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The Impact of the Science-Technology-Society Model on the Enhancement of Student's HOTS: A Systematic Literature Review

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Abstract

The Science Technology Society (STS) model is a contextual approach that links science concepts with social issues to encourage higher order thinking skills (HOTS). This study aims to systematically review various empirical studies related to the application of STS in Biology learning to improve students' HOTS at the high school level. The method used is Systematic Literature Review (SLR) with the PRISMA approach, involving the selection of 15 articles published in 2015–2025 from Scopus, Sinta, and reputable proceedings. The analysis is focused on publication trends, methodology design, implementation context, and its impact on HOTS. The results of the review show that the application of STS consistently improves analytical (C4), evaluation (C5), and creative (C6) skills, as well as supporting students' science process skills, scientific attitudes, and active engagement. The majority of the studies analyzed used quasi-experimental design and learning contexts based on local environmental, health, and technological issues. Challenges include time constraints, teacher understanding, and supporting infrastructure. Therefore, intensive teacher training, contextual media development, and STS integration into the curriculum are needed. This study confirms that STS is a relevant and effective pedagogical approach in supporting HOTS-based 21st century learning.

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INTRODUCTION

Higher Order Thinking Skills (HOTS) are very important competencies in facing the challenges of the 21st century. HOTS includes the ability to analyze, evaluate, and create, which are necessary to solve complex problems in the real world. Despite being the main focus in global education, the results of international evaluations such as the Programme for International Student Assessment (PISA) 2022 show that the HOTS ability of Indonesian students, especially in the field of science, is still relatively low. Research shows that Indonesian students have difficulty in thinking critically and creatively in the context of science, leading to a low quality of education in this sector (Lustyantie et al., 2019). This indicates a gap in the development of HOTS among Indonesian students, which is mainly due to traditional learning approaches that tend to emphasize memorization rather than deep conceptual understanding (Asfiyah, 2021).

Previous research has shown that traditional learning approaches do not encourage students to think at a higher cognitive level, leading to limitations in their ability to analyze, evaluate, and create solutions (Eng et al., 2023) Therefore, a more innovative and contextual learning model is needed. One promising approach is the Community Science and Technology Learning Model (STS), which links science concepts to relevant social issues. The STS model aims to improve students' critical and creative thinking skills through analysis of the impact of technology and science in daily life (Ahmad & Sukiman, 2019)

However, although there are many studies that show the potential of STS in improving HOTS, there are still shortcomings in the literature regarding the systematic evaluation of the application of the STS model, especially in the learning of Biology at the high school level in Indonesia (Liliasari, 2015). This gap demonstrates the need for more in-depth and comprehensive research to explore the effectiveness of STS models in improving HOTS, as well as to identify relevant implementation challenges and strategies in the Indonesian context.

This study aims to fill this gap through the Systematic Literature Review (SLR) approach to analyze the trend of the application of STS in Biology learning and its influence on the development of HOTS in high school students. This study is expected to provide clearer insights into the effectiveness of the STS model, its implementation challenges, and its contribution to science education in Indonesia. Thus, the objectives of this study are to: 1) analyze the application of STS in the context of Biology learning in Indonesia; 2) explore its impact on students' HOTS, and 3) identify relevant challenges and implementation strategies.

METHODS

This study uses the Systematic Literature Review (SLR) approach by following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (Moher et al., 2015). This approach was chosen to provide a systematic and structured summary of various empirical findings related to the application of the Community Science and Technology (STS) Learning Model in improving Higher Order Thinking Skills (HOTS) in Biology learning. Using the PRISMA protocol, this study ensures transparency and reduces bias in the process of selecting and analyzing articles.

Article Screening Process

The article screening process is carried out in four stages according to the PRISMA protocol: identification, screening, eligibility, and inclusion. In the first stage, article searches are conducted through leading academic databases such as Scopus, Google Scholar, Springer, and Web of Science, using relevant keywords such as "Science Technology Society", "STS model", "Higher Order Thinking Skills", and "Biology Education". From the initial search, 1039 articles were found. The next screening stage involves selecting articles based on predetermined inclusion and exclusion criteria. Articles included in the inclusion criteria are the following: 1) Using the STS model in Biology learning, 2) Publish empirical data or evaluations related to HOTS, 3) Published between 2015 and 2025, 4) Published in Scopus indexed journals or other recognized platforms. Meanwhile, the exclusion criteria include articles that are not relevant to HOTS learning or do not meet methodological standards.

