P-ISSN: 1693-1246
E-ISSN: 2355-3812
December 2025

Jurnal Pendidikan Fisika Indonesia 21 (2) (2025) 129-149
DOI: 10.15294/jpfi.v21i2.24712

http://journal.unnes.ac.id/journals/jpfi

Development of Socio-Scientific Issues (SSI) Based Digital Teaching Materials with A Flipped Classroom Model to Increase Students' Interest and Cognitive Learning Outcomes

Ahmad Azan Akbari[1], Isa Akhlis[1*], Siti Masfuah[2]

[1]Department of Physics Education
Universitas Negeri Semarang, Semarang, Indonesia
[2]Department of Primary Teacher Education
Universitas Muria Kudus, Kudus, Indonesia
*Corresponding author: isa.akhlis@mail.unnes.ac.id

Received: 22 September 2025. Accepted: 22 October 2025. Published: 12 December 2025

Abstract

This study aims to develop Socio-Scientific Issues (SSI)- based digital teaching materials on impulse and momentum, and to determine whether they are suitable and effective in enhancing students' interest and learning outcomes. The research employed the Research and Development (R&D) method, utilizing the ADDIE development model, which comprises the stages of analysis, design, development, implementation, and evaluation. Data collection techniques include observation, interviews, learning interest questionnaires, and learning outcomes tests. The data were analyzed through a feasibility test and an effectiveness test. The results showed that SSI-based digital teaching materials were feasible to use and had a positive effect on increasing students' interest and cognitive learning outcomes. This research offers benefits by providing alternative teaching materials that are contextual, interesting, and relevant, thereby improving the quality of physics learning in schools.

Keywords: cognitive learning outcomes, digital teaching materials, flipped classroom, learning interest, socio-scientific issues.

INTRODUCTION

The era of rapid technological development affects all aspects of human life; changes in the educational sector impact the way the learning process is perceived. Educators are required to be able to facilitate the learning process. (Putri & Eka, 2022). Educators as facilitators are required to provide learning resources that are relevant, innovative, and support active student participation. (Nababan, Marpaung, & Koresy, 2023). Learning resources that are not innovative can negatively impact student interest and learning outcomes. (Agustina, Arief, & Fitri, 2022).

Interest is identified as a mental tendency and impulse that encourages a person to feel attracted and happy to a specific person, object, or activity. Indicators of student interest in learning are divided into four aspects: feelings of pleasure, student involvement, interest, and student attention (Slameto, 2010). Interest is an important factor in the success of the learning process (Damayanti, Rizky, & Sofiyah, 2024). However, students' interest in learning remains low at SMA Negeri 12 Semarang. Based on observations, it is found that students experience a problem with low interest in learning, especially in physics. This is characterized by a lack of student participation in class, a tendency for students not to pay attention to the material during learning, and low enthusiasm. Low student interest in learning has a direct impact on students' cognitive learning outcomes (Sunami & Aslam, 2021). Low student interest can lead to boredom when students find something too easy or too difficult, resulting in disengagement. This lack of challenge reduces motivation and attention, ultimately hindering cognitive learning outcomes as students struggle to find value in their academic tasks (Hu, 2020). Abstract physics concepts that are difficult for students to understand and visualize through the monotonous presentation of material based on textbooks and lecture models (teacher-centred) can make students passive, less involved in the learning process, and have no control over their learning (Murphy, Eduljee, & Croteau, 2021).

To solve this problem, technology-based learning media development is needed, one of which is the use of technology-integrated learning media as an innovative and effective step. (Nurillahwaty, 2022). The form of technology-integrated learning media is digital teaching materials, which can contain video, text, animation, audio, and simulation. (Purwanto & Risdianto, 2022). Digital teaching materials must be interactive, contextual, and not only informative, but also able to stimulate student curiosity and creativity. (Muzayanah, 2020). One form of digital teaching materials with technological development through the Google Sites platform (Wulandari, Hakim, Sulistyowati, & Mian, 2022).

