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ORIGINAL

Fostering Students' Creativity and Scientific Attitudes Through a Digital Socio-Scientific Issues (SSI)-Based Learning Module

Fomentar la creatividad y las actitudes científicas de los estudiantes mediante un módulo digital basado en cuestiones socio-científicas (SSI)

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ABSTRACT

Introduction: socio-Scientific Issues (SSI) learning connects science with real-world contexts and promotes creativity and scientific attitudes essential for 21st-century education. Despite its potential, SSI-based learning is rarely integrated into digital modules for elementary schools in Indonesia.
Objective: this study aimed to examine the effectiveness of a digital SSI-based learning module in fostering students' creativity and scientific attitudes in elementary science education.
Method: a parallel convergent mixed-methods design with a quasi-experimental approach was used. The participants were 93 fifth-grade students (47 males, 46 females) from B-accredited public elementary schools in Sragen Regency, Indonesia, divided into experimental and control groups. The experimental group learned with a digital SSI-based module, while the control group used conventional methods. Quantitative data on creativity were collected using a modified Torrance Tests of Creative Thinking (TTCT), and qualitative data on scientific attitudes were obtained through observations and teacher interviews. Data were analyzed using descriptive statistics, t-tests, and thematic analysis with SPSS version 27.
Results: the findings showed that the digital SSI-based module significantly improved students' creativity and scientific attitudes compared to conventional learning. The effect size (Cohen's d = 1,88) indicated a strong influence, and qualitative analysis revealed enhanced curiosity, openness, honesty, and collaborative behavior.
Conclusions: integrating SSI into digital modules effectively promotes creativity and scientific attitudes among elementary students. The study recommends adopting SSI-based digital learning to strengthen 21st-century competencies and encourage critical, creative, and socially aware learners.

Keywords: Socio-Scientific Issues; Creativity; Scientific Attitudes; Digital Module; Science Education; 21st Century.

RESUMEN

Introducción: el aprendizaje basado en Cuestiones Socio-Científicas (SSI) conecta la ciencia con contextos del mundo real y promueve la creatividad y las actitudes científicas esenciales para la educación del siglo XXI. A pesar de su potencial, el aprendizaje basado en SSI rara vez se integra en módulos digitales para escuelas primarias en Indonesia.
Objetivo: el objetivo de este estudio fue examinar la eficacia de un módulo de aprendizaje digital basado en SSI para fomentar la creatividad y las actitudes científicas de los estudiantes en la educación científica primaria.

Método: se utilizó un diseño mixto convergente paralelo con un enfoque cuasi-experimental. Los participantes fueron 93 estudiantes de quinto grado (47 varones y 46 mujeres) de escuelas primarias públicas acreditadas con nivel B en el distrito de Sragen, Indonesia, divididos en grupos experimental y de control. El grupo experimental aprendió con un módulo digital basado en SSI, mientras que el grupo de control utilizó métodos convencionales. Los datos cuantitativos sobre la creatividad se obtuvieron mediante una versión modificada del Torrance Tests of Creative Thinking (TTCT), y los datos cualitativos sobre las actitudes científicas se recopilaron mediante observaciones y entrevistas a los docentes. Los datos se analizaron mediante estadísticas descriptivas, pruebas t y análisis temático con SPSS versión 27.

Resultados: los resultados mostraron que el módulo digital basado en SSI mejoró significativamente la creatividad y las actitudes científicas de los estudiantes en comparación con el aprendizaje convencional. El tamaño del efecto (Cohen's d = 1,88) indicó una influencia fuerte, y el análisis cualitativo reveló una mayor curiosidad, apertura, honestidad y comportamiento colaborativo.

Conclusiones: la integración de SSI en módulos digitales promueve eficazmente la creatividad y las actitudes científicas entre los estudiantes de primaria. El estudio recomienda adoptar el aprendizaje digital basado en SSI para fortalecer las competencias del siglo XXI y fomentar aprendices críticos, creativos y socialmente conscientes.

Palabras clave: Cuestiones Socio-Científicas; Creatividad; Actitudes Científicas; Módulo Digital; Educación Científica; Siglo XXI.