To reduce selection bias, two independent assessors conducted article screening. If there is a difference of opinion between the assessors, discussions are held to reach an agreement, and if necessary, a third assessor is involved. It aims to ensure quality and consistency in the selection of relevant articles. Table 1 describing the steps in the article selection process and the number of articles that passed at each stage.

Table 1. Article Selection Process

Stage	Number s	Description
Identification	1039	Initial search in Scopus, Google Scholar, Springer, and Web of Science using relevant keywords (e.g., "Science Technology Society", "STS model", "Higher Order Thinking Skills", "Biology Education").
Screening	54	Titles and abstracts were screened for relevance based on inclusion and exclusion criteria.
Eligibility	29	Full-text articles were assessed for eligibility, ensuring they met inclusion criteria (e.g., empirical studies, published between 2015 and 2025, in English or Bahasa Indonesia).
Included	15	Final articles included for in-depth analysis (15 articles that met all criteria).

Data Analysis Process

The filtered data was then analyzed using a thematic narrative synthesis approach with the help of NVivo software. NVivo was chosen for its ability to systematically analyze qualitative data, allowing the identification and categorization of themes relevant to the research objectives (Akçay & Akçay, 2015).

The analysis process begins with open coding, in which the researcher identifies the themes that appear in the selected articles. The initial categories used in the analysis include:

1) Methodology design: to explore the types of research designs used in STS application studies, 2) Context of application: to understand the context or topic of science learning used in the STS model, 3) Impact on HOTS: to analyze the extent to which STS models affect students' analysis, evaluation, and creation skills, 4) Implementation challenges: to identify the barriers faced in the application of the STS model in the field.

Once the coding is open, the data is further categorized into large themes relevant to the research objectives. The results of this analysis are then presented in the form of a thematic narrative synthesis, which summarizes the trends in the application of STS in Biology learning, its impact on HOTS, as well as the challenges and implementation strategies found in the analyzed articles.

To visualize the steps for article selection, Figure 1 below shows the stages of searching, screening, eligibility, and inclusion of articles carried out in this study. This chart also lists the number of articles that were filtered at each stage, from the initial search to the articles that were finally selected for further analysis.

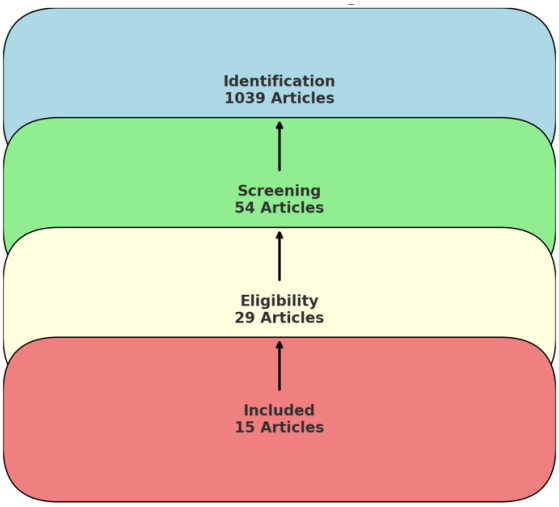

Figure 1. PRISMA Flow diagram

RESULTS AND DISCUSSION

Based on the results of the selection carried out using the PRISMA protocol, as many as 15 relevant articles were successfully reviewed in this study which are shown in Table 2.

Table 2. Selected articles reviewed

No	Article Title	Researchers	Key Focus	Research Results
1	The Influence of Science Technology Society (STS) Learning Model Toward Biology Learning Achievement of X Degree Students at SMA Negeri 3 Boyolali in 2012/2013 Academic Year	(Wati et al., 2015)	The influence of the STS model on students' biology learning outcomes (cognitive, affective, psychomotor)	The STS model has a significant influence on all three domains of learning outcomes (t count > t tables in all domains)
2	The Influence of Science Technology Society Model on The Capability of Science Literacy Skills in Biology Subject	(Hamzah & Suhartini, 2019)	The influence of the STS model on the science literacy skills of high school students	The STS model significantly improved students' science literacy compared to the conventional model ($F = 8,840$, $p < 0.05$)
3	Penerapan model science technology society melalui eksperimen lapangan dan eksperimen laboratorium ditinjau dari sikap peduli lingkungan dan kreativitas verbal siswa	(Santoso et al., 2013)	The Effect of STS (Field Experiment vs Lab) on Learning Outcomes and Interaction with Environmental Care & Creativity	Field experiments give better results than laboratories; Positive interaction with caring & creativity
4	The Impact of Science Teaching based on Science-Technology-Society (STS Approach to Elementary School Students	(Çınar & Çepni, 2021)	The influence of STS on elementary school students on: creative thinking, attitudes towards science, and academic achievement	STS meningkatkan kemampuan berpikir kreatif, sikap positif terhadap IPA, dan prestasi belajar secara signifikan
5	The Effect of the Science Technology Society and the Quantum Teaching Models on Learning Outcomes of Students in the Natural Science Course	(Kristiyanto et al., 2020)	Comparison of the effectiveness of STS vs Quantum Teaching with the moderation of critical thinking skills	Quantum Teaching is superior to STS; no significant interaction with critical thinking levels
6	Penerapan Pendekatan SETS dalam Pembelajaran Biologi Berbasis Imtaq untuk Meningkatkan Hasil Belajar Siswa	(Komariah et al., 2015)	The implementation of IMTAQ-based SETS to improve students' learning outcomes and character values	The IMTAQ-based SETS approach improves students' activities, learning outcomes, and religious attitudes and honesty
7	Science Technology Society Approach Application on Students Literacy and Process Skills of Science to Study Dynamic Fluids	(Muhibbuddin et al., 2019)	The effect of the STS approach on science literacy and science process skills in dynamic fluid materials	STS significantly improves students' science literacy and science process skills

