the other group [32]. The independent sample t-test is performed to compares the means of two groups from the same population to determine whether there is a significant difference between them. The data analysis technique uses SPSS 25.

Table 1. Critical thinking indicators

Indicator	Indicator Description
Recognition of Assumptions	1) Students respond to and question assumptions 2) Students gather further information
Analyzing Argument	1) Students analyze information objectively and accurately 2) Students question the quality of supporting information
Deduction	1) Students formulate possible alternative answers. 2) Students provide information through a decision-making list

Indicator	Indicator Description
Information	1) Students look for information that still needs to be added 2) Students give reasons for thinking that it is the correct answer or an accurate solution
Conclution	1) Students give the best assessment with a quality decision 2) Students provide evidence that leads to a conclusion

3. RESULTS AND DISCUSSION

This study aims to describe the effect of the socio-scientific issue-based inquiry learning model on students' critical thinking skills. Data were obtained through two measurements, namely a pretest to determine students' initial abilities and a posttest to determine the increase in learning outcomes after treatment. Before analyzing the pretest and posttest results to determine improvements in student learning outcomes, the instrument consisting of 10 questions was tested for Cronbach Alpha reliability using SPSS. Reliability testing is the accuracy or consistency of the tool in assessing what it is assessing. This means that whenever the assessment tool is used, it will provide relatively the same results [33]. An instrument can be said to be accurate or stable if the Cronbach's alpha reliability test results are >0.60 [34]. The Cronbach Alpha results obtained are shown in Table 2.

Table 2. Cronbach Alpha Reliability Results

Cronbach's Alpha[a]	N of items
.797	10

Based on the Cronbach Alpha results obtained, which were 0.797 and adjusted to the Cronbach Alpha indicator indicator According to [35] A variable is said to be reliable when it has a Cronbach Alpha ($r11$)> 0,70. The results obtained show are > 0,70, so that the question instrument used can be said to be reliable and can be used for research. The pretest and posttest data were then analyzed to obtain the N-gain value. The pretest, posttest, and N-gain data are presented in Table 3.

Table 3. Pretest, posttest, and N-gain data

Class		Max	Min	Average	N-gain Average	Category
Control	Pre-test	70	40	49.38	0.6	Medium
	Post-test	100	60	80.63		
Experiment	Pre-test	70	30	46.88	0.7	High
	Post-test	100	70	85.31		

Based on Table 3, it is known that the pretest and posttest scores increased in both the control class and the experimental class. The control class obtained an average score of 49.38 on the pretest, while the experimental class obtained an average score of 46.88. The average pretest score was low because the students had not yet learned about the digestive system. The posttest in the control class had an average score of 80.63 with an N-gain of 0.60, which is in the moderate category. The experimental class had an average posttest score of 85.31 with an N-gain of 0.72, which is in the high category. These results show that the socio-scientific issue-based inquiry learning model is effective in improving students' critical thinking skills, which is in line with the results of [36], [37]. The socio-scientific issue-based inquiry learning model has been proven to improve critical thinking skills because students are actively involved in the scientific investigation process related to relevant social issues [38]. Students are trained to think logically, reflectively, and argumentatively through activities such as questioning, collecting data, analyzing information, and making decisions based on evidence. Involvement in discussions and decision-making related to scientific social issues can train students' ability to analyze problems from various perspectives, which leads to improved critical thinking skills

Critical thinking skills indicators

To determine student improvement in each critical thinking skill indicator, an analysis of critical thinking skill indicator achievement was conducted, covering five indicators, namely Recognition of Assumptions, Analyzing Arguments, Deduction, Information, and Conclusion. The improvement in student scores in each critical thinking skill indicator can be seen in Figure 2.