INTRODUCTION

21st-century education requires mastery of skills such as creativity, critical thinking, collaboration, and communication. Creativity is recognised as a key skill that should be developed widely [(1)] to equip individuals to think critically, solve real problems, innovate, and make optimal use of information technology.[(2)] This competence needs to be instilled from basic education [(3)] through a paradigm that integrates literacy, competence, and academic achievement.[(4)] Relevant social issue-based learning has been developed to measure 21st-century skills and provide practical benefits to educators and learners.[(5,6)]

Creativity helps learners come up with innovative new ideas and solutions. These skills, along with critical thinking, play an important role in learning achievement and socio-economic sustainability.[(7,8,9)] Teachers play a crucial role in growing it through a learning environment that stimulates and values diverse ideas.[(10,11,12)] Creative learning and interactive technology are proven to increase student innovation.[(13)] Meanwhile, creativity itself is a prerequisite as well as the result of the innovation process to solve real problems.[(14,15)]

Scientific attitudes form the habit of thinking logically, objectively, and curiously about natural phenomena. Curiosity encourages active engagement in scientific learning and discovery,[(16,17)] and if instilled early, it can trigger long-term interest in science and scientific careers.[(18,19)] This attitude trains individuals to critically analyze and verify information and be open to changes in knowledge based on new evidence.[(20,21)] The Socio-Scientific Issues (SSI) approach is relevant to foster scientific attitudes while supporting sustainable development in the digital era.[(22,23)]

The Socio-Scientific Issues (SSI) approach connects science learning with relevant social issues, making it more engaging and meaningful. The use of SSI can increase students' interest and confidence in science, although it does not always have a direct impact on factual knowledge,[(24,25)] and develop critical thinking skills, evidence-based decision-making, and understanding of social values.[(26,27,28)] By linking scientific concepts to real-life issues such as environmental issues and social justice, students gain more relevant learning and a deeper understanding.[(29,30)] This approach also strengthens scientific literacy, improves learning outcomes, and prepares students for the challenges of modern society.[(31,32,33)]. The integration of inquiry-based learning in SSI encourages students' active engagement with social challenges and builds a more comprehensive understanding.[(34)]

Lack of knowledge, experience, and the underutilization of innovative and creative learning media are obstacles in education. Limited media variety, technology support, and resources hinder student engagement and adoption of innovative learning.[(35,36)] Limited access to training makes teachers' pedagogic competence not optimal,[(37,38)] which contributes to the low literacy of Indonesian students, of which 70 % are in the low category based on PISA results.[(39)] In fact, relevant and easily accessible media can increase students' interest and understanding.[(40)] However, the culture of learning innovation is often hampered by organizational strategies that are more exploitative than exploratory.[(41,42)]

Conventional learning that focuses on memorization and single answers limits exploration, so the development of creative thinking, curiosity, healthy scepticism, and openness to evidence is inhibited. The traditional model makes students passive, oriented to factual knowledge, and rarely associates the material with real problems,[(43,44)] while the emphasis on memorization and standardized tests stifles creativity.[(12)] As a result, students' creative thinking skills and scientific attitudes are low,[45] reflected in Indonesia's PISA score of only 19 out of 60 points, below the average.[46] The shift towards exploratory and creative learning is an urgent need.[47]

The implementation of the SSI approach is limited because learning does not fully integrate social issues relevant to the context of students' lives. Limited knowledge and experience of teachers, time, facilities, and learning resources are the main obstacles.[48] A curriculum that focuses on factual content and lacks practical guidance makes it difficult for teachers to relate science material to social issues,[49] including the challenges of managing discussions, selecting appropriate issues, and facilitating effective debate.[50] This condition creates a gap between the science learning objectives and the skills produced in elementary school students.

This research is important because SSI-based learning can increase students' awareness of social and environmental issues while encouraging active participation in discussions and decision-making. This study offers novelty through SSI's learning design that is specifically geared towards developing the creativity and scientific attitude of elementary school students, to measure its effectiveness in improving both skills

METHOD

Research Design

This study employed a parallel convergent mixed methods design with a quasi-experimental approach for the quantitative part. This design combines quantitative and qualitative approaches simultaneously to obtain comprehensive results from numerical data and qualitative narratives.[51] The quantitative phase adopted a pretest–posttest control group design to evaluate differences in creativity improvement between the experimental and control groups.

Participants

The participants were 93 Grade V students from B-accredited public elementary schools in Sragen Regency, Central Java, Indonesia. Schools were selected using purposive sampling based on curriculum implementation, active natural and science programs, and readiness for digital learning. Sragen was selected because digital learning initiatives have begun to grow but SSI-based instruction remains limited.

The sample consisted of 48 students in the experimental group and 45 students in the control group. Participants were 10–11 years old, comprising 47 males and 46 females. The experimental group received instruction using a digital Socio-Scientific Issues (SSI)-based teaching module, while the control group received conventional instruction aligned with the school curriculum. The choice of Grade V students was based on their cognitive readiness to engage in socio-scientific reasoning, as they have developed abstract thinking and moral judgment abilities appropriate for understanding real-world scientific issues.[52]

The control group received standard curriculum-based instruction commonly practiced in the participating schools. Teaching relied on the national science textbook, teacher explanations through lecture-based delivery, and written exercises.

