



SSI-Based Newton's Laws Flipbook to Enhance Critical Thinking and Science Literacy

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Abstract

To effectively enhance critical thinking and science literacy in physics, there is a need to use instructional materials that effectively relate concepts to real-life situations. The objective of this study was to design and validate a Newton's Laws flipbook teaching material using Socio-Science Issues (SSI) to enhance critical thinking and science literacy in physics. The ADDIE model was used in this study, which comprised Analyze, Design, Develop, Implement, and Evaluate stages in developing a new instructional material. Experts validated the product, while small- and large-scale tests were conducted using validation sheets, readability tests, pretest-posttest, and questionnaire tests. The results revealed a high level of content validity, with Aiken's V values ranging from 0.85 to 0.89. The readability level of the material was 73.06%, indicating that the material is easy to comprehend. The experimental group scored higher in the N-gain analysis, with a moderate level of critical thinking (0.54) and science literacy (0.48). The teaching material received high practicality ratings from both students (90.04%) and teachers (93.87%). This indicates that SSI-based flipbook materials effectively integrate physics concepts with socio-science issues, which enhance critical thinking and science literacy in students. This study contributes to developing innovative digital teaching materials, and future research should explore its application in other physics topics.

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INTRODUCTION

Education in the twenty-first century emphasizes the development of higher-order thinking skills, including critical thinking, problem-solving, communication, and informed decision-making (Hermita et al., 2025; Otaya et al., 2025; Simanjuntak et al., 2019; Suratno et al., 2019). In the context of science education, critical thinking is vital for students to think critically about the information available to them as they try to solve science-related problems (Khoiriyah et al., 2018; Sumanik, 2022). This is because these higher-order thinking skills are closely related to science literacy, which is the ability to use science knowledge to make sense of the world, think critically about the information available, and make informed decisions in real-life contexts (Jufrida et al., 2019; Novita et al., 2021).

Empirical studies revealed that students in Indonesia still show low science literacy competence and critical thinking skills (Ayu et al., 2025; Erlangga et al., 2024; Mujakir et al., 2024; Nurwati et al., 2024). According to the Programme for International Student Assessment (PISA) 2022, Indonesian students scored an average result of 383 on the science domain, which is far from the OECD average. This score is an indicator of the mean performance of 15-year-old students in applying science knowledge to real-life contexts. This is an issue that requires effective learning

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strategies to enhance science literacy competence and the development of higher-order thinking skills (OECD, 2022). This is an issue where students in Indonesia experience difficulties in understanding data, science arguments, and applying science concepts to real-life contexts (Khayati & Raharjo, 2020). Theoretically and empirically, it is found that low science literacy competence is associated with the lack of higher-order thinking skills, including analysis, evaluation, and inference (Facione, 2013; Zohar & Dori, 2003). However, science literacy is not limited to the conceptual knowledge of science and extends to the ability to use science knowledge to explain and make decisions. According to Bybee (2014) science literacy cannot develop without the integration of critical thinking into the curriculum. Fives et al. (2014) also revealed that some students are not yet free from the conceptual level of knowledge and are not yet oriented to scientific reasoning. The empirical study conducted in Indonesia also revealed some evidence of the problem. Syarif et al. (2025) revealed that senior high school students have low critical thinking skills in physics, especially in the analysis and evaluation of problems in a context. The above studies revealed that science education is not yet optimally developing critical thinking skills for science literacy.

This challenge is most evident in the learning of Newton's laws of motion. As a basic concept in physics, Newton's laws are generally understood to be conceptually complex, with a high potential for students to harbor misconceptions. Past studies have indicated that students generally face challenges in understanding forces on stationary objects, drawing correct diagrams, and understanding action-reaction concepts (Huda et al., 2022; Mushthofa et al., 2020). Many students are found to use intuitive but incorrect thinking, such as in their understanding of action-reaction forces, where they think these forces act on the same object. These are basic misconceptions, which are a challenge to students, indicating a need to change current instructional strategies, which are largely formula-based, with little emphasis on analytical thinking (Zubaidah, 2019). However, current instructional strategies are largely based on theoretical explanations, with little emphasis on real-world examples (Huda et al., 2022).

However, these challenges demand instructional strategies that establish significant links between concepts of physics and students' everyday experiences. Socio-Science Issues (SSI) is an instructional framework that attempts to do this by grounding science education in socially relevant science-based issues that demand evidence-based reasoning and decision-making (Sadler et al., 2007; Zeidler & Nichols, 2009; Zeidler et al., 2019). The framework is based on the constructivist theory of learning and science argumentation. The process is consistent with the essential components of critical thinking (Ennis, 2018; Facione, 2013) and modern science literacy models that focus on the application of science knowledge in personal and social contexts (Bybee, 2014; OECD, 2019a), making it a conceptual bridge between critical thinking and science literacy.

In terms of Newton's laws, transportation safety can be viewed as a very significant socio-science issue in the broader sense. Lack of understanding of force, inertia, and acceleration has been associated with a general lack of awareness of the use of seat belts and child safety restraints (Litt et al., 2014). Research has revealed that students are not capable of explaining the role of seat belts in physics, especially in terms of forces on the human body in deceleration (Beesten and Bresges, 2025). Such socio-science issues in physics learning are likely to help students relate abstract concepts to reality while promoting science literacy and social responsibility.

Past studies have shown the potential benefits of using SSI-based instruction to improve the level of critical thinking and science literacy among learners (Azmi, 2020; Febriana et al., 2023; Fihani et al., 2021). Nevertheless, the majority of the studies were centered on classroom activities and discussion-based learning, with little emphasis on the incorporation of SSI into learning materials to support independent learning. Studies on digital learning media, such as flipbooks, have shown the potential benefits in enhancing student engagement, active participation, and improved conceptual understanding with the incorporation of text, images, and multimedia (Amanullah, 2020; Astiti & Hali, 2019; Fitriani et al., 2025). Despite the benefits associated with the use of digital learning media, the majority of the studies were centered on the improvement of critical thinking and/or science literacy. Moreover, the application of SSI-based instruction in the development of digital learning materials is still limited, particularly in the context of Newton's laws, which is considered to be one of the topics with high levels of misconception among learners.