No	Article Title	Researchers	Key Focus	Research Results
8	Penerapan Model STS Berbasis Produk Pada Materi Fungi Untuk Meningkatkan Pemahaman Konsep Siswa	(Hidayatullah et al., 2023)	Application of product-based STS to improve understanding of biological concepts (fungi matter)	The product-based STS model significantly improves students' conceptual understanding on indicators C3–C6
9	Pengaruh Model Pembelajaran STS Terhadap Kemampuan Literasi Sains dan Hasil Belajar Kognitif	(Amilia et al., 2022)	The effectiveness of the STS model on science literacy and cognitive learning outcomes	STS significantly improves science literacy and cognitive learning outcomes compared to conventional models
10	Pengaruh Pendekatan STS Terhadap Literasi Sains dan Hasil Belajar Siswa pada Materi Sistem Ekskresi	(Handayeni et al., 2021)	The effect of the STS approach on science literacy and student learning outcomes	STS is effective in significantly improving students' science literacy and learning outcomes (t-test shows a noticeable difference)
11	Pengaruh Model Pembelajaran STM terhadap Kemampuan Berpikir Kritis dan Keterampilan Proses Sains	(Jayadiningrat et al., 2022)	STS vs traditional approach to improving critical thinking skills and science processes	The STS model is superior to conventional methods on all indicators of critical skills and science processes
12	Pengaruh Model STM terhadap Peningkatan Aktivitas dan Hasil Belajar IPA Siswa	(Rosana et al., 2017)	Evaluation of STS learning with solar energy-based ABHS technology	STS+ABHS increases crop productivity by up to 76% and improves the competence of students
13	Effectiveness of Science-Technology-Society (STS Approach on Students' Learning Outcomes in Science Education	(Acut & Antonio, 2023)	The effectiveness of the STS approach in improving student learning outcomes in various cognitive, affective, and psychomotor domains.	The STS approach had a significant positive influence on student learning outcomes, with an overall effect size of 1,882.
14	Pengaruh Model Pembelajaran Sains Teknologi Masyarakat (STM) Terhadap Kemampuan Berpikir Kreatif dan Self-Regulation	(Novitasari et al., 2020)	Investigating the effect of the Science, Technology, and Society (STS model on creative thinking skills and self-regulation in students.	The STS model significantly improves students' creative thinking and self-regulation, suggesting its efficacy in improving 21st-century learning skills.
15	The Impact of the Science Technology Society (STS Approach on Critical Thinking Ability and Student Learning Outcomes	(Mulyanti et al., 2021)	The effect of the STS approach on critical thinking skills and student learning outcomes in high school learning.	Research shows that the STS approach significantly improves critical thinking skills and learning outcomes.

A review of the year and country of publication of the analyzed article shows an increasing trend of interest in the application of STS in Biology learning that developed HOTS in recent years. More publications were found in the period 2019 to 2023, with the dominance of articles from Indonesia (73%). Figure 1 illustrates the distribution of the year of publication of the relevant article.

