BIO-INOVED
Jurnal Biologi-Inovasi Pendidikan
Volume 8, Issue 2, June 2026 page. 309-321

P-ISSN : 2684-9062 | E-ISSN : 2714-9803
https://ppjp.ulm.ac.id/journal/index.php/bino
DOI: 10.20527/bino.v8i2.25438

The effectiveness of SSI-based digital science book on Jetis Sidoarjo batik waste to improving higher order thinking skills

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Article Information

Keyword:
Digital science books; Socioscientific issues; Higher-order thinking skills; Batik waste; Environmental pollution

Kata Kunci:
Buku digital IPA; Isu sosiosains; Keterampilan berpikir tingkat tinggi; Limbah batik; Pencemaran lingkungan

History:
Received : 03/02/2026
Revised : 05/06/2026
Accepted : 10/06/2026
Published : 28/06/2026

Abstract

Enhancing higher order thinking skills (HOTS) in science education poses a difficulty due to the limitation of digital teaching resources focused on local environmental issues that facilitate students' abilities in analysis (C4), evaluation (C5), and creation (C6). The novelty in its examination of a digital textbook addressing the Jetis Sidoarjo batik waste issue as a contextual medium to enhance HOTS in the C4, C5, and C6 indicators. This research aims to evaluate the effectiveness of a digital science textbook based on Socioscientific Issues (SSI) in enhancing students' HOTS. This research specifically examines: the validity of the SSI-based digital science textbook, the enhancement of students' HOTS after using the digital textbook, and the disparities in student learning results between digital and conventional textbooks. This research uses a quasi-experimental approach with a nonequivalent pretest-posttest control-group design. The research instruments comprise a HOTS test, expert validation forms, and documentation of learning results. The findings indicate that the developed digital textbook has valid criteria and very high quality. The experimental class' N-Gain score of 0.72 is in the high category, indicating that the use of digital textbook is effective in improving students' HOTS. The experimental class showed higher improvements than the control class in the C4, C5, and C6 indicators. The integration of the Jetis Sidoarjo batik waste issue encouraged students to actively analyze, evaluate, and propose solutions to environmental problems in their surrounding context. These findings suggest that SSI-based digital teaching materials can be an effective pedagogical alternative to facilitate contextual science learning and fostering HOTS.

Abstrak. *Penguatan keterampilan berpikir tingkat tinggi (HOTS) masih menjadi tantangan dalam pembelajaran IPA karena bahan ajar digital berbasis isu lingkungan lokal yang mengajarkan siswa pada proses analisis, evaluasi, dan kreasi masih terbatas. Kebaruan penelitian terletak pada pengujian buku ajar digital berbasis isu limbah batik Jetis Sidoarjo sebagai media kontekstual untuk meningkatkan HOTS pada indikator analisis (C4), evaluasi (C5), dan kreasi (C6). Tujuan penelitian ini adalah mengkaji efektivitas buku ajar digital IPA berbasis Socioscientific Issues (SSI) untuk meningkatkan HOTS siswa. Secara khusus, penelitian ini mendeskripsikan: validitas buku digital IPA berbasis SSI, peningkatan HOTS siswa setelah menggunakan buku digital, dan perbedaan hasil belajar siswa pada penggunaan buku digital dan buku teks konvensional. Penelitian ini menggunakan metode kuasi eksperimen dengan desain nonequivalent pretest-posttest control-group. Instrumen penelitian meliputi tes HOTS, lembar validasi ahli, dan dokumentasi hasil belajar. Hasil penelitian menunjukkan bahwa buku digital yang dikembangkan memenuhi kriteria valid dan memiliki kualitas yang sangat tinggi. Skor N-Gain kelas eksperimen sebesar 0.72 berada pada kategori tinggi yang mengindikasikan penggunaan buku ajar digital efektif dalam meningkatkan HOTS siswa. Kelas eksperimen menunjukkan peningkatan lebih tinggi dibandingkan kelas kontrol pada indikator C4), C5, dan C6. Integrasi isu limbah batik Jetis Sidoarjo mendorong siswa untuk secara aktif menganalisis, mengevaluasi, dan mengusulkan solusi terhadap permasalahan lingkungan di sekitar mereka. Temuan ini menunjukkan bahwa bahan ajar digital berbasis SSI dapat menjadi alternatif pedagogis yang efektif untuk mendorong pembelajaran sains yang kontekstual dan mengembangkan HOTS siswa.*

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A. Introduction

Society 5.0 drives the transformation of education towards the digitalisation era by integrating internet technology into online learning as an effort to prepare human resources who master 21st-century skills, namely the 4C skills (Creative, Critical Thinking & Problem Solving, Collaboration, and Communication) (Larson & Miller, 2023). These skills are important because technological developments and the dynamics of the 21st century present complex challenges and problems that must be faced by young generations, especially students (Manik & Ngurah, 2020). Learning that emphasizes thinking skills can be developed as an effort to improve student quality. Higher-order thinking skills (HOTS) are skills that help people make decisions and solve problems by encouraging them to think critically and creatively (Qamariyah et al., 2021). HOTS can be linked to 4C abilities through indicators of higher-order thinking according to critical thinking, problem-solving, and creativity. The importance of these cognitive products is greater if students can express ideas well and collaborate to find solutions (Mulyani et al., 2023). Mastery of HOTS makes students able to adapt to the progress of science and technology, which is an essential basis to face future challenges (Busdayu et al., 2021). HOTS in science learning is the ability to understand phenomena, analyze scientific data, and design solutions to environmental problems relevant to students'lives.