This gap is also reflected in school practice, where preliminary observations conducted as part of the needs analysis in SMAN 1 Slawi revealed that Newton's laws are taught using textbooks

and worksheets with a focus on mathematical problem-solving, with little emphasis on socio-scientific issues in contexts. The teachers in these schools have identified students' difficulties in analyzing real-world issues and relating them to concepts of force, acceleration, and interaction, which are not supported by instructional materials that facilitate critical thinking and science literacy. This situation, therefore, represents a gap in meeting the needs of twenty-first-century education and existing practice, which this innovative digital teaching material will fill.

This study, based on its theoretical underpinnings, research findings, and empirical conditions, contributes to existing knowledge in a novel manner by developing a Socio-Science Issues-integrated Newton's laws flipbook as a digital teaching material, which is different from other studies in its integration of SSI in a flipbook format and its investigation of its effect on two interrelated aspects of twenty-first-century education: critical thinking and science literacy, simultaneously. Accordingly, this study aims to (1) design and develop a Newton's Laws flipbook based on Socio-Science Issues that is both valid and practical for classroom use, and (2) assess its effectiveness in fostering students' critical thinking and science literacy within physics instruction.

METHOD

This study adopted a Research and Development (R&D) methodology, which is oriented toward the systematic creation of a specific educational product (Sugiyono, 2022). The development process was guided by the ADDIE instructional design model, encompassing five sequential stages: Analyze, Design, Development, Implementation, and Evaluation (Branch, 2009). The procedure was conducted up to the evaluation phase to determine the validity, effectiveness, and practicality of the developed product. The resulting product is a Socio-Scientific Issues (SSI)-based flipbook on Newton's Laws, intended to foster students' critical thinking skills and scientific literacy. Each stage of the ADDIE model was implemented in a systematic and structured manner, as depicted in Figure 1.

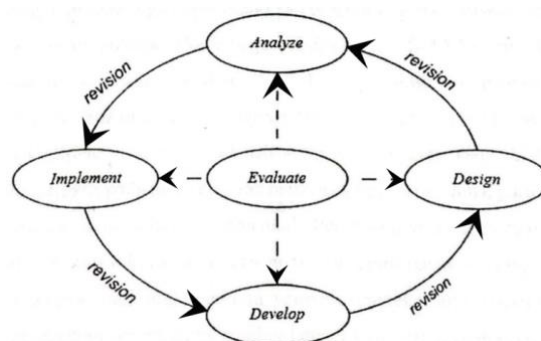


Figure 1. ADDIE Design Stages
Source: Branch (2009)

The research instruments comprised a mixed-format assessment consisting of multiple-choice and essay items designed to evaluate students' critical thinking and science literacy in the context of learning Newton's Laws. The research instrument consisted of two types of items. First, ten multiple-choice questions were used to assess students' conceptual understanding of Newton's Laws as a prerequisite for higher-order thinking tasks. Second, ten essay questions were designed to evaluate students' critical thinking and science literacy. Essay items were chosen to capture students' reasoning, argumentation, and evidence-based decision-making within socio-science contexts. Critical thinking was measured using items derived from Ennis's framework, encompassing elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. Science literacy was assessed through items adapted from the PISA framework, addressing the ability to explain phenomena scientifically, evaluate science investigations and evidence, and construct and appraise science arguments. All questions were contextualized in Socio-Science Issues relevant to Newton's Laws, particularly transportation safety scenarios. Before implementation, the instruments were validated by experts in physics education and educational assessment to ensure content validity and alignment with the intended constructs.

The analysis stage involved the identification of the learning needs, the analysis of the characteristics of the students, and the analysis of Newton's laws of motion related to SSI. This involved conducting interviews with physics teachers as well as observations to determine the difficulties experienced by the students, the conditions for learning, and the necessity for the design of teaching materials related to SSI. The design stage involved the design of the preliminary version of the teaching materials according to the analysis. This involved the design of the content's structure, the integration of the SSI, as well as the design of the elements related to the teaching process, such as the visual elements, the concept maps, the exercises, and the activity sheets for the promotion of critical thinking and science literacy. The development stage involves the realization of the initial design of the complete product. The content was developed using an SSI approach, visual illustrations, videos, simulations, and exercises. The product was then validated by subject matter experts and media experts, consisting of two physics lecturers and three physics teachers, to assess its suitability in terms of content, presentation, language, and appearance. The developed product was then revised according to the experts' suggestions and input to produce valid teaching materials. The expert validity results were calculated using the Aiken (1985) formula. In addition, the expert validity results were also analyzed using the percentage formula and teaching material validity criteria Fendiyanto and Siregar (2024).

After the validation and revision process, a small-scale trial was conducted in one class consisting of 36 students from class XI-4 SMAN 1 Slawi to assess the quality of the pretest-posttest instruments and the readability of the product. The data obtained included item validity, reliability, difficulty level, discrimination power, and readability. Item validity was analyzed using Pearson's product-moment (Hanan et al., 2023), while reliability was measured using Cronbach's Alpha (Yusuf, 2023). The analysis of reliability was conducted using Cronbach's Alpha based on Sugiyono (2019). Item difficulty was analyzed according to Jumini et al. (2023), while item discrimination was determined based on Fatayah et al. (2022). In addition, the readability of the teaching materials was evaluated following the criteria proposed by Susanti et al. (2015).