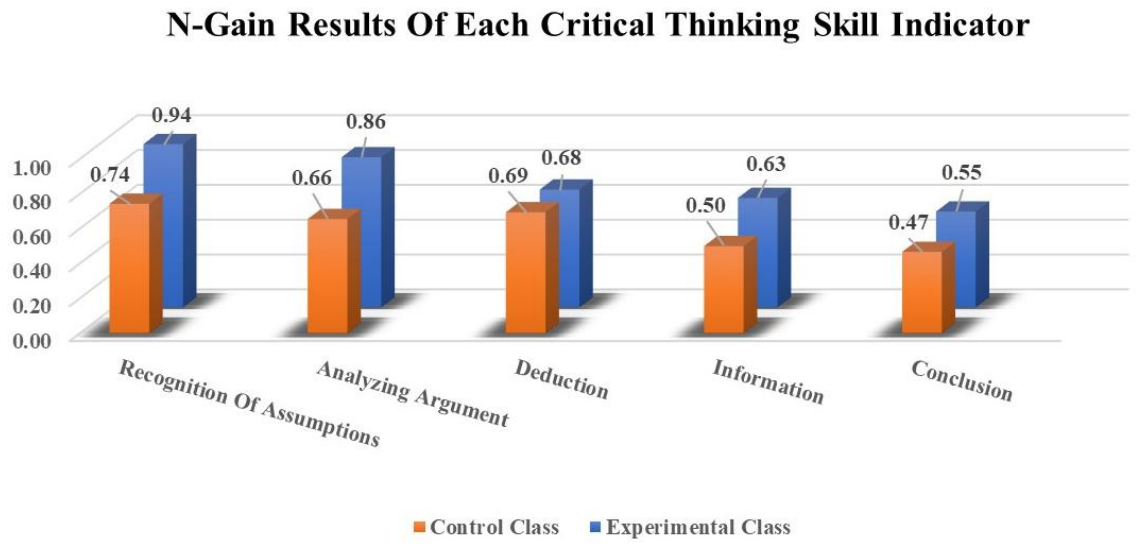

Figure 2. N-gain critical thinking skills indicator

On the first indicator, recognition of assumptions, the control class scored 0.74 in the high category and the experimental class scored 0.94 in the high category. Both classes were in the high category, but the N-gain results for the experimental class were higher than those for the control class. The N-gain results obtained are in the high category because the first indicator is the simplest indicator so that students do not have difficulty. This is in line with [39] which also obtained high category N-gain results on the first indicator. These findings indicate that during the orientation stage of the socio-scientific issue-based inquiry learning model, students were presented with real issues regarding obesity and GERD, which are social issues that many people experience today. Students were asked to identify assumptions that have developed in society, such as "eating a lot will definitely cause obesity" or "coffee is always bad for the stomach." This activity trained them to identify assumptions that are false or inaccurate. Students are encouraged to question the truth of these assumptions, seek relevant scientific evidence, and assess its validity rationally through the inquiry process. The stages in the inquiry model, such as questioning, investigating, analyzing data, and drawing conclusions, train students to think reflectively about the basis of every statement or belief they encounter. Students not only receive and understand information but are also able to distinguish between facts, opinions, and unfounded assumptions. The application of socio-scientific issue (SSI)-based inquiry can significantly improve students' critical thinking skills, particularly in the aspects of recognition of assumptions and evaluation of arguments, because students are directly involved in analyzing various perspectives that arise from scientific-social issues. This is in line with the results of research Dusturia et al [40] which states that socio-scientific issue (SSI)-based learning involves the process of exploring scientific evidence to assess the truth of claims and identify biases or assumptions in the information received by students. According to Zeidler and Nichols [41], socio-scientific issue (SSI)-based learning can foster critical thinking and moral reasoning through a reflective process on the values and assumptions inherent in scientific issues in society.

The second indicator, analyzing arguments, scored 0.66 in the control class, which is in the moderate category, and 0.86 in the experimental class, which is in the high category. In the syntax of formulating problems and making hypotheses, students in the experimental class analyzed arguments arising from issues (pros and cons of fast food consumption on GERD). Students distinguished between arguments based on scientific data and arguments based solely on opinion. Through the socio-scientific issue-based inquiry learning model, students critically evaluated the quality of evidence and arguments because they were directly confronted with socio-scientific complexity. This process fosters students' ability to think reflectively, logically, and based on evidence. Group discussion activities provide opportunities for students to present, critique, and defend their arguments scientifically, thereby strengthening their argument analysis skills. The results of the study Setianingsih et al [36] show that students' ability to analyze arguments improved significantly because they became accustomed to evaluating claims based on scientific data and relevant social values. Learning with socio-scientific issues makes students more skilled at identifying argument structures, assessing data validity, and constructing logical, evidence-based arguments [42]. Tumanggor and Jayanti [43] states that socio-scientific issue-based learning significantly improves students' argumentation skills in terms of claims, evidence, and reasoning (CER). Students become accustomed to assessing the strength of evidence and the logic underlying an argument before reformulating it into a rational scientific opinion. These results reinforce that socio-scientific issue-based learning can improve argumentation skills and develop indicators of analyzing arguments in critical thinking skills.

The third indicator, deduction, scored 0.69 in the control class, which is in the moderate category, and 0.68 in the experimental class, which is also in the moderate category. In the syntax of hypothesis making and data collection, students in the experimental class formulated hypotheses about the relationship between diet and digestive health, which were then proven through experiments (fat and protein tests). This activity trained students to formulate logical alternative answers based on the information obtained, test the relationship between variables, and conclude rational solutions from general principles to specific situations. The deduction category is still classified as "moderate" because students find it difficult to generalize the results of the practicum to a broader social context. Deductive skills require repeated practice and involvement in real-world contexts so that students become accustomed to making valid alternative explanations. According to Tumanggor and Jayanti [44], the application of socio-scientific inquiry significantly improves critical thinking skills, particularly in the aspect of drawing logical conclusions based on scientific evidence. The concept mapping process helps students structure their arguments rationally and connect theory with observational results deductively. Guided inquiry learning based on Socio-Scientific Issues can train students' critical thinking skills, especially in applying scientific principles deductively to assess and conclude the impact of an environmental phenomenon [45].