HOTS refers to thinking abilities that go beyond merely remembering, understanding, and applying information. Students are required to be able to analyze and evaluate the information received, thereby being able to form a complete understanding in their minds and express that information in their own words based on their comprehension (Amalia & Pujiastuti, 2020). Students who possess HOTS will be able to analyze, evaluate, and create innovations in solving problems, including environmental issues. This ability is very necessary in science learning, as many problems in this field can be resolved through the application of HOTS (Ichsan et al., 2019). Environmental pollution for example, in that case students must have good HOTS abilities in analyzing the factors behind the occurrence of pollution (C4) so that they can evaluate (C5) the causes and impacts of pollution. After being able to evaluate, the next step is to create a suitable solution (C6) to address the environmental problem. The level of designing and creating in HOTS is the highest level that students need to master in the 21st century (Saputri et al., 2018), but this ability remains a challenge for students in Indonesia, as seen from international assessment results such as TIMSS.

Indonesia has participated in the TIMSS assessment 4 out of 6 times, namely in 2003, 2007, 2011, and 2015. The global trends in international mathematics and science study evaluation is designed to evaluate students' abilities in mathematics, reading literacy, and science (Hadi & Novaliyosi, 2019). The questions in the TIMSS study are designed to reflect characteristics capable of measuring students' HOTS, so when the TIMSS assessment is conducted, it automatically also measures their level of HOTS (Mandini & Hartono, 2018). The TIMSS results showed that Indonesian students' science achievement was below the international average, indicating that students are not yet optimal in using scientific reasoning to understand and solve complex problems (Busdayu et al., 2023). The low TIMSS achievement is not only understood as a problem of reading ability alone buat also as an indication that science learning requires teaching materials that can transform conceptual knowledge into higher-order thinking activities, especially in the processes of analysis, evaluation, and creation. Thus, the relationship between the TIMSS results and this research is the need for teaching materials that present contextual problems, encourage cause-and-efeect analysis, evidence-based evaluation, and develop a solution.

Field data show that the educational activities carried out in the school have not adequately equipped students with HOTS (Syahri & Ahyana, 2021). This is because in the learning process, assessment of HOTS skills has not been widely applied in depth and comprehensively. Learning instead focuses more on LOTS, while HOTS still receive little attention (Listiani et al., 2025). In addition, the use of printed books, which are still the main source of learning in schools, often only presents material in the form of text and practice questions oriented towards memorization, rather than developing critical and analytical thinking skills. As a result, students tend to merely memorize the material without connecting it to real-life situations and have difficulty applying the knowledge they possess in real situations (Gulnara, 2024; Laksono & Wibowo, 2022). Science learning has now been designed in such a way that students have the freedom to express their opinions, but only a small number of students take advantage of this opportunity to ask questions about the material, discuss or debate the topics being covered, and express agreement or disagreement with a statement (Martini et al., 2021). Conventional learning approaches also often fail to develop the HOTS needed by students to catch up and face future challenges (Effendi & Yoto, 2024).

Efforts to optimize students' HOTS need to be carried out through an approach that links science concepts to real-world problems. Therefore, the researcher proposes learning using the Socio-Scientific Issue (SSI) approach, which is an approach that discusses important social issues faced in daily life and is closely related to scientific knowledge, particularly science concepts (Putra, 2022). SSI can engage students in a discussion that connects science with human values and societal perspectives (Erman et al., 2022). In SSI-based learning, there is an interaction

between three main elements, namely the teacher, the students, and the contextual problems that need to be solved (Kristiana et al., 2019). SSI-based learning encourages students to construct convincing arguments about controversial issues and evaluate their peers' arguments, thereby stimulating critical thinking processes such as analysis, evaluation, and the integration of information that can build a strong foundation of thought (Owens et al., 2018). The presence of SSI in surrounding environment becomes a contextual problem that can stimulate HOTS, reasoning, enhance learning engagement, and develop students' argumentative skills (Azizah et al., 2022; Rahayu, 2019).