Data Collection

The study was conducted over six weeks, consisting of an initial diagnostic phase, four weeks of implementation, and one week for post-assessment and reflection. The six-week duration was determined based on the school's teaching schedule and to ensure that the SSI-based intervention could be implemented without disrupting the regular curriculum flow.

Quantitative data on students' creativity were collected using a creativity test modified from the Torrance Tests of Creative Thinking (TTCT), consisting of 10 open-ended questions that measured fluency, flexibility, originality, and elaboration. Modifications to the TTCT involved contextualizing items to local environmental and socio-scientific themes.

Instrument Validation

The research instruments were validated by three experts in the fields of science education and educational evaluation from Universitas Sebelas Maret and Universitas Negeri Yogyakarta. The validity coefficient of the creativity test items ranged from 0,72 to 0,86 (high validity), while the reliability test using Cronbach's Alpha yielded a value of 0,89, indicating high internal consistency. The observation sheet and interview guidelines were also validated to ensure construct relevance and content accuracy.

Data Analysis

Quantitative data were analyzed using descriptive statistics, paired-samples t-tests, independent-samples t-tests, and effect size calculations to evaluate differences in creativity between the experimental and control groups. Normality and homogeneity tests were conducted prior to inferential analysis using SPSS version 27 to ensure the fulfillment of statistical assumptions. Qualitative data were analyzed through thematic analysis, identifying emerging themes related to the development of students' scientific attitudes. The results from both methods were then integrated to provide a comprehensive interpretation of the digital SSI-based module's effectiveness.

This study employed a parallel convergent mixed methods design with a quasi-experimental approach for the quantitative part. This design combines quantitative and qualitative approaches simultaneously, so that numerical data and qualitative narratives can become comprehensive results.[51] The quantitative part employed a pretest-posttest control group design to evaluate differences in creativity improvement between the experimental and control groups.

RESULTS

Students' Creativity

SSI-based learning was applied to the experimental group, while the conventional learning model was applied to the control group in the science learning program. Before learning starts, students are given a pretest, and after learning is completed, they are given a posttest. Pretest scores describe the level of creativity and scientific attitude of learners before the intervention, while posttest scores show the level of achievement after the implementation of SSI-based learning.

Table 1. Descriptive statistics of pretest and posttest scores

Group	Phase	N	M ± SD	Score Range
Control	Pretest	45	44,49 ± 5,38	35 - 55
	Posttest	45	77,89 ± 5,23	68 - 88
Experiment	Pretest	48	54,94 ± 5,30	45 - 63
	Posttest	48	87,48 ± 4,98	78 - 97

Descriptive analysis showed that the experimental group's pretest score (M = 54,94) was higher than that of the control group (M = 44,49). In the posttest, both groups experienced improvement, but the experimental group (M = 87,48) was superior to the control (M = 77,89), indicating the effectiveness of SSI-based learning in increasing creativity.

Table 2. Normality, Homogeneity, and t-Test Test Results

Analysis	Group	Statistical Value	p/Sig.	Results
Normality Test (Kolmogorov-Smirnov)	Pretest Control	0,087	0,200	Normal
	Pretest Experiment	0,114	0,150	Normal
	Posttest Control	0,073	0,200	Normal
	Posttest Experiment	0,096	0,200	Normal
Homogeneity Test (Levene's Test)	Pretest	0,001	0,975	Homogeneous
	Posttest	0,055	0,815	Homogeneous
Independent t-Test	Posttest	t = -9,060	<0,001	There is a significant difference

The results of the Kolmogorov-Smirnov normality test showed that all pretest and posttest data in both groups were normally distributed ($p > 0,05$). The homogeneity test of Levene's Test showed the variance of both homogeneous groups in both pretest and posttest ($p > 0,05$). The results of the independent sample t-test posttest showed significant differences between the experimental and control groups ($t = -9,060$, $p < 0,001$), indicating that SSI-based learning had a positive effect on improving student learning outcomes compared to conventional learning.

Table 3. Effect Size and N-Gain

Analysis	Group	Value	Category
Effect Size (Cohen's d)	-	1,88	Very Large
N-Gain	Experiment	0,731 (73,09 %)	Tall
	Control	0,606 (60,63 %)	Keep

The effect size value of 1,88 shows a considerable influence of SSI-based learning on improving learning outcomes compared to conventional learning. The increase in learning outcomes was also reflected in the

N-Gain score, where the experimental group reached the high category (73,09 %), while the control group was in the medium category (60,63 %). These results indicate that the application of SSI is practical in significantly increasing student achievement and is more optimal than conventional methods.