The fourth indicator is information. The control class scored 0.50, which is in the moderate category, while the experimental class scored 0.63, which is also in the moderate category. Although both classes are in the same category, the experimental class showed better results. This means that the socio-scientific issue-based inquiry learning model is effective in training students' ability to manage scientific information more critically. The information indicator in critical thinking skills relates to students' ability to identify, collect, and evaluate relevant information before drawing conclusions or constructing scientific arguments. In the syntax of collecting and analyzing data, students are required to relate their observations to solutions to social problems, such as the importance of reducing fatty food consumption to prevent obesity and increasing protein intake to reduce the risk of GERD. This process encourages students to seek additional information from relevant scientific sources to strengthen their arguments. The socio-scientific issues inquiry model has proven effective in stimulating students to assess the reliability of evidence, distinguish between facts and opinions, and integrate scientific information into real social contexts. Information indicators improve because students actively receive, test, and interpret information based on scientific principles and complex social contexts. The results of study López-Fernández et al [46] show that socio-scientific issues-based learning helps students develop critical thinking skills through in-depth evaluation and selection of scientific information.

The fifth indicator is conclusion, with the control class scoring 0.47, which is in the moderate category, and the experimental class scoring 0.55, which is also in the moderate category. Although the increase is not very large, these results show a positive effect of applying the socio-scientific issues-based inquiry learning model on students' ability to draw logical conclusions based on scientific evidence. In the syntax of formulating conclusions, students in the experimental class were directed to integrate the findings of the discussion, scientific data, and arguments that had been developed during the learning process. The inquiry model based on socio-scientific issues helped students develop the ability to draw conclusions that were reasonable, consistent with the data, and considered scientific and ethical perspectives. Students learn to relate theory to empirical conditions, so that the conclusions drawn are more rational, logical, and based on scientific data. In addition, according to Maryam and Suwono [47] this indicator enables students to make decisions as solutions to the issues presented after conducting investigations and group discussions based on the information and evidence they have obtained so that they can help resolve these issues. However, the category is still moderate because some students find it difficult to formulate systematic conclusions. In line with research Setianingsih et al [36], the indicator for drawing conclusions obtained results in the medium category and the smallest compared to other indicators, this is because in this indicator students must connect all the results of information, analysis and discussions that have been carried out so that a conclusion is obtained. Overall, the socio-scientific issue-based inquiry learning model can improve all critical thinking skill indicators.

The effect of socio-scientific inquiry-based learning models on critical thinking skills

To determine the effect of the socio-scientific issues-based inquiry learning model, inferential statistical tests were conducted. Normality and homogeneity tests were performed first as prerequisite tests. The Kolmogorov-Smirnov test was used for the normality test. The results of the normality test are shown in Table 4.

Table 4. Test of normality

	Kolmogorov-Smirnov			Shapiro-Wilk		
Class	Statistic	df	Sig.	Statistic	df	Sig.
Control	.132	32	.168	.917	32	.017
Experimen	.136	32	.139	.919	32	.020

Based on Table 4, it is known that the significance value is 0.168 in the control class and 0.139 in the experimental class. The significance values obtained are greater than the predetermined significance level of

0.05. Therefore, it can be concluded that the data obtained in both classes are normally distributed. After obtaining normally distributed data, a homogeneity test was conducted to determine whether the data obtained were homogeneous or came from populations with the same variance. The results of the homogeneity test are shown in Table 5.

Table 5. Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Control	Based on Mean	1.644	1	62	.205
	Based on Median	1.542	1	62	.219
	Based on Median and with adjusted df	1.542	1	61.796	.219
	Based on trimmed mean	1.688	1	62	.199
Experimen	Based on Mean	0.17	1	62	.896
	Based on Median	.026	1	62	.872
	Based on Median and with adjusted df	.026	1	61.586	.872
	Based on trimmed mean	.021	1	62	.885

Based on Table 5, it is known that the significance value obtained in the control class was 0.205 for Based on Mean and in the experimental class, a significance value of 0.896 was obtained. The significance values in both classes were greater than 0.05, so the pretest and posttest data in the control and experimental classes were homogeneous. The data obtained is normal and homogeneous, then a parametric statistical test is performed, namely the Independent Samples Test (t-test). The Independent Samples Test is used to determine the difference in the means of the two classes, namely the control class and the experimental class. The results of the Independent Samples Test (t-test) can be seen in Table 6.