Previous research has proven that SSI-based learning is effective in developing students' HOTS, including research by Wildan et al. (2021), which found that students' scientific thinking skills can improve using SSI-oriented learning strategies. In addition, several other studies indicate that this approach also contributes to the enhancement of critical thinking abilities (Suastrawan et al., 2021; Utami et al., 2023) as well as problem-solving abilities (Sahertian & Hidayati, 2022), all of which are important components of HOTS. The implementation of SSI-based learning can be effectively carried out in the classroom when the curriculum material includes relevant social science issues (Gustia et al., 2024), for example, ecosystem topics and efforts to address environmental pollution, which can be linked to real problems faced by students in Sidoarjo, such as the waste from the Jetis Batik. The creation of batik produce liquid waste which is relevant to contamination of the ecosystem and environment. The topic can be used as teaching material since it connects science principles, community economic activity, local culture, and environmental impact. Selecting of Jetis Sidoarjo batik waste problem can further contextualize the scientific education so the students can learn about pollution not only in theory but also in their social environment.

The material on ecosystems and environmental pollution is linked to the SSI of Jetis Batik waste and is presented in an interactive digital book that is easily accessible on various devices. The digital book has become a modern form of reading that is increasingly popular and is predicted to remain favored in the future because it is easily accessible, environmentally friendly, durable, and easy to distribute (Makdis, 2020; Prasetya et al., 2018). In addition, the digital book can also be accessed by students through gadgets or laptops, which can enhance learning flexibility, and the use of more than one medium, such as images, text, video, and audio, provides students with control over these media during the learning process (Deta et al., 2021; Susanti et al., 2021). The digital book developed by the researcher not only combines text, images, and videos but also provides innovative learning activities to train HOTS. Each chapter is equipped with a final project that encourages creative application of concepts; in addition, videos and links to current news support the implementation of SSI, along with additional learning resources from other websites. All content in this digital book is based on SSI, focusing on the Jetis Sidoarjo batik waste, making the material in the digital book more relevant and closer to the students' lives, considering that Jetis batik culture is part of their identity, and waste issues are a real problem in the Sidoarjo environment.

Students' learning outcomes are significantly improved by using SSI-based digital books (Asi et al., 2021). Other studies indicate that, besides learning outcomes, the use of digital textbooks based on the SSI approach is proven effective in enhancing students' scientific argumentation skills, critical thinking, and creative thinking (Khasanah et al., 2023; Septiningrum et al., 2021). Recent research confirms the relevance of SSI in science education but also indicates limitations that need further study. Research conducted by Högström et al. (2025) shows that SSI has been widely studied across various learning objectives, topics, and teaching methods. These findings suggest that the novelty of SSI-based research needs to be more clearly described, not only based on the use of the SSI approach but also through the uniqueness of the design, context, media, and the constructions of the learning outcomes studied. Hasni et al. (2026) emphasized the need for the development of e-modules based on SSI integrating local environmental issues such as the river pollution and land modification. This study was limited to needs analysis an did not continue to product validation and assessment of HOTS effectiveness. Songer and Recalde (2021) developed an SSI-based curriculum unit using an eco-solutions approach to encourage students to develop solutions to local environmental problems. The research was focused on curriculum design and solution-oriented learning rather than on the effectiveness of digital science textbooks in improving HOTS indicators. Based on the synthesis, the research gap is the lack of empirical information on SSI-based digital science textbooks with local environmental issues that are empirically proven to improve student's HOTS at the level of analysis, evaluation, and creation. Therefore, this research places the digital science textbook based on the Jetis Sidoarjo batik waste issue as a contextual medium to improve students' HOTS. This research aims to examine the effectiveness of SSI-based science digital books on Jetis Sidoarjo batik waste in enhancing students' HOTS abilities. The contribution of this research lies in providing empirical evidence regarding the use of digital teaching materials based on local environmental issues as a pedagogical strategy to strengthen analysis, evaluation, and creation in science learning.

B. Material and method

This study employs a quasi-experiment as an experimental method in conjunction with a quantitative approach. The Nonequivalent (Pretest and Posttest) Control-Group Design, a quasi-experimental design with two groups, namely the experimental group and the control group, without random assignment of individuals (Creswell & David Creswell, 2018). A pretest and a posttest are administered to each group, but only the experimental group receives special treatment. This design was chosen because it is suitable for the school context, which does not allow for individual randomization of students (see Table 1).

Table 1 Research design

Class	Pretest	Treatment	Posttest
EC	O_1	X	O_2
CC	O_1	Y	O_2

Description:
EC = Experimental class
CC = Control class
O_1 = Pretest HOTS using 12 essay questions
X = Treatment using digital science books based on SSI batik waste from Jetis, Sidoarjo
Y = Treatment using conventional books commonly used by students
O_2 = Posttest HOTS using 12 essay questions

Students in the seventh grade at SMP Muhammadiyah 10 Sidoarjo, categorized by gender in accordance with school regulations, served as the study's subjects. From several available classes, two classes were randomly selected: EC consisted of 20 female students from class VII-C, and CC consisted of 20 male students from class VII-B. Both classes were randomly chosen from the available classes. The usage of SSI-based digital books with a Jetis Sidoarjo batik waste topic was the focus of this study, designed to integrate HOTS skills, and compared to the use of conventional books that are also based on HOTS.