The implementation stage used the quasi-experimental design with the non-equivalent control group pretest-posttest design to assess the effectiveness and practicability of the teaching materials developed. Large-scale trials were carried out on two intact classes with the help of purposive sampling techniques on the basis of the same academic characteristics. The control group consisted of 36 students from class XI-5 of SMAN 1 Slawi, who were taught with the help of the Problem-Based Learning (PBL) model with traditional teaching materials. The experimental group consisted of 36 students from class XI-1, who were taught with the help of the teaching materials developed on the basis of the SSI-based Newton's Laws flipbook with the PBL model. The same teacher was used to teach both the control and experimental groups to ensure the equivalence of the teaching process. The effectiveness of the product was measured with the help of the normalized gain formula as suggested by Hake (1998). The practicability of the product was measured with the help of the percentage criteria.

The evaluation stage was carried out in order to evaluate the quality of the product through both formative and summative evaluation. In this stage, expert validation, product revisions, and small-scale tests were carried out under formative evaluation, while summative evaluation was carried out through analysis of pretest-posttest data and questionnaire responses in order to determine the product's effectiveness and practicality. The outcome of this stage was used to determine the feasibility of the product for implementation.

RESULTS AND DISCUSSION

The improvement in students' critical thinking skills and science literacy observed in this study can be explained through the cognitive and pedagogical mechanisms inherent in the Socio-Science Issues (SSI) approach. Conceptually, SSI is designed to connect science concepts with real, contextual, and often dilemmatic social issues, requiring students not only to understand science knowledge but also to apply it in analyzing situations, evaluating multiple perspectives, and making evidence-based decisions (El Arbid & Tairab, 2020; Sadler et al., 2007; Zeidler & Nichols, 2009; Zeidler et al., 2019). This approach aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed through reasoning, experience, and reflection.

From a critical thinking perspective, SSI-based learning provides opportunities for students to engage in problem clarification, reasoning, inference, and decision making, as described in Ennis's framework. When students are confronted with socio-science issues, such as transportation safety, they are required to identify core problems, assess the credibility of scientific information, construct arguments based on evidence, and consider the consequences of alternative decisions, thereby promoting higher-order thinking (Dalaila et al., 2022). In addition, SSI learning stages, including subject matter knowledge, informal reasoning, decision making, argumentation, and reflective judgment, play a central role in fostering science literacy (Rohmawiyah, 2020). Science literacy includes the ability to explain phenomena scientifically, evaluate scientific information, and apply scientific understanding in personal and societal contexts (Bybee, 2014). Through SSI-based learning, students are actively engaged in interpreting real-world phenomena, evaluating scientific claims, and integrating scientific and social considerations, which supports the development of science literacy competencies.

Furthermore, the integration of SSI into digital teaching materials in the form of a flipbook strengthens its impact on both critical thinking and science literacy. The flipbook format enables multimodal presentation of socio-science issues through text, images, illustrations, and contextual visualizations, which supports deeper conceptual understanding (Amanullah, 2020). When Newton's laws are learned through the context of transportation safety, concepts such as force, inertia, and acceleration become more meaningful and connected to students' everyday experiences, thereby enhancing cognitive engagement and facilitating knowledge transfer.

Analyze

The analysis stage began with a literature review focusing on the application of the Socio-Science Issues (SSI) approach in enhancing critical thinking and science literacy. The review revealed that SSI integration in physics education, particularly in Newton's Laws, remains limited. Existing teaching materials generally focus on conceptual understanding and problem-solving. Contextual teaching materials, such as those developed by Astiti & Hali (2019), help students understand concepts through real-life examples but do not explicitly integrate SSI. Other studies Ningsih et al. (2022) Yani (2023) emphasize science literacy and environmental approaches, but still do not involve the analysis of complex social issues. Problem-solving modules developed by Fitriani et al. (2025) support higher-order thinking but do not include SSI as a core element. Meanwhile, studies Högström et al. (2025) confirm that SSI integration can improve science literacy, critical thinking, and evidence-based decision making. These findings indicate that SSI-based teaching materials for Newton's Laws are still limited and have not become a primary focus in Indonesia.

From the analysis of the field through observations and in-depth interviews with physics teachers in SMAN 1 Slawi, it was found that the level of students' critical thinking skills and science literacy was still low. The learning process emphasized conventional learning materials that were less contextualized, not connecting the concepts of physics with phenomena in the real world. Based on the above analysis, it is essential to create SSI-based learning materials in the form of a flipbook to support the development of critical thinking skills.

Design

The design stage involved organizing the teaching materials based on the needs analysis results. The integration of Newton's Laws and Socio-Science Issues (SSI) helped to improve the contextualization of the materials. The teaching materials were created in the form of a flipbook to improve accessibility and interactivity. The materials were divided into three subtopics: Newton's First Law, Second Law, and Third Law. The materials were also mapped to critical thinking and science literacy indicators. Each of these components aims to facilitate student engagement in analytical and evaluative thought processes.

The design of the flipbook teaching material on Newton's Laws based on SSI is arranged systematically. This is to ensure that each component is able to support the learning process as a whole. The results of the teaching material design are presented in Figure 2.



Figure 2. Design of Newton's Laws Flipbook Teaching Materials Based on SSI


As depicted in Figure 2, the structure of the teaching material is such that it includes a cover page showing the identity of the material and the author. Following this is a preface and a table of contents for a better understanding of the material. Next is a description of the teaching materials and a concept map, which provides an overview of the framework of the teaching materials and concepts. Learning instructions, outcomes, and objectives are also provided for better use of the teaching materials by the students. The main part of the teaching materials includes material on Newton's laws enriched with SSI-based contextual phenomena. The material also includes summaries and exercises for better student understanding. The glossary and bibliography are also provided for better clarity of concepts and authors. This overall structure forms the main features of teaching materials that strengthen critical thinking and science literacy skills. The features in the developed teaching materials are presented in Figure 3.

HUKUM I NEWTON

Mengingat Kembali


Pernahkah kalian naik bus yang tiba-tiba berhenti mendadak? Apa yang kalian rasakan saat itu? Atau ketika baru saja naik bus lalu sopir langsung menginjak gas, apa yang terjadi pada tubuh kalian?

Yuk, kita pelajari rahasia di balik peristiwa ini melalui Hukum I Newton!