Google Sites, as a website creation platform, can be used to create digital teaching materials that are easily accessible and easily developed (Murtikaningrum et al., 2024). Digital teaching materials, such as those created with Google Sites, reduce boredom in learning and facilitate the learning process by incorporating a variety of content types, including text, videos, simulations, and other multimedia elements. (Amarulloh, 2022). Digital teaching materials that can be accessed anytime and anywhere also help increase student learning flexibility. (Khikmawati et al., 2021). In the learning process, students are required to be active in exploring the existing material independently and have complete control over what they learn (Sulistyawati, Suarjana, & Wibawa, 2022). The use of Google Sites significantly enhances user experience and engagement by providing a centralized platform to access modules, interactive worksheets, and resources, leading to positive perceptions among students and promoting independent learning, convenience, and effective time management (Data, 2022). Google Sites-based digital teaching materials are suitable for use in the Flipped Classroom learning model (Osman, Noor, Hat, Rouyan, & Saad, 2023).

Flipped Classroom is a learning model that reverses the state of conventional learning through the delivery of concepts in the form of materials or other learning resources outside the classroom, independently by students, followed by direct discussion in class (Annajmi & Kuswandi, 2024). This approach assimilates content independently before direct instruction, thereby allowing for deeper exploration of concepts throughout the in-class educational experience (Arslan, 2020). It encourages learning independence and awareness, as seen from student participation and contribution during learning activities, doing well on assignments, and being eager to take part in learning (Fakhri, Andayani, Kaswar, Adistia, & Fadhilatunisa, 2023). The Flipped Classroom model is very relevant when combined with the Socio-Scientific Issues (SSI) approach, because both encourage active student involvement in analyzing contextual issues related to science and everyday life.

The SSI approach, developed in digital teaching materials, is designed to illuminate the contextual challenges encountered in real life, thereby fostering critical thinking and emotional engagement among students (Macalalag Jr et al., 2024). It enhances student engagement, interest, and attention through the discussion and analysis of social issues that connect science and the circumstances surrounding students (Nur, 2023). Students are directly involved in science learning by applying their knowledge to issues that are both interesting and relevant to their own circumstances (Zeidler & Nichols, 2009). SSI is suitable and relevant for development based on impulse and momentum, as it addresses numerous social issues that occur in students' daily lives, which can be explained by the concept of physics (Jumadi & Dwandaru, 2023). Based on the description above, it is necessary to research the development of digital teaching materials based on SSI to increase students' interest and cognitive learning outcomes in impulse and momentum material.

METHOD

This research employs a research and development model based on the ADDIE development model (Analyze, Design, Develop, Implement, and Evaluate). The ADDIE research design was developed by (Branch, 2009) with procedures including analysis, design, development, implementation, and evaluation. The ADDIE model was chosen because it can be a systematic and efficient framework in directing developers with an instructional design process that ensures every aspect of learning is considered (Suratnu, 2023). The flowchart in Figure 1 illustrates the stages involved in developing the digital teaching materials. Each phase was carried out by integrating the principles of SSI to contextualize physics concepts and by adopting the Flipped Classroom approach to enhance student engagement and autonomy in the learning process.

a. Analyze Stage

At this stage, the needs and problems in learning are identified, including curriculum analysis, learner characteristics, and the suitability of learning materials with digital media.

b. Design Stage

This stage focuses on designing the structure of digital teaching materials, including determining the learning flow, selecting content, utilizing visual media, incorporating interactivity, and implementing evaluation tools.

c. Develop Stage

At this stage, the manufacture and production of digital teaching materials is carried out based on the design that has been prepared, and based on media and material validation.

d. Implement Stage

The developed digital teaching materials were utilized in the learning process, and a post-test assessment was conducted.

e. Evaluate Stage

Evaluation is carried out at each stage of the ADDIE development model, particularly to assess the media developed, with improvements implemented at each stage. The assessment was conducted by comparing student competence between the pretest and posttest.

The research was conducted at SMA Negeri 12 Semarang, located at Jl. Raya Gunungpati, Plalangan, Kec. Gunung Pati, Semarang City, Central Java Province. The sample in this study consisted of 68 students from class XI F2 and XI F3 at SMA Negeri 12 Semarang. The data collection techniques employed were observation, interviews, questionnaires, and tests. Data analysis techniques were carried out through feasibility tests and effectiveness tests. The stages of the ADDIE development model are as follows.