The pretest-posttest design reduces the possibility of gender bias in determining the initial HOTS ability in both classes before treatment. Researchers also equate several aspects of learning, namely education level, school, curriculum, materials, time allocation, test instruments, and learning procedures. However, class composition remains a limitation because the experimental class consists of female students, while the control class consist of male students. This condition has the potential to affect the internal validity of the research. Thus, the effectiveness of digital textbooks in this research needs to be interpreted carefully due to differences in gender composition between classes. Generalization of research results is limited to learning contexts that have similar characteristics.

This research involved 40 students hence the sample size is a limitation in the generalization of the results. This number shows the difference in HOTS increase between the experimental class and the control class but it is not enough to represent the wider population. Therefore, researchers interpret the results of this research as initial empirical evidence regarding the effectiveness of SSI-based digital textbooks in the context of science learning at the school where the research was conducted.

The type of data in this study is quantitative data, obtained from the results of students' HOTS tests. This data comes from the pretest and posttest given to both groups. The data sources were obtained from students of class 7B and 7C as primary data, as well as learning outcome documentation as supporting data.

The data collection process was carried out in a controlled classroom environment and in accordance with the established learning procedures. The instruments used in the pretest and posttest consisted of HOTS tests with 12 essay questions, including 5 analysis questions (C4), 3 evaluation questions (C5), and 4 creation questions (C6). These questions were developed based on the revised Bloom's Taxonomy to measure various levels of students' HOTS. The pretest was given to determine students' initial abilities in HOTS aspects, while the posttest was used to measure learning improvement after the treatment was given. All questions were designed contextually by integrating real cases, namely the batik Jetis Sidoarjo waste, into the ecosystem and environmental pollution material.

The experimental class received the treatment in five meetings, each of 90 minutes duration. The session began with the teacher's orientation on the problem of Jetis Sidoarjo batik waste issue. Next, students read a digital textbook and learned about ecosystems and environmental pollution, analyzed the causes and impacts of pollution, discussed evidence-based information, evaluated alternative solutions, and formulated solution ideas as a creative activity. The teacher applied the SSI technique through the presentation of real-life problems, the utilization of scientific and contextualized sources of information, discussions from different social and environmental perspectives, and decision-making based on scientific reasoning. The control class was taught the same subject as the experimental class by the teacher with a normal textbook with the same time frame and evaluation equipment.

Before being employed in the research, the HOTS test instrument underwent validity and reliability testing. The content validity of the digital book and teaching module instruments was reviewed by two science expert lecturers and analyzed using Aiken's V index with value categories of ≤ 0.40 (low), > 0.40–≤ 0.80 (moderate), and > 0.80 (high). Content validation was conducted by two expert validators who assessed the aspects of content feasibility, graphic and presentation feasibility, and language feasibility. Researchers selected validators based on competency

in science education, teaching materials development, assessment, and ecosystem and environmental pollution materials. In the aspect of content feasibility, validators assessed the suitability of science concepts, integration of Jetis Sidoarjo batik waste issues, and HOTS indicators. In the aspect of graphic and presentation feasibility, validators assessed the display structure, integration of text, images, videos, links, and ease of access to digital books. In the aspect of language feasibility, validators assessed sentence clarity, readability of instructions, accuracy of terms, and suitability of language to the characteristics of junior high school students. The Pearson Product-moment correlation was used to examine the validity of the HOTS test items. All test items demonstrated $r_{calculated} > r_{table}$, at a 5% significance level, showing that the items were legitimate. Cronbach's Alpha analysis was used to determine instrument reliability, and the results showed that the instrument was consistent and reliable, with a value of 0.885 > 0.70.

Data from the HOTS pretest and postest were evaluated in many stages. In the first stage, the researchers assessed N-Gain score to find out the rise in HOTS of students on experimental and control classes. The N-Gain criteria are presented in Table 2. Second, the researchers assessed the rise in each HOTS indicator including analysis (C4), evaluation (C5), and creation (C6) to see the increase in cognitive abilities in the experimental and control classess. Third, as the number of samples was fewer than 50, the normality of the data was evaluated by Shapiro Wilk test and the homogeneity of variance was tested by Levene's test. Fourthly, the researchers employed independent sample t-test to analyze the difference in HOTS of students in experimental and control classes. Fifth, researchers calculated effect size (Cohen's d and eta squared) to strengthen the interpretation of treatment effectiveness. Cohen's d was used to evaluate the magnitude of the difference of HOTS between the experimental and control classes and eta squared was used to estimate the proportion of HOTS variance related to the treatment. Effect sizes are needed because statistical significance simply reveals the presence or absence of a difference but effect sizes reflect the degree of the influence of the treatment in practical terms (Jané et al., 2024; Nissen et al., 2018).