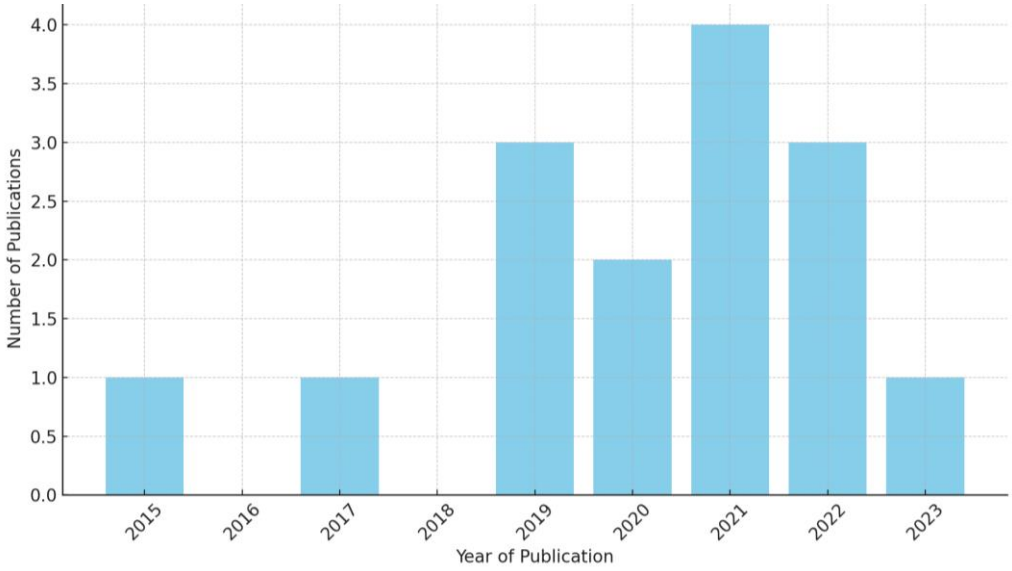

Figure 2. Distribution of Year of Publication of the Article

In this study, we analyzed 15 articles relevant to the application of the Community Science and Technology (STS) Learning Model in improving Higher Order Thinking Skills (HOTS) in Biology learning at the high school level. Based on the selection results, most of the articles used a quantitative approach (13 out of 15 articles), with quasi-experimental design being the most widely used method (9 articles). Some articles also use qualitative and evaluative approaches, although there are fewer in number.

Country Distribution and Research Methods

Most of the articles analyzed were from Indonesia (73%), while other articles came from countries such as Turkey and the United States, with smaller contributions. Here is a visualization of the distribution of the countries where the articles were published:The majority of the articles used a quasi-experimental design (9 articles) to measure the impact of STS on HOTS. The other three articles used a qualitative approach and two articles used an evaluative approach. The distribution of this research method is illustrated in the following bar diagram:

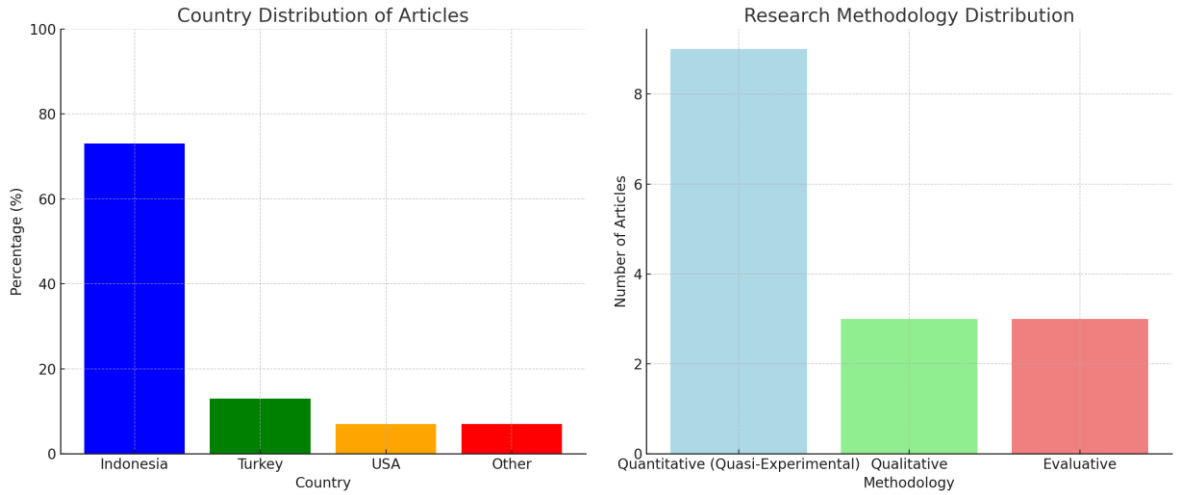

Figure 3. Country Distribution and Methods

Based on the results of the analysis, the STS Model has been proven to be effective in increasing students' HOTS, especially in analysis, evaluation, and creation skills. However, there are several strengths and weaknesses that need to be considered related to the research methods used.