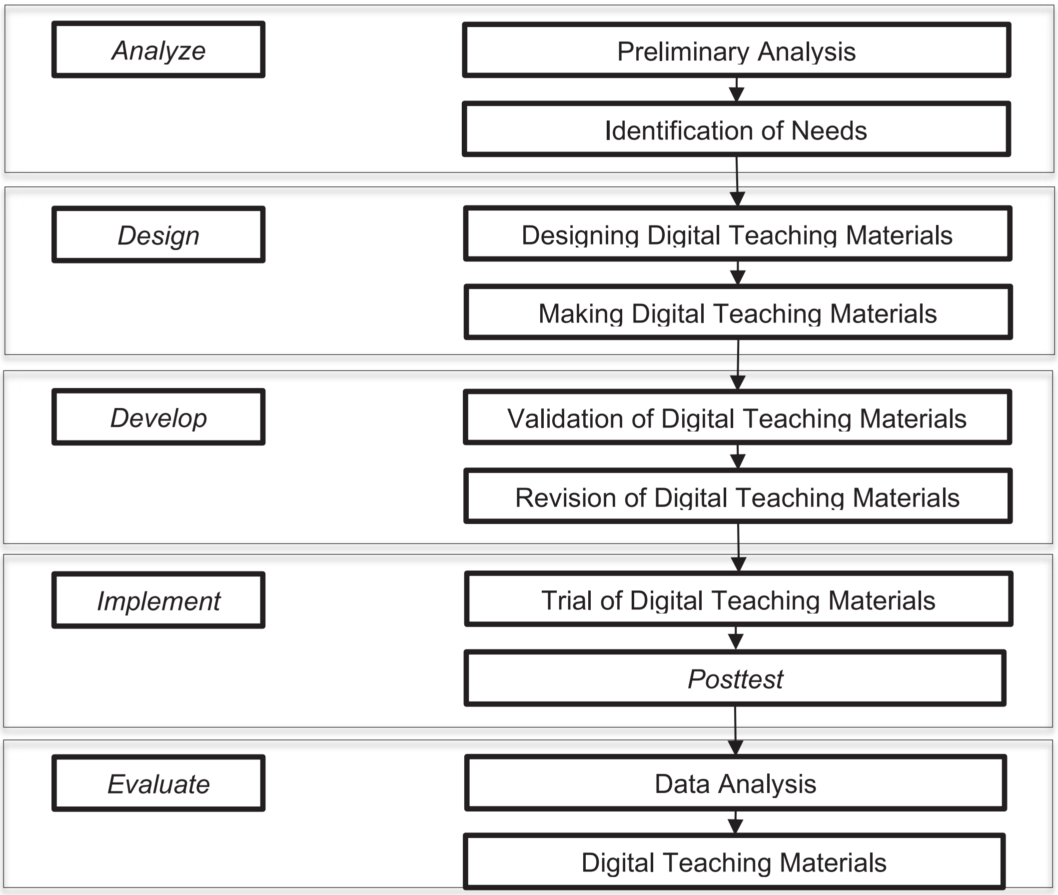


Figure 1. Digital Teaching Material Flowchart

Data collection techniques included media and material expert validation questionnaires, student cognitive learning outcomes instruments, and student interest questionnaires. The media and material expert validation questionnaire was developed on a Likert scale. The media expert validation questionnaire was tested on five validators, who focused on aspects of software engineering, learning design, and visual communication, as shown in Table 1. The material expert validation questionnaire was tested on five validator experts, who focused on content feasibility, contextual assessment, and language feasibility, as shown in Table 2.

Table 1. Media Expert Validation Questionnaire Grid

Aspect	Indicator	Item Number
Software Engineering	Media effectiveness and efficiency	1, 2
	Ease of operation and development	3, 4
	Development platform suitability	5
	Cross-device compatibility	6
Learning Design	Clarity of content and presentation structure	7, 8
	Interaction and media appeal	9, 10
	Relevance of content to real context	11, 12
Visual Communication	Attractive design and layout	13, 15, 20, 22
	Ease of message comprehension	14, 18, 19
	Quality of multimedia elements and typography	16, 17
	Visual comfort	21
Total		22

Table 2. Material Expert Validation Questionnaire Grid

Aspect	Indicator	Item Number
Content Feasibility	Material coverage	1, 2, 3
	Accuracy of the material	4, 5, 6
	Presentation technique	7, 8
Contextualized Assessment	The Nature of Contextualization	9, 10
Language Feasibility	Straightforward	11, 12
	Accuracy of language rules	13, 14
	Communicative	15
	Appropriateness to learner development	16
Total		16

To see the increase in student interest and cognitive learning outcomes using student cognitive learning outcomes instruments and student interest questionnaires. The questionnaire of students' interest in learning was made based on aspects of interest in learning by Slameto (2010) which consisted of feelings of pleasure, student involvement, interest, and student attention, as measured on a Likert scale, as shown in Table 3. The instrument of students' cognitive learning outcomes was based on the revised Bloom's taxonomy with reference to the six cognitive domains (Anderson & Krathwohl, 2001) Attached in Table 4.