Table 2 Criteria for improving the N-Gain score

Score	Criteria
> 0,70	High
0,30 ≤ N-Gain ≤ 0,70	Medium
N-Gain < 0,30	Low

(Source: Nissen et al., 2018)

C. Results and disscussion

The validity results of the learning device indicate that the SSI-based digital science book on the topic of Jetis Sidoarjo batik waste has met the very good feasibility criteria. The validity of a device can be interpreted as The degree to which an instrument can accurately measure the elements that it is intended to measure (Farida & Musyarofah, 2021). Validity is used to assess whether each item in an instrument truly represents all aspects contained in the material or object being measured, as well as the extent to which these items reflect the behavior or competencies intended to be assessed (Prihono, 2019). Aiken's V formula is used to examine the data once validity is established by expert judgment from experts with knowledge pertinent to the research field conducted by the researcher. Instruments and devices can be considered suitable for use if they obtain an Aiken's V value > 0.80 and a Cronbach's Alpha value > 0.70, indicating that their validity and reliability levels are in the high category. High validity and reliability ensure that differences in test results statistically reflect the effects of the treatment given to students and also indicate that the instruments used are consistent (Putri et al., 2021). The instruments are reliable as indicated by the reliability results, which revealed a value of 0.885 > 0.70. As indicated in Table 3, the digital science book's validation results included evaluations of three factors.

Table 3 The validation results of the digital science book

Aspects	Aiken's V value	Category
Content feasibility	0,95	High
Graphics and presentation feasibility	0.93	High
Language feasibility	0.95	High

The content feasibility aspect of the developed digital science book shows high quality. The Aiken's V value for this aspect is 0,95, reflecting that the content presentation in the digital book is designed systematically with attention to the accuracy of concepts in the ecosystem and environmental pollution materials, as well as their alignment with the applicable curriculum. Each part of the material contains various interactive activities linked to the SSI issue raised, namely the Jetis Sidoarjo batik waste, allowing students to understand concepts through real-life contexts. The questions in the digital book contain HOTS and are compiled with a good level of accuracy to ensure that the instruments used are truly capable of measuring students' HOTS. This high percentage indicates that the material's substance has been well designed, thereby minimizing the occurrence of misconceptions among students while also supporting deep conceptual understanding. Findings by Heny et al. (2018) emphasize that a clear

flow of material makes students less likely to become confused and better able to connect each concept. Conversely, teaching materials that are less detailed or not adapted to the local context tend to be difficult to understand, while teaching materials that include controversial elements and are linked to real life have been shown to increase students' interest in learning as well as their critical thinking skills (Widiastuti, 2020). This corresponds with SSI theory, which posits that controversial and pertinent socio-scientific topics can enhance students' ability to assess scientific data and information, hence rendering learning more significant (Zeidler et al., 2019). Despite the high validity score, the validators provided several suggestions for improvement. Two rounds of revisions were conducted to refine the product, including clarifying several explanations of ecosystem and environmental pollution concepts, strengthening the linkage between the Jetis Sidoarjo batik waste issue and the scientific concepts, and revising several HOTS questions to better reflect higher-order cognitive processes and align with the intended learning objectives.

In terms of graphics and presentation, Aiken's V value of 0.93 indicates that the visual presentation of the digital book, including layout, use of images and illustrations, colors, and arrangement of graphic elements, has effectively supported students' understanding. A neat and structured visual presentation helps students study the material independently without confusion in following the learning flow. Students' learning of complex subject, particularly in the field of science is accelerated and made easier by the use of visual media including pictures, charts, illustrations, and videos. A visually appealing presentation in the digital book enhances conceptual comprehension and cultivates students' willingness to learn (Rahmanda & Maharani, 2022; Wahidin, 2025). Nevertheless, a minor revision was suggested during the validation process. The validators recommended adding source information to all images included in the digital book, including those derived from personal documentation, to enhance the completeness and credibility of the visual presentation.

The language aspect received the highest Aiken's V score of 0.95, indicating that sentence structure, word choice, and clarity of instructions greatly assist in conveying science concepts and SSI content to students. The language used was assessed as communicative, accurate, and clear, thereby reducing the risk of misinterpretation and the potential for conceptual misunderstandings. This aligns with Asropah et al. (2021), which emphasizes that the selection and arrangement of words in a sentence play an important role as they can affect meaning, accuracy of information, and the level of clarity received by the reader.

The digital scientific book is regarded as legitimate and appropriate for use in education, according to the high validity results. This finding provides a strong basis that the content, construction, and readability of the device are in accordance with the development objectives, particularly in supporting SSI-based learning. A high Aiken's V score indicates that a digital textbook meets the eligibility criteria based on expert assessment. But this score does not imply a digital textbook that is free of weaknesses. The feedback received from the validators in the validation process will be utilized to improve the quality of the digital textbook. Furthermore, the N-Gain test was used to gauge the device's efficacy and the degree to which the created textbook can enhance students' skills.