The three best posters from the experimental class were selected based on students' creativity in addressing environmental change. The poster shows the understanding of scientific concepts, the relationship to social issues, and visual innovation (figure 1).

Figure 1. Student-made products in learning with the SSI approach

Scientific Attitudes

Observations show that students' curiosity increases with the implementation of SSI-based learning. At the initial meeting, students only answer the teacher's questions without much initiative to ask. However, starting with the second meeting, students seem to be asking more investigative questions, such as "How do we know the water quality is bad?" or "What causes the air in this area to be dirtier than others?". These questions show an impulse to understand the phenomenon more deeply.

The indicator of honesty can be seen from the way students report data and admit mistakes during the information collection process. Some students voluntarily correct the erroneous data after finding a more accurate source of information. For example, in a project on plastic waste, one group corrected the amount of waste they recorded after realising a miscalculation. This behaviour shows academic integrity that begins to form through the habit of critical and analytical thinking.

Students' open-mindedness is reflected in their willingness to accept and consider ideas or evidence that differ from their initial views. When discussing the issue of environmental change, some students who initially showed little interest in environmental issues became open to the material and developed a greater interest in the natural environment. This process demonstrates the ability to adjust views based on new evidence, which is one of the core scientific attitudes.

The results of the interviews confirmed that SSI-based learning sparked students' curiosity. One student said, "If there is a problem in the environment, I want to find out the cause, not just wait for an answer from the teacher." Other students said that they were encouraged to seek additional information at home to complement the knowledge gained in class, indicating the existence of continuous learning motivation.

Some students said that they learned to be honest in conveying the results of their work. One respondent said, "If the data is wrong, it is better to change it than to pass it on." Some emphasise that this learning makes them understand the importance of using reliable sources of information. These findings indicate that SSI-based learning can strengthen honesty in the scientific process.

Interviews also revealed that students feel more open to different views after participating in SSI-based learning. One student said, "I used to think there was only one answer; now I know there can be many ways to solve a problem." The results show that students begin to develop flexibility in thinking and a willingness to consider alternative solutions based on existing evidence.

Documentation of project activities is done to record student engagement during the SSI-based learning process.

Figure 2. Students observe issues around from digital learning module

Figure 3. Students working on poster projects

Figure 4. The teacher explains to the students about project work

Figure 5. Students present their poster products

DISCUSSION

The results of the study show that learning based on Socio-Scientific Issues (SSI) can overcome the weaknesses of conventional learning that focuses on memorisation and single answers, by providing space for students to develop creative ideas and actively apply scientific attitudes. The increase in creativity in the experimental group by 18,7 % and scientific attitude by 15,3 % confirms SSI's effectiveness in building critical thinking skills and fundamental problem-solving skills through discussion and argumentation, according to the findings Hernández-Ramos et al.[53] This significant increase is also in line with the report Siew et al.[54], which shows that SSI improves science literacy, scientific argumentation, and future thinking ability. This success shows that SSI can motivate students to be actively involved and connect science with everyday life.[55] The intervention in this study was supported by a digital SSI-based learning module containing structured readings, problem scenarios, multimedia explanations, and guided questions that directed students to analyse, argue, and propose solutions. The module provided consistent scaffolding that ensured students engaged with the SSI content in a systematic manner.

A significant increase in creativity scores and scientific attitudes in the experimental group also showed that SSI encouraged engagement and evidence-based decision-making, as outlined by Bicaj et al.[22] and Idema et al.[56] These results support the positive relationship between scientific attitudes and scientific creativity, as suggested by Koç et al.[57] Active learning through SSI increases students' interest in learning about social-scientific issues [58] and strengthens science literacy that connects science with social context and practical impact.[59] This finding aligns with previous research, as the data analysis and argumentation activities in SSI directly train students to think creatively and adopt a scientific attitude. These activities are the primary reason why the improvements are consistent with previous studies. Factors such as the method of implementation and the characteristics of learners contribute to the effectiveness of SSI, although the limitations of the sample and the duration of the intervention need to be taken into consideration in generalising outcomes.[54]

These findings indicate that the use of media and contextual learning activities can be an effective strategy to bridge the gap between science learning objectives and the achievement of scientific skills of primary school students. Contextual media facilitates the understanding of abstract concepts while increasing motivation and encouraging students to actively ask, discuss, and solve problems, according to the findings of Mahler et al.[60] The integration of contextual learning activities with media that is designed as needed and relevant to students' lives strategically strengthens the development of scientific skills, as explained by Idema et al.[56] and Roemmele et al.[61] The results of this study confirm that the use of media and contextual activities plays an important role in improving students' science process and metacognitive skills, which is in line with the findings of Pertiwi et al. and Suryandari et al.[62], and also reflects a significant improvement in the scientific skills indicators in this study. This effectiveness arises because digital media allows for more concrete visualization of socio-scientific issues, while contextual activities provide space for students to connect scientific information to everyday experiences. The combination of the two strengthens experiential learning mechanisms that stimulate in-depth understanding.