Sumber: jember.com
Gambar 1.1 Peristiwa yang terjadi di bus saat perjalanan


Pemantik



Sumber: antara.com
Gambar 1.2 Kecelakaan akibat tidak menggunakan sabuk pengaman


Kota Cianjur menjadi sorotan publik setelah sebuah kecelakaan tragis merenggut satu keluarga pada dini hari kemarin. Mobil yang mereka tumpangi dilaporkan menabrak sebuah pohon dengan keras, dan para penumpang dihuga kuat tidak menggunakan sabuk pengaman saat kejadian. Kondisi ini menyebabkan tubuh mereka terpental ke bagian depan kendaraan dan mengalami benturan fatal. Peristiwa tersebut sangat memicu perhatian luas di media nasional.

Banyak warganet menyoroti rendahnya kesadaran penggunaan sabuk pengaman, terutama pada perjalanan jarak dekat yang sering dianggap aman. Struksi ini memunculkan kekhawatiran baru mengenai tingginya risiko cedera serius ketika terjadi tabrakan mendadak, bahkan pada kecepatan yang tidak terlalu tinggi. Kalian dapat mengkaji permasalahan ini dalam materi Hukum Newton dan penerapannya dalam keselamatan berkendara yang akan kita pelajari pada bab ini.




Sekilas Info

Hukum III Newton menjadi dasar dari berbagai teknologi modern. Roket dapat meluncur karena gas panas hasil pembakaran didorong ke bawah (aksi), sehingga roket terdorong ke atas (reaksi). Pesawat jet juga dapat melaju karena mesin mendorong udara ke belakang, sehingga udara mendorong pesawat ke depan. Bahkan teknologi sederhana seperti alat pemadam kebakaran bertekanan bekerja dengan prinsip yang sama, yaitu air disemprotkan ke depan, kemudian tabung terdorong ke arah sebaliknya. Tanpa hukum aksi-reaksi, perkembangan transportasi udara dan antariksa tidak akan mungkin terwujud.




Sumber: galeripesawat.com
Gambar 3.3 Peluncuran pesawat jet




Sekilas Info

Pandangan tentang gerak mengalami perubahan dari waktu ke waktu. Pandangan pada zaman Aristoteles diyakini bahwa benda hanya bisa bergerak jika terus-menerus diberi gaya. Pandangan ini kemudian dibantah oleh Galileo melalui percobaan bidang miring menyimpulkan bahwa benda akan tetap bergerak dengan kecepatan konstan jika tidak ada gaya luar seperti gesekan. Gagasan tersebut disempurnakan oleh Sir Isaac Newton dalam Hukum I Newton yang menyatakan bahwa benda akan tetap diam atau bergerak lurus beraturan selama tidak ada gaya luar yang bekerja padanya.




Sumber: britannica.com
Gambar 1.4 Sir Isaac Newton




Digital Literasi


Kalian dapat menonton video di bawah ini agar lebih memahami konsep dan prinsip Hukum I Newton. Kalian dapat scan *barcode* atau klik tautan youtube yang telah disajikan.



Sumber: britannica.com
Gambar 1.5 Sir Isaac Newton




Sumber: @ YouTube



Diskusi

- Perhatikan bacaan singkat mengenai fenomena di bawah ini, kemudian jawablah pertanyaan yang disajikan.
- Indonesia pernah meluncurkan roket sonda dari Pameungpeuk, Garut, Jawa Barat, untuk penelitian atmosfer. Roket dapat naik ke udara karena mesin pembakaran mendorong gas panas ke bawah dengan kecepatan tinggi. Gas yang terdorong ke bawah itu memberi gaya balasan ke atas, sehingga roket meluncur menembus atmosfer. Berdasarkan bacaan di atas, mengapa roket bisa meluncur ke atas meskipun tidak ada pijakan di luar angkasa?
- Mengapa roket dapat bekerja di antariksa sedangkan mesin jet tidak?
- Betapa kuatnya kita melompat, kita selalu jatuh kembali ke tanah karena terdapat gaya tarik Bumi yang arahnya ke bawah. Hukum III Newton menyatakan bahwa Bumi pun ditarik oleh diri kita. Mengapa Bumi tampak tidak bergerak mendekati kita ketika kita melompat?
- Jawablah pertanyaan tersebut pada form yang telah disediakan!

SUBMIT






Figure 3. Features of Newton's Laws Flipbook Teaching Material Based on Socio-Science Issues

Based on Figure 3, the teaching materials integrate SSI in various features. The issues raised focus on driving safety issues that are close to everyday life, such as the use of seat belts, the effectiveness of child car seats, the importance of SNI standard helmets, the risk of accidents due to sudden braking, and inadequate friction conditions. In addition, the teaching materials developed integrate the Socio-Science Issues approach with the Problem-Based Learning (PBL) model. The application of the PBL model provides a learning framework that guides students to identify problems, search for valid information, formulate arguments based on evidence, and design science solutions to the situations analyzed. The relationship between SSI teaching materials and PBL syntax is presented in Table 1.

Table 1. Integration of Newton's Laws Flipbook Teaching Materials Based on SSI in PBL Syntax

PBL Model Syntax	Features	Description
Student orientation to the problem	Guiding Question	Arouse curiosity and direct students to the need to understand Newton's Laws.
Organizing or arranging students for learning	Digital Literacy	A QR code containing a video link as supporting information to help students access digital learning resources.
Guiding or monitoring student investigations	Discussion	Includes guiding questions and structured discussion spaces that encourage students to analyze issues.
Developing and presenting results	Discussion	Students compile science explanations of the analysis results and present solutions or findings in groups.
Analyze and evaluate the problem-solving process	Individual Projects	Guide students to reflect on the problem-solving process and assess the effectiveness of the physics concepts used.
	Caring for the Environment	Includes invitations or reflective activities related to the social and environmental impacts.