Table 6. Independent sample t-test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1.644	.205	-1.840	62	.021	-.11676	.06346	-.24362	.01011
Equal variances not assumed			-1.840	59.895	.021	-.11676	.06346	-.24371	.01019

Based on Table 6, it is known that the sig value (2-tailed) < 0.05, namely 0.021, so Ho is rejected and Ha is accepted, namely there is a significant difference between the average learning outcomes of students in the control class and the experimental class. The socio-scientific issues-based inquiry learning model has proven to be effective in improving students' critical thinking skills because it combines the scientific process with a real social context. Students not only learn scientific concepts conceptually but also learn to assess evidence, connect scientific facts with social issues, and construct arguments based on logic and empirical data. The socio-scientific issues approach plays an important role in encouraging students to think reflectively, analytically, and evaluatively. Students are given the opportunity to present various alternatives, consider scientific and social impacts, and develop rational and responsible decisions. The learning process stimulates all aspects of critical thinking skills, from the ability to identify assumptions, analyze arguments, evaluate evidence, to draw logical conclusions. The inquiry-based learning model using socio-scientific issues strengthens collaboration and dialogue, thereby promoting social interaction that plays an important role in the formation of scientific understanding. Students engage in argumentative discussions, confirm each other's ideas, and evaluate scientific evidence to support their conclusions [48]. The results of research [49] show that socio-scientific issues-based science learning effectively improves students' critical thinking skills and sustainability awareness. This is in line with research [50] showing that socio-scientific issues-based learning can improve critical thinking skills in digestive system material through relevant social contexts. The socio-scientific issues-based inquiry learning model provides meaningful, reflective, and contextual learning experiences in developing students' critical thinking skills.

Novelty this study's originality resides in employing a socio-scientific issues-based inquiry learning paradigm to the topic of the digestive tract, specifically addressing obesity and GERD as socio-scientific concerns. This method distinctly combines scientific inquiry with relevant social challenges, prompting students

to evaluate real-world problems from both scientific and societal viewpoints. The study offers novel insights into the incorporation of socio-scientific issues inside science education to improve critical thinking skills, a combination that has not been thoroughly examined in prior studies on science education for critical thinking. Implications this study's conclusions possess significant consequences for scientific education. Integrating socio-scientific topics into inquiry-based learning can markedly improve students' critical thinking abilities, essential for the 21st century. This method promotes scientific literacy and the capacity to assess intricate societal challenges through evidence and reasoning. The study emphasizes the importance for educators of integrating real-world issues like as obesity and GERD into the curriculum, facilitating students' connection of theoretical knowledge to practical, pertinent matters. Incorporating socio-scientific themes in education helps foster critical thinking among students regarding the social and ethical ramifications of scientific advancements.

Limitations the study provides significant insights into the influence of socio-scientific issues-based inquiry learning on critical thinking, although it has some drawbacks. The sample size was limited, consisting of only 64 students from two classes, potentially restricting the generalizability of the findings to a wider population. The study concentrated exclusively on one topic area digestive system biology indicating that the findings may not be directly relevant to other domains of science education. The study utilized a pretest-posttest design without random participant assignment, potentially leading to selection bias. Subsequent study may rectify these shortcomings by increasing the sample size, investigating other topic areas, and utilizing a randomized controlled trial methodology. Recommendations this study's findings yield various recommendations for future practice and research. Educators should integrate socio-scientific themes into inquiry-based learning activities to enhance critical thinking and engagement with the material. Future research may investigate the enduring impacts of this pedagogical paradigm on students' critical thinking capabilities and its ability to improve their decision-making skills across other academic fields. Moreover, subsequent study should investigate the implementation of this learning model throughout various educational environments, encompassing secondary and tertiary education, along with its incorporation of digital tools and technology to enhance accessibility and engagement. Broadening the range of socio-scientific issues and analyzing their effects on various student demographics could enhance the generalizability of these results.

4. CONCLUSION

The inquiry-based learning model based on socio-scientific issues has been proven effective in improving students' critical thinking skills with increasing N-gain of 0,94 or high category, especially their ability to recognize assumptions, analyze arguments, evaluate information, draw conclusions, and apply scientific reasoning reflectively. Therefore, the application of the inquiry-based learning model based on socio-scientific issues can be used as an alternative to science learning to develop critical thinking skills comprehensively. Further research could integrate inquiry-based learning models based on socio-scientific issues with interactive digital technology to increase student engagement and conceptual understanding.