Table 4 Average data of pretest and posttest higher order thinking skills

Class	Average score		N-Gain score	Category
	Pretest	Posttest		
EC	28,30	74,40	0,72	High
CC	20,55	34,15	0,19	Low

The calculation results (Table 4) show that the average N-Gain value for the EC is 0.72, which falls into the high category, while the CC only reaches 0.19, which is in the low category. These findings demonstrate that the use of SSI-based digital science books on batik waste from Jetis Sidoarjo is effective in improving students' HOTS skills in the topics of ecosystems and environmental pollution. After an independent sample t-test demonstrated that there was a substantial difference between the two groups, the N-Gain test was employed, further bolstering the efficacy of the created digital book. The researchers employed N-Gain to illustrate the change in students' abilities from pre-test to post-test. However, they did not use N-Gain alone for measuring the effect of the digital textbooks. Researchers improved the interpretation of N-Gain by adding assumption tests and effect sizes, making it more objective to estimate the influence of the treatment. This was done because effect sizes can give different information than N-Gain, especially if the students in both groups do not start with exactly the same skills. As a result, N-Gain data were analysed thoroughly in conjunction with the results of normality tests (Table 5), homogeneity tests (Table 6), t-test (Table 7) and effect sizes (Table 8).

Table 5 Normality test

Test of normality (Shapiro-Wilk)			
Class	**Statistic**	**df**	**Sig.**
EC	0,963	20	0,605
CC	0,960	20	0,536

Table 6 Homogeneity test

Test of homogeneity (Levene's test for equality of variances)		
	Levene statistic	**Sig.**
Based on Mean	0,139	0,712

Table 7 Results of the independent sample t-test

	t	**df**	**Mean difference**	**Sig. (2-tailed)**
t-test for equality of means	20.196	38	40.250	0,000

Table 8 Effect size analysis

Effect size	**Score**	**Category**
Cohen's d	6.39	Large
Eta squared	0.91	Large

The t-test conducted using SPSS 26.0 for Windows. Before the study, Levene's test was performed and yielded a significance value of 0.712 (> 0.05), indicating that the variances of both groups were homogeneous and that the t-test could be conducted under the assumption of equal variances. The t-test results showed a Sig. (2-tailed) value of 0.000 (< 0.05), which means there is a significant difference between the class using the SSI-based digital science book on Jetis Sidoarjo batik waste and the class using conventional books. In Table 7, the t-value = 20.196 with df = 38 and a Mean Difference = 40.250 indicates a very large and significant difference between the two groups. These findings demonstrate that using the SSI-based digital science book improves students' HOTS abilities, demonstrating the validity and efficacy of the produced tool when used in the classroom.

Result of effect size calculation supports the finding that the difference of HOTS achievement between experimental class and control class is quite big (see Table 8). A t-value of 20.196, df of 38, and equal number of students in both the classes generated a Cohen's d value of 6.39 and eta squared value of 0.91 (Table 8). These figures show that the difference in HOTS outcomes between the two classes is in the very large effect category. However, this result must be considered in proportion to the small sample size, the differing gender compositions of the groups and the possible novelty effect related to the usage of digital textbook. The degree of the influence of SSI-based digital textbooks should therefore be interpreted to the limitations of the quasi-experimental design, the characteristics of the students and the conditions of implementation of learning at the school where the research was done.

The positive results from the use of digital science books are inseparable from the characteristics of the SSI approach applied in these digital books. This is in line with the findings of Tullah et al. (2025), which state that digital books containing SSI content can have a positive impact because they enhance students' thinking skills as well as their collaboration abilities. Students are encouraged to participate more actively in the learning process via the SSI approach through the analysis of science-based issues that cover local, national, and even global problems. Students' involvement in examining the positive and negative aspects of an issue makes the arguments they build more comprehensive, based on complete information, and not partial. Thus, SSI-based learning can stimulate students to improve their thinking skills and address problems that are relevant to everyday life (Anisa et al., 2020; Imaduddin & Khafidin, 2018).

The local issue raised as SSI content in this digital book is directly tied to the actual circumstances in the students' surroundings, namely the problem of batik wastewater in Jetis, Sidoarjo. This issue is used as a trigger for thinking so that students not only understand the concepts of ecosystems and environmental pollution but are also able to objectively assess the social and environmental impacts it causes. Additionally, a number of earlier research have demonstrated the efficacy of the SSI strategy in improving HOTS in science education. Among others, according to Sismawarni et al. (2020), who stated that the SSI approach is capable of training students in higher-order thinking because they participate in the procedure of analyzing, evaluating, and making decisions based on scientific evidence. Similar findings from Pauzi & Windiaryani (2021) indicate that students' critical thinking abilities about

the subject of global warming are significantly impacted by SSI-based learning, which is one of the main components of HOTS. In addition, research by Maryam & Suwono (2023) found that the SSI approach is also able to improve students' decision-making skills, and lastly, research by Zahroh et al. (2024) demonstrated that the use of SSI in education can enhance problem-solving abilities because students are encouraged to actively seek information, evaluate sources, and form their own opinions.