Development

The development stage entailed the testing of the validity of the subject matter experts and the media experts. The content validity was intended to ensure that the flipbook on Newton's Laws, which integrated with Socio-Science Issues (SSI), was scientifically correct, educationally sound, and consistent with learning outcomes in the 21st century, especially in critical thinking and science literacy. The product validity was examined via Aiken's V coefficient. For this study, values higher than 0.80 were considered to indicate a high level of agreement among the experts regarding the importance of the developed product. The results of the assessment of the teaching materials by the subject matter experts are shown in Table 2.

Table 2. Results of Content Expert Validity

Assessment Aspect	Aiken's V			Percentage	
	Calculated V value	Table V value	Criteria	Value (%)	Criteria
Content	0.85	0.80	Valid	87.80	Very good
Presentation	0.86	0.80	Valid	88.86	Very good
Language	0.87	0.80	Valid	89.33	Very good
Environmental awareness	0.88	0.80	Valid	90.67	Very good

All aspects of content validity met the criteria for "valid" and "very good," as shown in Table 2. These findings show that the flipbook is accurate, clear, and appropriate to support the critical thinking and science literacy of the students. It is related to physics concepts and SSI, enabling the students to analyze the real-life problems related to Newton's Laws. These findings support the Rahmayanti et al. (2023) study, which states that teaching materials integrated with SSI are very appropriate for learning. Fitriany (2020) also emphasized the importance of the validity of teaching materials, which is based on the theoretical foundation and the integration of the components. Moreover, the media validity test is intended to measure the feasibility of the flipbook as a medium for learning. It is related to the flipbook's visual design, its readability, and the level of the reader's engagement. Media experts assessed the flipbook using the criteria with Aiken's $V > 0.80$, as shown in Table 3.

Table 3. Media Expert Validity Results

Graphic Assessment Aspect	Aiken's V		Criteria	Percentage	
	Calculated V value	Table V value		Value (%)	Criteria
Size of Teaching Materials	0.88	0.80	Valid	90.00	Very good
Cover Design	0.86	0.80	Valid	88.67	Very good
Content Design	0.89	0.80	Valid	90.86	Very good

Based on Table 3, all aspects of media validity met the “valid” and “very good” criteria. High media validity supports student engagement, facilitates information processing, and promotes independent learning (Astuti & Hali, 2019). These results are in line with Irawan et al. (2024) those found that SSI-based digital teaching materials have high media validity and support students' independent learning. Overall, the results indicate that the developed flipbook meets the criteria of a valid digital teaching material for SSI-based physics learning.

Then, a pretest and posttest of these instruments were conducted on a small scale to test their validity, reliability, difficulty level, discrimination power, and readability. The results showed that all 20 questions developed in the instrument were valid; 10 were multiple-choice questions based on conceptual questions, and 10 were essay questions based on critical thinking and science literacy. The reliability test results showed that the developed instrument is reliable; the results were 0.66 (very high) for multiple-choice questions and 0.93 (very high) for essay questions based on Cronbach's Alpha reliability test results. Moreover, the results showed that the questions were appropriately distributed in terms of difficulty level and discrimination power; therefore, the developed instrument is able to differentiate students' abilities. Furthermore, a readability test of the teaching materials was conducted by using a cloze test. The results showed that the readability score is 73.06%, which means that these materials fall into the category of “easy” because a text can be read independently by a student in this category.

Implementation

The implementation of the SSI-based Newton's Laws flipbook was conducted within the Problem-Based Learning (PBL) framework. Both the experimental and control groups were taught using the PBL model; however, the experimental group used the developed SSI-integrated flipbook, while the control group used conventional learning materials. Thus, the instructional model was held constant, and the flipbook served as the main treatment in this study (Zeidler et al., 2019). During the student orientation to the problem stage, the teacher presented contextual socio-science issues related to Newton's Laws through digital media such as videos, illustrations, or text. Students were then prompted to generate critical questions using the Guiding Question feature in the flipbook, stimulating their ability to identify relevant issues and formulate science inquiries (Ennis, 2018; Facione, 2013). This activity promotes elementary clarification and basic support indicators of critical thinking while supporting the explaining phenomena scientifically indicator of science literacy.

In the organizing students for learning stage, students were divided into groups, developed investigation strategies, and collected information from multiple sources using the Digital Literacy feature, which provides access to videos, articles, and science data. They formulated hypotheses and proposed solutions by integrating Newtonian concepts with socio-science issues. This process supports critical thinking indicators such as inference and strategies and tactics, while simultaneously developing science literacy skills in research and evaluation (Bybee, 2014). During the guiding and monitoring student investigations stage, teachers facilitated the investigative process, and students used the Discussion feature to analyze issues, construct science arguments, and evaluate evidence critically. This structured discussion fosters advanced clarification in critical thinking as well as constructing and evaluating in science literacy (Högström et al., 2025).

The developing and presenting results stage involved students compiling science reports in the form of posters, tables, graphs, or digital presentations. This activity cultivates science communication skills and the ability to construct evidence-based arguments. In the analyzing and evaluating problem-solving process stage, students reflected on the strengths and weaknesses of

their solutions through the Individual Project and Caring for the Environment features, while assessing the social and environmental implications of applying Newton's Laws. These activities enhance students' science awareness and social responsibility, key components of science literacy (Zeidler et al., 2019). Overall, the integration of the SSI-based flipbook with the PBL model ensures that Newton's Laws learning does not merely focus on conceptual understanding but simultaneously develops students' critical thinking and science literacy. The flipbook provides real-life contexts and interactive features that allow students to connect physics concepts to everyday phenomena, aligning with 21st-century learning demands (Facione, 2013).

The implementation stage was carried out through large-scale testing of teaching materials in two control and experimental classes to determine the effectiveness and practicality of teaching materials in improving critical thinking and science literacy skills. Before data analysis, prerequisite tests were conducted to ensure that the data met the assumptions required for further statistical analysis. These included a normality test and a homogeneity of variance test. The results indicated that the data were normally distributed and homogeneous ($p > 0.05$), indicating that the assumptions for subsequent analysis were satisfied. The student N-Gain test was used to assess the effectiveness of the teaching materials developed. The results of the N-Gain test for critical thinking skills for the experimental and control groups are presented in Table 4.