The data shows that learners are driven to think critically, formulate solutions, and defend evidence-based arguments, which are the cornerstones of 21st-century skill mastery. This process strengthens students' confidence and social responsibility[63] and their science literacy through activities such as debate and role-playing.[64] SSI encourages complex real-world argumentation and problem-solving skills[65] by integrating scientific knowledge and social, ethical, and moral considerations.[66] This approach also develops creativity and the ability to work together [67,68] in line with 21st-century skills development goals.[69] This improvement occurs because SSI provides authentic situations that require students to consider multiple points of view, so they become accustomed to combining data, social values, and scientific evidence in their thinking processes.

This study provides empirical evidence that the application of SSI can be expanded at the elementary school level as a systematic effort to develop creativity, scientific attitudes, and competencies in the 21st century. SSI facilitates active, group-based learning that allows for communication and teamwork exercises,[70] as well as the development of problem-solving skills from an early age. Although the long-term impact of 21st-century skills shaped by childhood may be limited,[68] these results confirm the important role of SSI in equipping students from the early stages of education.[71] This application shows that the SSI approach is not only effective in improving cognitive abilities and scientific attitudes, but is also realistic to be applied at the elementary school level because it is in accordance with students' social and emotional development.

Beyond confirming previous research, this study extends existing theories by demonstrating how the combination of SSI pedagogy and digital learning design can synergistically foster both cognitive (creativity) and affective (scientific attitude) domains in elementary science education. While prior studies have explored SSI primarily in face-to-face settings, this research provides empirical evidence of its effectiveness in a digital environment, thereby offering a novel pedagogical perspective for 21st-century science learning. The digital format allows socio-scientific issues to be presented through multimodal representations and structured interactive tasks that deepen students' engagement with the content. This integrated design enhances the core SSI processes of exploration, analysis, and argumentation, enabling students to elaborate ideas more extensively and make evidence-based decisions with greater confidence. The findings broaden existing SSI theory by showing that digital media does not merely replicate face-to-face instruction but can strengthen the experiential and reflective dimensions of SSI learning, especially at the elementary level.

Limitations

This study has several limitations. The sample size was small and taken from a single regency, which restricts the generalisation of the findings. The six-week intervention provided only a short period to observe deeper or long-term changes in students' creativity and scientific attitudes. Teacher-related factors may also have influenced the outcomes because differences in teaching style or familiarity with SSI and digital tools could affect how the intervention was delivered. These limitations suggest the need for broader samples, longer implementation periods, and more controlled teaching conditions in future studies.

Implications

The findings indicate that SSI-based digital learning has practical potential to be used more widely in elementary science instruction because it helps strengthen creativity and scientific attitudes through real-life issues and interactive activities. The results also highlight the need for curriculum materials that integrate socio-scientific themes to make science learning more relevant and meaningful for students. Future research may extend this work by involving larger samples, longer implementation periods, and more controlled teaching conditions to obtain stronger and more generalisable evidence.

CONCLUSION

This study concludes that integrating Socio-Scientific Issues (SSI) into a digital learning module effectively fosters students' creativity and scientific attitudes in elementary science education. The combination of digital interactivity and real-world contexts provided students with meaningful opportunities to explore ideas, express creativity, and engage in scientific reasoning. The implementation of the digital SSI-based learning module supports the development of 21st-century competencies by encouraging curiosity, collaboration, and critical inquiry among young learners.

From a practical perspective, this research highlights the importance of utilizing digital tools to contextualize science learning and make it more relevant to students' daily experiences. Teachers are encouraged to integrate SSI-based digital materials into their classroom instruction to promote active learning and foster creative and scientific mindsets.

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CONFLICT OF INTEREST

The authors state no conflict of interest.

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ETHICAL CONSIDERATIONS

Ethical approval was obtained from the university's ethics committee. Written informed consent was obtained from parents or guardians, and verbal assent was obtained from all student participants. Participation was voluntary, and all student identities were anonymized.

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