These findings are consistent with the results of this study, where the use of SSI-based digital science textbooks in the EC resulted in a more significant increase in HOTS compared to the CC using conventional textbooks integrated with HOTS. HOTS itself encompasses various indicators that help students think more deeply and be prepared for diverse learning situations. These indicators include analyzing skills, which involve breaking down and categorizing data to find patterns or relationships as well as distinguishing cause-and-effect in complex situations (Wulandari et al., 2023); evaluating, which includes the ability to critically assess ideas, solutions, or methods based on certain criteria to determine their effectiveness (Basri et al., 2021), and creating, which involves the ability to combine existing ideas to solve while also developing or reorganizing concepts into something more creative and innovative (Wakifah et al., 2023).

Table 9 Results of the increase for each HOTS indicator

HOTS	EC			CC		
	Pretest	Posttest	Percentage increase (%)	Pretest	Posttest	Percentage increase (%)
Analyze	41.00	94.20	129%	39.60	55.60	40%
Evaluate	32.08	88.12	175%	19.79	34.17	73%
Create	21.56	61.88	187%	12.29	25.10	104%

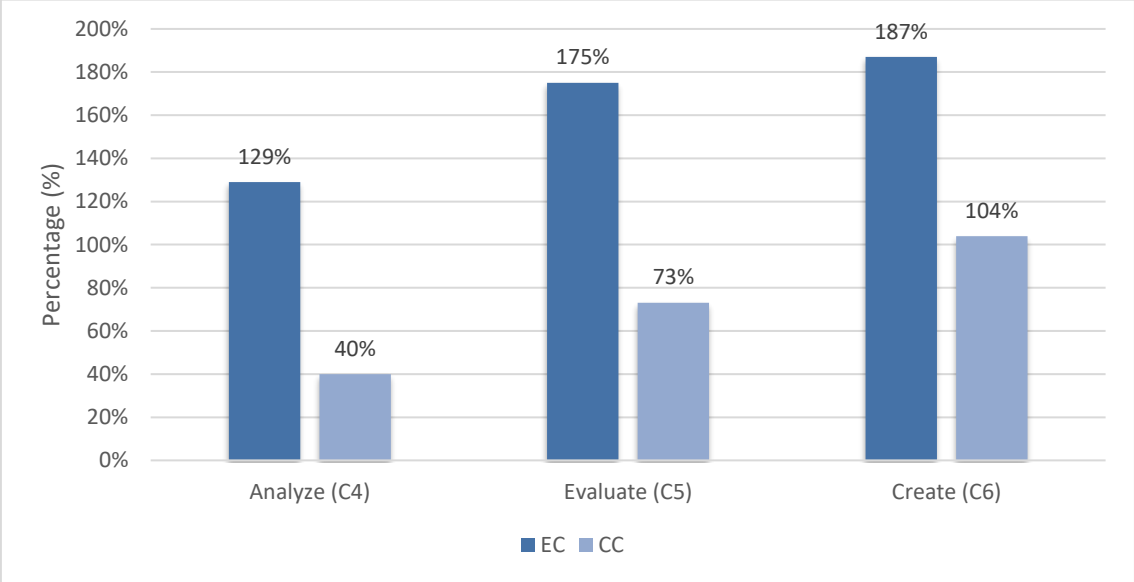

Figure 1 Percentage of achievement results for each HOTS level

The findings of the HOTS analysis on the analyzing indication (C4) demonstrate an improvement in abilities in both classes, the EC and the CC, according to Table 9 and Figure 1. The average score in the CC grew by 40% from 39.60 to 55.60, whereas in the EC, it increased by 129% from 41.00 in the pretest to 94.20 in the posttest. The significant difference in the increase indicates that the SSI-based digital science book has a much stronger impact on students' analytical abilities compared to conventional learning. Analytical ability itself includes students' skills in breaking down problems into their main components and identifying the relationships among these components. At this stage, students are trained to distinguish facts from opinions, filter relevant information, differentiate main ideas from supporting ideas, connect concepts, link conclusions with supporting statements, and find evidence that underpins a particular objective (Rochman & Hartoyo, 2018). The significant improvement in the EC indicates that students can examine information from real-world contexts more deeply, making the analysis process more focused and meaningful. Meanwhile, students in the CC tended to experience lower improvement because the learning provided did not involve authentic contexts that required in-depth analysis. This shows that the use of SSI in digital books can provide rich problem-based situations, thereby

directly enhancing students' ability to analyze complex scientific issues. These results are consistent with the research of Adumiranti & Widyaningrum (2022), which states that SSI packaged in the form of learning materials is effective in improving students' analytical skills.