Strengths and Disadvantages of Research Methods

Quasi-experimental, qualitative, and evaluative approaches each have strengths and weaknesses that are important to consider in research on the application of the Science-Technology-Society (STS) model in learning. The quasi-experimental approach allowed researchers to measure the direct impact of the STS model by comparing experimental and control groups, which were shown to improve students' high-level thinking skills (HOTS) and science skills (Amali et al., 2019). However, the main drawback is the inability to control external variables, such as differences in students' initial abilities, which can affect the internal validity of results (Santoso et al., 2013).

Meanwhile, the qualitative approach provides in-depth insights into how students interact with STS materials and concepts, as well as how they build understanding through social reflection and discussion (Handayeni et al., 2021). The disadvantage lies in the limitations of the sample and the subjectivity in data collection, which often makes it difficult to generalize findings to a wider population (Irsan, 2021).

The evaluative approach, on the other hand, provides a clear understanding of the effectiveness of STS implementation and the challenges faced by teachers (Irsan, 2021), but it often relies on self-reports that can contain biases, as well as a lack of measurement of the long-term impact of this model. Thus, while these three approaches make an important contribution to the understanding of STS implementation, each has limitations that need to be considered in the analysis and interpretation of research results.

International Context and STS Practice in Indonesia

Most of the articles analyzed came from Indonesia (73%), which shows that the application of STS is more studied in the local context. Although the STS model in Indonesia shows positive results in improving HOTS, it is important to consider whether these findings can be generalized to the international context.

In Turkey and the United States, the implementation of STS has also shown similar results in improving students' HOTS skills (Çınar & Çepni, 2021), although the implementation is often more focused on specific topics such as renewable energy and environmental pollution. Meanwhile, in Indonesia, topics that are more often taught through the STS model involve local environmental issues such as air pollution and food security.

It is important to remember that contextual factors, such as national curriculum, the role of teachers, and educational infrastructure, can influence the success of STS models in different countries. Therefore, although the implementation of STS in Indonesia has shown encouraging results, the success of this model in other countries can be influenced by differences in education policies, resources, and the readiness of educators.

Study Limitations

This review has some limitations to be aware of. First, the scope of the study area is limited to articles published between 2015 and 2025, with a primary focus on research originating from Indonesia. This limits the potential generalizability of the findings to countries with different educational contexts. Second, although article searches are conducted through various credible databases, the potential for search bias remains, especially related to the availability of relevant articles in Indonesian and English. Third, the limitations of data obtained from quasi-experimental and qualitative studies can affect the depth of analysis, especially in terms of differences in the implementation of STS models in different educational settings.

Strategic Recommendations

Based on the findings and analysis conducted, we suggest several strategic recommendations that can strengthen the implementation of the Science-Technology-Society (STS) model in Biology education in Indonesia. First, we propose the integration of STS into the national curriculum, particularly in science subjects at the high school level, to strengthen students' higher level thinking

skills (HOTS). By formally integrating STS, learning that connects science concepts with contemporary social issues can become a structured part of formal education. Second, reflective practice-based teacher training is needed to increase teachers' understanding of the application of STS in learning. This training should involve hands-on experience and group discussions to build teachers' competence in implementing STS effectively in the classroom. Finally, we suggest the development of local context-based STS modules that are relevant to social issues in Indonesia, such as food security, climate change, and local technology. This module will help students more easily relate science concepts to their real lives, and should be accompanied by clear teaching guidance to support the implementation of this model by teachers. By following these recommendations, it is hoped that STS can become a more integrated and sustainable learning approach in the Indonesian education system, as well as contribute to the development of human resources who are able to think critically and creatively in facing global challenges in the 21st century era.

CONCLUSION

This study makes a significant contribution in the field of science education, especially related to the application of the Science Technology Society (STS) Learning Model to improve students' Higher Order Thinking Skills (HOTS) in Biology learning at the high school level. Through this Systematic Literature Review (SLR), we highlight the trend of implementing the STS model in Indonesia, which shows great potential in encouraging students' ability to analyze, evaluate, and create. The STS model, which connects science concepts with contextual social issues, has been shown to improve HOTS skills and students' active involvement in learning. However, these findings also emphasize that although STS shows positive results in Indonesia, the application of this model in other countries has also shown similar success, despite differences in the context of the topics taught. Therefore, these findings enrich the literature on the implementation of STS in different countries, while also showing contextual differences that can affect the effectiveness of this model.

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