ACKNOWLEDGEMENTS

We wish to convey our heartfelt appreciation to all who supported and contributed to the success of our research. We extend our profound gratitude to the students who engaged in this study, as their commitment and zeal rendered this research feasible. We express our appreciation to the Department of Science Education, Universitas Muhammadiyah Sidoarjo, for supplying essential resources and fostering a supportive research environment.

AUTHOR CONTRIBUTIONS

Drafting the initial draft of the article, Validation, Data collection, Data analysis, Article revision: Sabrina Oktavia Irawati. Methodology, Guidance, Article revision, Article finalization: Ria Wulandari.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] T. Tanti, D. A. Kurniawan, K. Kuswanto, W. Utami, and I. Wardhana, "Science process skills and critical thinking in science: Urban and rural disparity," *Jurnal Pendidikan IPA Indonesia*, vol. 9, no. 4, pp. 489-498, 2020, doi: 10.15294/jpii.v9i4.24139.

[2] A. Rahardhian, "Kajian kemampuan berpikir kritis (critical thinking skill) dari sudut pandang filsafat [Study of critical thinking skills from a philosophical perspective]," *J. Filsafat Indones*., vol. 5, no. 2, pp. 87–94, 2022, doi: 10.23887/jfi.v5i2.42092.

[3] R. Wijayanti dan J. Siswanto, "Profil kemampuan berpikir kritis siswa sma pada materi sumber-sumber energi [Profile of high school students' critical thinking skills on energy sources]," *J. Penelit. Pembelajaran Fis*., vol. 11, no. 1, pp. 109–113, 2020, doi: 10.26877/jp2f.v11i1.5533.

[4] I. J. Fitriyah, Y. Affriyenni, dan E. Hamimi, "Efektifitas model pembelajaran inkuiri terbimbing untuk meningkatkan kemampuan bepikir kritis mahasiswa [The effectiveness of guided inquiry learning models in improving students' critical thinking skills]," *Biormatika J. Ilm. Fak. Kegur. dan Ilmu Pendidik*., vol. 7, no. 2, pp. 122–129, 2021, doi: 10.35569/biormatika.v7i2.1017.

[5] H. Hairida, "The effectiveness using inquiry based natural science module with authentic assessment to improve the critical thinking and inquiry skills of junior high school students," *J. Pendidik. IPA Indones*., vol. 5, no. 2, pp. 209–215, 2016, doi: 10.15294/jpii.v5i2.7681.

[6] F. Dora, A. Afandi, A. B. Tenriawaru, W. Artika, dan T. Titin, "Pengaruh model guided inquiry disertai socioscientific issues terhadap keterampilan berpikir kritis siswa [The effect of guided inquiry model accompanied by socioscientific issues on students' critical thinking skills]," *J. Penelit. Sains dan Pendidik*., vol. 4, no. 1, pp. 95–107, 2024, doi: 10.23971/jpsp.v4i1.8033.

[7] Ariyana, Y., Pudjiastuti, A., Bestary, R., & Zamroni, *Buku Pegangan Pembelajaran Berorientasi pada Keterampilan Berpikir Tingkat Tinggi [Handbook for Learning Oriented towards Higher-Order Thinking Skills*], Jakarta: Direktorat Jenderal Guru Dan Tenaga Kependidikan Kementerian Pendidikan Dan Kebudayaan, 2018.

[8] I. Azmi, D. Sabda, dan B. Prasetya, "Profil berpikir kritis siswa smp pada mata pelajaran ipa [Critical thinking profile of junior high school students in science subjects]," *J. Classr. Action Res.*, vol. 7, no. 1, pp. 163–175, 2025, doi: 10.29303/jcar.v7i1.10570.

[9] Y. T. Akwantin, Y. Hidayati, N. Qomaria, L. K. Muharrami, dan I. Rosidi, "Profil tingkat kemampuan berpikir kritis siswa smp pada materi pemanasan global [Profile of junior high school students' critical thinking skills on global warming]," *Nat. Sci. Educ. Res*., vol. 5, no. 1, pp. 20–30, 2022, doi: 10.21107/nser.v5i1.12104.

[10] A. R. Hidayati, W. Fadly, dan R. F. Ekapti, "Analisis keterampilan berpikir kritis siswa pada pembelajaran ipa materi bioteknologi [Analysis of students' critical thinking skills in science learning biotechnology material]," *J. Tadris IPA Indones.*, vol. 1, no. 1, pp. 34–48, 2021, doi: 10.21154/jtii.v1i1.68.

[11] D. L. Kamsinah, A. Abdullah, dan S. Suryajaya., "Analysis of critical thinking skills in junior high school students," *J. Adv. Educ. Philos*., vol. 4, no. 6, pp. 234–237, 2020, doi: 10.36348/jaep.2020.v04i06.002.