The analysis results on evaluative ability (C5) showed an improvement in both classes, but the EC experienced a much higher increase. In the EC, the average score rose from 32,08 in the pretest to 88.12 in the posttest, with a percentage increase of 175%, while in the CC, the percentage increase was only 73%, rising from 19.79 to 34.17. The significant increase in the EC indicates that the learning approach used was able to encourage students to assess, compare, and provide logical considerations regarding an issue. The ability to self-evaluate requires students to formulate hypotheses, critique information, assess the truth of a statement, and determine whether an argument can be justified or rejected (Octaviana & Setyaningsih, 2022). This result is in line with the characteristics of of SSI-based learning, which encourages students to consider various perspectives before making decisions (Öztürk & Erabdan, 2019). Through exposure to controversial and contextual environmental issues, the SSI approach has demonstrated the ability to improve students' capacity for evaluation more optimally (Jaenudin et al., 2020).

In the creating indicator (C6), the improvement in learning outcomes is also clearly visible in both classes, however the EC again shows more significant progress. The pretest score in the EC was 21.56, which increased to 61.88 in the posttest, with a percentage increase of 187%, whereas in the CC, the score increased from 12.29 to 25.10, with a percentage increase of 104%. The ability to create represents the highest level in the HOTS domain, encompassing skills to design solutions, formulate new ideas, and combine concepts to produce an original idea. Greater improvements in the EC are inseparable from the use of digital science books based on SSI that present the batik waste issue in Jetis, Sidoarjo. This socio-scientific issue requires students to evaluate information from various sources, consider social and environmental impacts, and ultimately generate new ideas as a form of problem-solving. This situation encourages students to independently reconstruct knowledge, so they not only remember information but also create new concepts, solutions, and arguments based on the analysis they conduct.

Unlike the CC that uses conventional books, students in the EC found it easier to generate conclusions and creative solutions because they were directly involved in authentic thinking processes through real-life contexts they recognized. Thus, the implementation of SSI in digital books has been proven to optimally stimulate students' creative thinking abilities compared to learning that does not utilize contemporary issue contexts. This aligns with the findings of Anggraini et al. (2019), which stated that HOTS is not merely the ability to recall, but involves complex, creative, and critical thinking processes to find solutions to a problem. These findings are also reinforced by Naitul & Arsih (2025), who showed that integrating SSI into learning can enhance students' creative thinking abilities. However, slightly different from previous research, the results of this study show that even without being combined with other learning models or methods and purely using the SSI approach, students are still able to achieve significant improvements in creative skills.

The difference in thinking abilities between the EC and the CC in this study lies in the students' ability to use scientific reasoning more deeply. Students in the EC had the opportunity to develop logical reasoning through SSI-based digital science books, which required them to analyze real issues, evaluate information, and draw conclusions based on evidence. Conversely, students in the CC relied more on memory and basic knowledge from conventional textbooks, so the development of their HOTS was not as optimal as in the EC. This aligns with the view that logical thinking is not merely about recalling information, but involves understanding, applying concepts, analyzing, synthesizing, and evaluating as a comprehensive thinking process (Liber et al., 2024).

This study demonstrates that students' higher-order thinking abilities can be enhanced by using SSI-based digital scientific books. By presenting SSI that require analysis, evaluation, and decision-making, students become more active in processing information, considering various perspectives, and constructing logical and evidence-based arguments. Data analysis results also confirm that this digital book is not only valid and reliable as a learning medium but also effective in achieving the research objectives, namely helping students reach higher cognitive levels. Furthermore, this study has novelty value because there has been no previous research that purely investigates the effectiveness of SSI-based digital books in enhancing HOTS, making the SSI-based digital science book worthy of implementation as an alternative learning resource in schools.

D. Conclusion

Students' HOTS improved after using the SSI-based digital science book, as indicated by the high N-Gain score and the greater improvement in the analysis (C4), evaluation (C5), and creation (C6) indicators in the experimental class compared with the control class. These findings suggest that integrating local socio-scientific issues, such as the Jetis Sidoarjo batik waste issue, into digital science learning can facilitate contextual learning experiences and encourage students to engage in higher-order thinking processes. However, the findings of this study are limited to the characteristics of the participants and the specific learning context in which the digital book was

implemented. Future research should use larger and more diverse samples, more balanced class compositions and assess the application of SSI-based digital textbooks in different school situations. Further research can also examine supporting characteristics such as learning motivation, the role of teachers in aiding learning, the intensity of conversations, and technological readiness to use digital textbooks. Science teachers in the teaching practice can use local environmental problems as an entry point to develop analysis, evaluation, and creative activities, while adjusting learning methodologies to students' conditions, availability of devices, and technical infrastructure of the school.

E. Acknowledgement

This research received funding from the Muhammadiyah National Research Grant Batch VIII 2024 with research contract number 0258.409/I.3/D/2025

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