Table 4. Results of the N-Gain Test Analysis of Critical Thinking Skills

Group	Average Score		N-Gain Score	Criteria
	Pretest	Posttest		
Experiment	52.78	78.33	0.54	Moderate
Control	50.46	61.57	0.22	Low

Based on Table 4, the Newton's Laws flipbook teaching material based on Socio-Science Issues used in the experimental class proved to be more effective in improving students' critical thinking skills. This is in line with the research Pakonglean et al. (2024) that effective teaching materials can significantly improve student learning outcomes. The effectiveness of teaching materials is also assessed based on the achievement of learning objectives (Yusuf, 2023). Critical thinking skills, consisting of five indicators, were analyzed using N-Gain scores presented in Table 5. The interpretation of normalized gain followed the criteria proposed by Hake (1998), where $g \geq 0.70$ is categorized as high, $0.30 \leq g < 0.70$ as moderate, and $g < 0.30$ as low.

Table 5. Results of the N-Gain Score Analysis for Each Critical Thinking Ability Indicator

CT Indicator	Description	Experiment		Control	
		N-Gain	Criteria	N-Gain	Criteria
Elementary clarification	Students are able to focus questions, analyze ideas, and answer questions.	0.65	Moderate	0.35	Moderate
Basic support	Students are able to consider the accuracy of information and build basic skills.	0.60	Moderate	0.24	Low
Inference	Students are able to find important information about a problem and consider the solutions provided.	0.55	Moderate	0.16	Low
Advanced clarification	Students are able to assess the accuracy of terms, definitions, and assumptions through in-depth explanations.	0.47	Moderate	0.16	Low
Strategies and tactics	Students are able to develop strategies and tactics in interacting with others.	0.39	Moderate	0.09	Low

The first critical thinking indicator, elementary clarification, assesses students' ability to formulate questions, examine information, and analyze issues (Sunardjo et al., 2016). Students are given questions through short narratives to identify and examine contextual problems, such as

accidents caused by not wearing seat belts or brake failure on trucks carrying sand. Improvements in the first indicator in the experimental class were facilitated by prompts that helped students understand terms and information more clearly. This will help students develop critical thinking through reading, understanding context, and connecting concepts (Iwanda et al., 2022).

The second critical thinking indicator, basic support, assesses students' ability to evaluate the reliability of information and provide evidence-based reasoning (Bahri, 2017). Students understand short readings containing the process of an issue and interrelated variables before concluding. This is in line with the research Sundari & Sarkity (2021) that a deep understanding of concepts is needed to connect variables in a problem. The improvement in the second indicator in the experimental class was facilitated by digital literacy features that included learning videos and links to information sources. This visual-auditory integration helps students process information more effectively Azis et al. (2022), and the use of online facilities also improves the quality of the learning process (Meduri et al., 2022). These activities encourage students to explore data, clarify information, and distinguish between facts and opinions in the context of issues such as driving safety or the relationship between force and acceleration.

The third critical thinking indicator, inference, assesses students' ability to identify deductive and inductive processes to produce accurate conclusions (Anggraeni et al., 2018). Questions are presented in the form of short narratives containing statements and data on a problem. Students analyze the information, review the correlations between the data and statements, and relate them to Newton's Laws concepts to formulate conclusions. Evaluating the relationship between data or statements is part of the process of summarizing conclusions. The improvement in the third indicator in the experimental class was facilitated by the discussion feature related to the issues of seat belt/child car seat use, the importance of wearing SNI helmets, and driving safety in rainy conditions, on sandy roads, and on muddy roads. Students interpreted information, looked for patterns, compared data, and made logical implications to produce valid and evidence-based conclusions.

The fourth critical thinking indicator, advanced clarification, assesses students' ability to identify various terms and assumptions (Sunardjo et al., 2016). Questions are presented in the form of data that students must interpret. This interpretation can take the form of converting data into graphs or diagrams to identify problems. After that, students formulate assumptions based on situations that may arise from the information provided (Susanti & Hernawati, 2022). This process helps students think openly and present comprehensive explanations. The improvement in the fourth indicator in the experimental class was facilitated by the presentation of group discussion results according to the topics in the discussion feature.

The fifth critical thinking indicator, strategies and tactics, assesses students' ability to develop strategies and tactics in determining actions and interacting with others (Sunardjo et al., 2016). The questions are presented in the form of factual readings about child safety while driving and the use of child car seats. Students design effective communication strategies for parents, choose alternative methods of delivery, and relate their arguments to Newton's Third Law to assess the assumption that children are safer when held by their parents. This ability is influenced by daily experiences and the accuracy of students in choosing actions based on available information (Adinda et al., 2021). The improvement in the fifth indicator in the experimental class was facilitated by independent projects. Students solved problems by gathering information from various sources, including the use of technology and interviews with the surrounding community (Afkarina et al., 2024). This independent project also fostered students' sensitivity to environmental issues and encouraged the emergence of alternative solutions. The problem-solving stage helps students optimize their knowledge to produce critical solutions.

The five critical thinking indicators collectively demonstrate that the SSI-based flipbook effectively fosters students' critical thinking skills. Elementary clarification supports students in formulating questions and analyzing contextual problems (Iwanda et al., 2022; Sunardjo et al., 2016), while basic support enables them to evaluate the reliability of information through digital resources (Azis et al., 2022; Bahri, 2017; Sundari & Sarkity, 2021). Inference enhances students' ability to draw accurate conclusions through deductive and inductive reasoning (Anggraeni et al., 2018), advanced clarification promotes data interpretation and assumption formulation (Sunardjo et al., 2016; Susanti & Hernawati, 2022), and strategies and tactics strengthen planning,

communication, and problem-solving skills through independent projects related to real socio-science issues (Adinda et al., 2021; Afkarina et al., 2024; Sunardjo et al., 2016). Overall, these indicators indicate that the flipbook facilitates the integrated development of critical thinking within meaningful socio-science contexts.