[12] D. Darmaji, A. Astalini, D. A. Kurniawan, A. P. Ningsi, D. D. Romadona, dan R. W. Dari, "Regression of science process skills on critical thinking skills in two junior high schools in Jambi City," *JIPF (Jurnal Ilmu Pendidik. Fis*., vol. 5, no. 3, pp. 177, 2020, doi: 10.26737/jipf.v5i3.1788.

[13] A. Br Sembiring and E. Yusnaldi, "The impact of contextual teaching and learning on students' cognitive abilities in material of my region my pride", *JSWSE*, vol. 6, no. 3, pp. 1275–1288, 2025, doi: 10.52690/jswse.v6i3.1250.

[14] S. N. Qamariyah, S. Rahayu, F. Fajaroh, dan N. M. Alsulami, "The effect of implementation of inquiry-based learning with socio-scientific issues on students' higher-order thinking skills," *J. Sci. Learn*., vol. 4, no. 3, pp. 210–218, 2021, doi: 10.17509/jsl.v4i3.30863.

[15] T. Tanti, D. Darmaji, A. Astalini, D. A. Kurniawan, and M. Iqbal, "Analysis of user responses to the application of web-based assessment on character assessment," *Journal of education technology*, vol. 5, no. 3, pp. 356-364, 2021, doi: 10.23887/jet.v5i3.33590.

[16] A. Yuniswara, Erman, dan B. Ilham, "Peningkatan keterampilan berpikir kritis siswa terhadap pembelajaran inkuiri berbasis socio-scientific issues [Improvement of students' critical thinking skills in inquiry-based learning using socio-scientific issues]," *BIOCHEPHY J. Sci*., vol. 4, no. 1, hal. 447–457, 2024, doi: 10.52562/biochephy.v4i1.1190.

[17] S. Sa'adah, A. Y. R. Wulandari, A. Fikriyah, dan L. K. Muharrami, "Analisis kemampuan berpikir kritis siswa smp materi pemanasan global dengan sola berbasis pendekatan socioscientific issues (SSI) [Analysis of junior high school students' critical thinking skills on global warming using the socioscientific issues (SSI) Approach]," *Nat. Sci. Educ. Res*., vol. 4, no. 3, pp. 231–241, 2022, doi: 10.21107/nser.v4i3.8516.

[18] D. Setiadi dan E. P. Putra, "Pengembangan modul pembelajaran ipa berbasis socio scientific issues (SSI) materi sistem pernapasan manusia untuk siswa kelas viii smp [Development of science learning modules based on socio-scientific issues (ssi) on the human respiratory system for eighth grade junior high school students]," *Indones. J. Math. Nat. Sci. Educ*., vol. 2, no. 2, pp. 126–134, 2021, doi: 10.35719/mass.v2i2.73.

[19] S. R. Ramadhani dan E. Susiyawati, "Pembelajaran ipa berbasis socio scientific issues untuk meningkatkan kemampuan literasi sains siswa [Science learning based on socio-scientific issues to improve students' science literacy skills]," *BIOCHEPHY J. Sci. Educ*., vol. 5, no. 1, pp. 473–478, 2025, doi: 10.52562/biochephy.v5i1.1524.

[20] M. T. P. Putra, "Kajian literatur sistematis: integrasi model inkuiri berbasis socioscientific issues pada pembelajaran ipa [Systematic literature review: Integration of socioscientific issues-based inquiry model in science learning]," *Jurnal Pendidikan MIPA*, vol. 12, no. 3, pp. 919–928, 2022, doi: 10.37630/jpm.v12i3.704.

[21] H. Sa'diyah dan S. Aini, "Model pembelajaran inkuiri pada perkembangan berfikir kritis siswa: Literature review [Inquiry-Based learning models in the development of students' critical thinking: Literature review]," vol. 1, no. 1, pp. 73–80, 2022, doi: 10.46306/jpee.v1i1.8.

[22] N. Ketut Rapi, R. Sujanem, L. P. B. Yasmini, and K. Setemen, "Science process skills and critical thinking skills in inquiry-based learning model with project-based assessment," *International Journal of Innovative Research and Scientific Studies*, vol. 8, no. 2, pp. 938–946, 2025, doi: 10.53894/ijirss.v8i2.5393.

[23] D. Rahayu, "The effectiveness of socioscientific issue-based learning implementation as science learning material to improve learning motivation and critical thinking skills," *Journal of Innovation in Education and Curriculum Research (JIECR)*, vol. 3, pp. 118–128, 2022. doi: 10.62486/jiecr.v3i118.
[24] F. D. Devi dan E. Hariyono, "Pembelajaran materi perubahan iklim dengan model guided inquiry menggunakan pendekatan socio scientific issues (ssi) untuk meningkatkan keterampilan berpikir kritis peserta didik sma [Learning climate change material with the guided inquiry model using the socio scientific issues (ssi) approach to improve critical thinking skills of high school students]," *J. Ilmu Pendidik. dan Pembelajaran*, vol. 03, no. 01, pp. 16–24, 2024, doi: 10.58706/jipp.v3n1.p16-24.
[25] L. Fihani, Neti Hikmawati, Vitta Mu'minah, "Pendekatan socio-scientific issue (ssi) untuk meningkatkan keterampilan berpikir kritis siswa [The socio-scientific issue (ssi) approach to improve students' critical thinking skills]," *Semin. Nas. Pendidikan, FKIP UNMA 2021 "System Think. Ski. dalam Upaya Transform. Pembelajaran di Era Soc. 5.0"*. Agustus 2021, pp. 186–192, 2021.
[26] N. Ni'mah, "Analisis indikator berpikir kritis terhadap karakter rasa ingin tahu dalam kurikulum 2013 [Analysis of critical thinking indicators on the character of curiosity in the 2013 curriculum]," *Anterior J.*, vol. 22, no. Special-1, pp. 118–125, 2022, doi: 10.33084/anterior.v22ispecial-1.3220.
[27] C. K. Assuah, G. K. Mantey, dan L. Osei, "The effect of think-pair-share learning on junior high school students' achievement in algebraic expressions: Pre-test-Post-test Non-equivalent control group design," *Asian J. Probab. Stat.*, vol. 20, no. 2, pp. 46–55, 2022, doi: 10.9734/ajpas/2022/v20i2418.
[28] I. Abraham dan Y. Supriyati, "Desain kuasi eksperimen dalam pendidikan: Literatur review [Quasi-Experimental design in education: A literature review]," *J. Ilm. Mandala Educ.*, vol. 8, no. 3, pp. 2476–2482, 2022, doi: 10.58258/jime.v8i3.3800.
[29] Mardhiyah, N. A. Dinilhaq, Y. Amelia, A. Arini, R. Hidayatullah, dan Harmonedi, "Populasi dan sampel dalam penelitian pendidikan: Memahami perbedaan , implikasi , dan strategi pemilihan yang tepat [Population and sample in educational research: Understanding the differences, implications, and appropriate selection strategies]," *Katalis Pendidik. J. Ilmu Pendidik. dan Mat.*, vol. 2, no. 2, hal. 208–218, 2025, doi: 10.62383/katalis.v2i2.1670.
[30] N. U. Sa'idah, E. Handoyo, S. Supriyadi, and W. Sumarni, "Development of a critical thinking skills assessment instrument for elementary school science lessons on earth changes," *Journal of Elementary School Education*, vol. 5, no. 1, 2025, doi: 10.15294/jese.v5i1.6297.
[31] A. Triyono, R. H. Nuary, N. Permatasari, Y. Yuni, dan T. Wibowo, "The level of effectiveness of tps and conventional methods judging from students' geometry learning results using the n-gain test," *AlphaMath J. Math. Educ.*, vol. 10, no. 1, pp. 125, 2024, doi: 10.30595/alphamath.v10i1.21530.
[32] A. V. Chatzi, "Understanding the independent samples t test in nursing research," *British Journal of Nursing*, vol. 34, no. 1, pp. 56–62, 2025, doi: 10.12968/bjon.2024.0133.
[33] C. L. Kimberlin and A. G. Winterstein, "Validity and reliability of measurement instruments used in research," *American Journal of Health-System Pharmacy*, vol. 65, no. 23, pp. 2276–2284, Dec. 2008, doi: 10.2146/ajhp070364.
[34] B. J. Forester, A. I. A. Khater, M. W. Afgani, dan M. Isnaini, "Quantitative research: Data reliability test," *Edu Soc. J. Pendidikan, Ilmu Sos. dan Pengabdi. Kpd. Masy.*, vol. 4, no. 3, hal. 1812–1820, 2024, doi: 10.56832/edu.v4i3.577.
[35] I. Ghozali, *Aplikasi Analisis Multivariate dengan Program IBM SPSS 23 [Multivariate Analysis Application with IBM SPSS 23 Program]*, 8th ed. Semarang: Badan Penerbit Universitas Diponegoro, 2016.
[36] I. Setianingsih, R. Ismawati, dan E. Juliyanto, "The effectiveness of inquiry-based learning in the context of socioscientific issues (SSI) in improve students' critical thinking skills and global citizen character," *J. Pendidik. Sains*, vol. 13, no. 1, pp. 1–12, 2025, doi: 10.26714/jps.13.1.2025.1-12.
[37] A. Yuniswara, Erman, dan B. Ilham, "Peningkatan keterampilan berpikir kritis siswa terhadap pembelajaran inkuiri berbasis socio-scientific issues [Improving students' critical thinking skills in inquiry learning based on socio-scientific issues]," *BIOCHEPHY J. Sci.*, vol. 4, No. 1, no. 1, pp. 447–457, 2024, doi: 10.52562/biochephy.v4i1.1190.
[38] S. N. Qamariyah, S. Rahayu, F. Fajaroh, dan N. M. Alsulami, "The effect of implementation of inquiry-based learning with socio-scientific issues on students' higher-order thinking skills," *Journal of Science Learning*, vol. 4, no. 3, pp. 210–218, 2021, doi: 10.17509/jsl.v4i3.30863.
[39] I. Mahanani, S. Rahayu, dan F. Fajaroh, "Pengaruh pembelajaran inkuiri berkonteks socioscientific-issues terhadap keterampilan berpikir kritis dan scientific explanation [The effect of socioscientific-issues contextual inquiry learning on critical thinking skills and scientific explanation]," *J. Kependidikan*, vol. 3, no. 1, pp. 53–68, 2019, doi: 10.21831/jk.v3i1.20972.
[40] N. Dusturia, S. Nurohman, dan I. Wilujeng, "Socio-Scientific issues (ssi) approach implementation in science learning to improve students' critical thinking skills: Systematic literature review," *J. Penelit. Pendidik. IPA*, vol. 10, no. 3, pp. 149–157, 2024, doi: 10.29303/jppipa.v10i3.6012.
[41] D. L. Zeidler dan B. H. Nichols, "Socioscientific Issues: Theory and practice," *J. Elem. Sci. Educ.*, vol. 21, no. 2, pp. 49–58, 2009.
[42] G. Amalia, E. Ellianawati, dan S. Alimah, "The effectiveness of an e-module based on socio-scientific issues to improve critical thinking," *Unnes Sci. Educ. J.*, vol. 13, no. 2, pp. 53–60, 2024, doi: 10.15294/usej.v13i1. 4169.
[43] A. I. K. Dewi, S. Suyono, dan E. Erman, "Effectiveness of socioscientific issues (ssi) based learning to improve argumentation skills," *J. Penelit. Pendidik. IPA*, vol. 9, no. 1, pp. 279–283, 2023, doi: 10.29303/jppipa.v9i1.2866.
[44] A. S. Tumanggor dan U. N. A. D. Jayanti, "The socio-scientific inquiry assisted by mind mapping effect on students' critical thinking skills in the digestive system material," *BIO-INOVED J. Biol. Pendidik.*, vol. 6, no. 2, pp. 146–153, 2024, doi: 10.20527/bino.v6i2.19054.
[45] F. W. Wulansari dan N. R. Dewi, "Development of guided inquiry learning tools using socio-scientific issue to train critical thinking ability and care for the environment of students," *J. Environ. Sci. Educ.*, vol. 2, no. 1, [[. 7–19, 2022, doi: 10.15294/jese.v2i1.50465.