After analyzing the effectiveness of teaching materials on critical thinking skills, this study also analyzed the effectiveness of using Newton's Laws flipbook teaching materials based on SSI on students' science literacy. Science literacy is an important aspect because it reflects students' ability to apply science knowledge to explain phenomena, evaluate information, and make evidence-based decisions. The results of the N-Gain test for science literacy for the experimental and control groups are presented in Table 6.

Table 6. Results of the N-Gain Science Literacy Test Analysis

Group	Average Score		N-Gain Score	Criteria
	Pretest	Posttest		
Experiment	55.56	77.50	0.48	Moderate
Control	47.50	57.50	0.19	Low

Based on Table 6, the Newton's Laws flipbook teaching material based on Socio-Science Issues used in the experimental class proved to be more effective in improving students' science literacy. Science literacy, which consists of three indicators, was analyzed using the N-Gain scores presented in Table 7.

Table 7. Results of the N-Gain Score Analysis for Each Science Literacy Indicator

Science Literacy Indicator	Description	Experiment		Control	
		N-Gain	Criteria	N-Gain	Criteria
Explaining phenomena scientifically	Students are able to recognize, generate, apply, and evaluate explanations and solutions for various natural phenomena.	0.57	Moderate	0.27	Low
Research, evaluate, and use science information for decision-making and action	Students are able to critique research designs, identify variables, formulate hypotheses, and evaluate results.	0.46	Moderate	0.20	Low
Construct and evaluate designs for science investigations and critically integrate data and evidence	Students are able to propose experimental designs, evaluate science investigations, interpret data, and draw appropriate conclusions based on the data.	0.43	Moderate	0.10	Low

The first science literacy indicator is explaining phenomena scientifically, assessing students' ability to use science concepts to explain everyday events and understand their implications for society (OECD, 2019b). In this study, the phenomena analyzed include real-life events related to driving safety, such as accidents caused by not wearing seat belts, brake failure in trucks carrying sand, risks of driving on sandy or muddy roads, and the incorrect use of child car seats. Students were asked to observe these phenomena through texts, images, and videos, then identify the underlying physics concepts, such as inertia, force, and action-reaction, and link them to social implications, for example, the risk of injury and the importance of safety standards. During the learning process, students were encouraged to ask critical questions, interpret information, and draw evidence-based conclusions, facilitated by the digital literacy and discussion features in the SSI-based flipbook. This approach enabled students to deeply integrate physics concepts with social contexts, enhancing reflective, argumentative, and analytical thinking skills. Observations indicated that this strategy significantly supported students in explaining phenomena scientifically,

consistent with Rubini et al. (2019) the integration of SSI in PBL, which can improve science literacy, particularly in the ability to explain phenomena scientifically.

The second science literacy indicator is researching and evaluating, assessing students' ability to read, analyze, and conclude science information based on the data presented (OECD, 2019b). Students are given data on friction and the speed of objects on various types of surfaces, and then they interpret speed changes based on scientific evidence. Improvements in the second indicator in the experimental class were facilitated by discussions and independent projects. This process develops reflective, argumentative, and ethical thinking skills, including the ability to present solutions, defend arguments, and reflect based on scientific evidence. This is in line with the research, Annisa et al. (2023) which states that SSI-based physics teaching materials can improve the ability to evaluate and use science information in decision-making.

The third science literacy indicator is constructing and evaluating, which assesses students' ability to design valid experimental procedures, identify variables, and interpret data logically to support science conclusions (OECD, 2019b). The questions presented require students to determine the appropriate steps to investigate problems, such as analyzing the effect of friction on vehicle fuel efficiency or designing experiments to test the relationship between mass and acceleration. The improvement of the third indicator in the experimental class is facilitated by the presentation of discussion results. Students systematically design experiments, select the necessary tools and materials, and estimate the type of data to be collected. After that, students evaluate the feasibility of the design, then use observational data to draw logical conclusions based on scientific evidence.

Overall, the observed improvements across the three science literacy indicators demonstrate that the integration of the SSI-based flipbook teaching materials effectively facilitates students' abilities to apply science concepts to real-life contexts, critically analyze information, and design and evaluate science investigations. The indicator explaining phenomena scientifically shows that students are able to connect theoretical concepts with social issues, while the researching and evaluating indicator reflects students' ability to engage in evidence-based reasoning and make ethical decisions. The constructing and evaluating indicator highlights students' competence in systematically planning and conducting experimental procedures. These results indicate that SSI, by situating physics concepts within socio-science contexts and leveraging digital and discussion features, simultaneously supports the development of higher-order thinking skills and science literacy. These findings are consistent with the OECD framework and prior research, such as Rubini et al. (2019) Annisa et al. (2023), which emphasize that socio-science contexts enhance students' capacity to interpret, evaluate, and apply science knowledge meaningfully.

The analysis of learning outcomes indicates that the improvement in students' science literacy is closely linked to the development of critical thinking skills fostered through the SSI-based flipbook. For instance, students' abilities in elementary clarification and basic support enabled them to understand phenomena, evaluate information, and pose critical questions, directly supporting science literacy indicators such as explaining phenomena scientifically and researching and evaluating science information. Similarly, skills in inference, advanced clarification, and strategies and tactics facilitated students in designing, assessing, and drawing conclusions from experiments or investigations systematically, thereby enhancing the constructing and evaluating aspect of science literacy. In other words, the development of critical thinking not only helps students improve their critical and argumentative thinking but also helps them improve their ability to apply science concepts in a social context, which leads to a mutually reinforcing relationship between critical thinking and science literacy (Ennis, 2018; Rubini et al., 2019). The results of this subproblem are consistent with the initial argument of the introduction that critical thinking is a key mediator in enhancing science literacy by applying the SSI-based method of learning.