[46] M. del M. López-Fernández, F. González-García, dan A. J. Franco-Mariscal, "How can socio-scientific issues help develop critical thinking in chemistry education? a reflection on the problem of plastics," *J. Chem. Educ*., vol. 99, no. 10, hal. 3435–3442, 2022, doi: 10.1021/acs.jchemed.2c00223.

[47] Maryam dan H. Suwono, "Assessing the effect of socio-scientific inquiry-based learning on socio-scientific decision-making skill among senior high school students," *Jurnal Penelitian Pendidikan IPA*, vol. 9, no. 11, pp. 10083–10090, 2023, doi: 10.29303/jppipa.v9i11.5067.

[48] T. Tanti, W. Utami, D. Deliza, and M. Jahanifar, "Investigation in vocation high school for attitude and motivation students in learning physics subject," *Journal Evaluation in Education (JEE)*, vol. 6, no. 2, pp. 479-490, 2025, doi: 10.37251/jee.v6i2.1452.

[49] A. D. Utami, S. Kurniasih, dan I. D. Pursitasari, "Development of global warming e-module based on socio scientific issues (ssi) to improve students' critical thinking skills and sustainability awareness," *J. Penelit. Pendidik. IPA*, vol. 9, no. SpecialIssue, pp. 224–232, 2023, doi: 10.29303/jppipa.v9ispecialissue.6008.

[50] M. R. Aisy, E. Trisnowati, dan S. Siswanto, "The effect of the problem-based learning (pbl) model in the context of socio-scientific issues (ssi) on critical thinking ability on digestive system material," *J. Inov. Pendidik. IPA*, vol. 10, no. 2, pp. 185–195, 2024, doi: 10.21831/jipi.v10i2.75231.