Having identified the effectiveness of the teaching materials, the next step is to assess the practicality of the materials. Practicality is an essential factor that helps ensure not only the effectiveness of the teaching materials but also their practicality in the process of learning. The questionnaire for the practicality of the teaching materials consisted of responses from 36 students of the experimental class who were provided with the SSI-based method of learning Newton's Laws flipbook. The results of the analysis of practicality are shown in Table 8.

Table 8. Practicality Scores of Teaching Materials by Students for Each Assessment Aspect

Aspect	Students (%)	Criteria	Teachers (%)	Criteria
Ease of use	89.63	Very Practical	95.56	Very Practical
Alignment with user needs	92.78	Very Practical	91.11	Very Practical
Efficiency of use	88.33	Very Practical	96.00	Very Practical
Product appeal	90.00	Very Practical	93.33	Very Practical
Long-term utility	89.44	Very Practical	93.33	Very Practical
Average	90.04	Very Practical	93.87	Very Practical

The results show that all aspects of practicality achieved the “very practical” category for both students and teachers. The average practicality score reached 90.04% from students and 93.87% from teachers, indicating that the teaching materials are easy to use, efficient, and aligned with user needs. This finding is consistent with Saragih et al. (2023), which states that practical teaching materials should be easy to understand and implement in the learning process. In addition, usability has been recognized as an important factor in the effectiveness of digital learning media (Abdulrahman & Rawf, 2022). Overall, the high practicality indicates that the developed flipbook can be effectively used in classroom learning without requiring additional complex instructions, and supports both teachers and students in facilitating the learning process.

Evaluation

The evaluation stage was conducted through an overall assessment of the product. Formative evaluation was carried out during the development process, while summative evaluation was conducted after the product was used in learning. In the formative evaluation, the results of expert validity showed that the teaching materials were in the highly valid category. Expert input regarding the suitability of the content with the curriculum, conceptual accuracy, visualization, and language consistency formed the basis for product revision. Furthermore, the results of small-scale trials show that the test instruments have good validity and reliability, and the test items meet the criteria for adequate difficulty and discriminating power. The high readability of the teaching materials also indicates that they can be easily understood by students.

Furthermore, summative evaluation aims to analyze pretest and posttest results showing that the experimental class experienced an increase in critical thinking and science literacy skills with a moderate N-Gain category, while the control class was in the low category. These results indicate that the integration of SSI in learning has a significant contribution to students' learning outcomes. Specifically, the flipbook enables students to improve science literacy through activities such as evaluating science information, analyzing data, and making decisions based on evidence (Sadler et al., 2007; Zeidler et al., 2019). Moreover, SSI-based learning triggers higher-order cognitive activities such as argumentation, interpretation, and scientific reasoning, which are part of critical thinking skills (Högström et al., 2025). Overall, the formative and summative evaluations indicate that the developed Socio-Scientific Issues (SSI)-based Newton's Laws flipbook meets the criteria of validity, readability, practicality, and effectiveness, suggesting its potential to support students' learning and higher-order thinking development.

LIMITATIONS

This study has some limitations, such as: This research was conducted on only two classes in a single school, and thus its findings might not be generalized to a broader context. The flipbook, being specifically designed to deal with Newton's Laws, cannot be directly applied to other physics topics. Although assessment tools were based on well-recognized frameworks of critical thinking and science literacy, they were locally developed and, apart from content validity, were not tested using psychometric methods such as reliability analysis. Future studies should be conducted to utilize standardized tools to measure critical thinking and science literacy skills. This product was tested and validated by only five experts, and more experts could be included to enhance its reliability.

Future studies should be conducted to expand the context to more schools with different characteristics, to design more flipbooks on different physics topics, and to utilize quasi-

experimental or RCT designs to further demonstrate the effectiveness of SSI-based flipbooks. It is also recommended to utilize standardized tools to measure critical thinking and science literacy skills. Longitudinal studies and dissemination phases should be conducted to evaluate the sustainability of SSI-based flipbooks in classrooms. Moreover, longitudinal studies and dissemination phases are recommended to evaluate the sustainability of SSI-based flipbook implementation in classroom practice.

CONCLUSION

This study developed Newton's Laws flipbook teaching materials based on Socio-Science Issues to improve students' critical thinking and science literacy skills. The teaching materials product showed high feasibility as a learning medium. The results of expert validation, small-scale trials, and large-scale trials showed that the product was feasible and well-received. The readability score of the product in the small-scale trial was 73.06%, which met the criteria for easy comprehension. The pretest and posttest scores in the large-scale test were analyzed using N-Gain, resulting in an N-Gain score for critical thinking skills of 0.54 in the experimental class, which is in the moderate category, and 0.22 in the control group, which is in the low category. The teaching materials also measured students' science literacy levels, which were analyzed using N-Gain. The N-Gain value for science literacy in the experimental class was 0.48 in the moderate category and 0.19 in the low category for the control group. In addition, an analysis of the practicality of teaching materials was conducted from the perspective of students and teachers. The practicality of teaching materials by students obtained a result of 90.04% with the criteria of very practical, and the practicality by teachers obtained a result of 93.87% with the category of very practical. These results indicate an increase in students' critical thinking and science literacy in learning Newton's Laws when using the developed teaching materials. However, the findings should be interpreted with caution, as the observed improvement reflects higher learning gains rather than definitive causal effects. Thus, Newton's Law flipbook teaching materials based on Socio-Science Issues are valid and practical to be applied in learning.

Further research is needed to evaluate the effectiveness of the developed teaching materials, particularly in improving students' critical thinking and science literacy skills. The research design can use a broader sample with the development of interactive features and more varied technology integration. Thus, the research also has the potential to improve the quality of learning and other higher-order thinking skills.

AUTHOR CONTRIBUTIONS

IIN, as a student, conducted the study, prepared the background, research methods, results, and discussion sections, and performed manuscript revisions. EE and HMS, as supervisors, provided conceptual guidance, critically reviewed the methodology and discussion, and supervised the overall research process. All authors contributed to the interpretation of results and approved the final manuscript.

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