Table 3. Student Learning Interest Questionnaire Grid

Aspect	Indicator	Item Number
Good Feelings	Happy with learning media	1
	Happy to have successfully solved the problem	2
	Enjoyed the discussion together	3
	Enjoys understanding contextualized concepts	4
Engagement	Active participation in classroom learning	5, 6
	Independence in learning outside the classroom	7, 8
Interest	Interest in the application of concepts in life	9, 11
	Interest in digital learning media	10
	Interest in concept delivery	12
Attention	Paying attention to the learning process	13, 14
	Active effort in understanding the material	15
	Ask questions when encountering difficulties	16
Total		16

Table 4. Grid of Student Cognitive Learning Outcome Instruments

Material	Indicator	Cognitive Level	Item Number
Momentum, impulse, and the relationship between momentum and impulse	List the definition of impulse based on examples in life	C1	1
	List the factors of momentum based on examples in life	C1	2
	Calculating the momentum of objects	C3	5
	Calculating the velocity of the ball after it has been subjected to an impulse force	C3	6
	Calculate the impulse of an object based on a graph of force against time	C4	8
	Calculate the final velocity of a table based on a graph of force versus time.	C4	9
	Analyze the design of the front of the car as a result of the concept of impulse.	C4	10
	Analyze the momentum comparison between before and after being changed	C4	11
	Comparing the initial momentum of the truck with the momentum after the velocity is increased by 3 times.	C5	12

Material	Indicator	Cognitive Level	Item Number
Law of conservation of momentum	Give examples of the law of conservation of momentum in life	C2	3
	Calculating the velocity of the beam after being hit by a bullet	C3	7
	Measuring the final velocity of the boat after the fisherman jumps into the water	C5	14
Collision	Estimating collisions that occur under certain circumstances	C2	4
	Evaluate the statement of vertically thrown and free-falling basketballs	C5	13
	Conclude the type of collision based on experimental data of collisions between identical billiard balls.	C6	15
Total			16

Instruments used to measure students' interest and cognitive learning outcomes were also validated before use. This ensures that the collected data accurately reflects the effectiveness of the developed teaching materials in improving both affective and cognitive aspects of learning. These findings align with the purpose of this study, which is to produce teaching materials that are not only theoretically sound but also practically implementable in authentic classroom contexts.

The student cognitive learning outcomes test instrument that has been developed is tested to see the quality of the instrument through a validity test that measures the validity of the instrument, a reliability test that measures the level of consistency of the instrument, a difficulty test that measures the distribution of instrument difficulty, and a differentiating test that measures the instrument's ability to distinguish high and low ability students. The results of the instrument validity test are presented in Table 5.

Table 5. Instrument Validity Test Results

Item Number	*P-Value*	Pearson Correlation	Description
1	0.556	0.001	Valid
2	0.369	0.029	Valid
3	0.226	0.193	Invalid
4	0.560	0.001	Valid
5	0.109	0.532	Invalid
6	0.396	0.018	Valid
7	0.394	0.019	Valid
8	0.495	0.003	Valid
9	0.652	0.001	Valid
10	0.207	0.232	Invalid
11	0.618	0.001	Valid
12	0.621	0.001	Valid
13	0.467	0.005	Valid
14	0.207	0.232	Invalid
15	0.091	0.602	Invalid
16	0.443	0.008	Valid
17	0.513	0.002	Valid
18	0.348	0.410	Valid
19	0.559	0.001	Valid
20	0.464	0.005	Valid

Table 5 presents the results of the instrument validity test, in which five items were identified as invalid because their correlation values fell below the acceptable threshold. These items were removed and excluded from further analysis. Meanwhile, 15 items were found to be valid, as their item-total correlation coefficients met or exceeded the critical value, and were subsequently subjected to a reliability test in IBM SPSS Statistics 27.

The results of the reliability test for the cognitive learning outcomes instrument showed a Cronbach's Alpha value of 0.739. According to commonly accepted standards, a Cronbach's Alpha above 0.7 indicates that the instrument has good internal consistency. This suggests the instrument is suitable for research. A valid instrument accurately measures what it is meant to, in this case, students' understanding of physics. Its reliability ensures consistent results across different tests, which is important for evaluating the success of the digital teaching materials..

The results of the item difficulty level test used to determine the extent to which each question can be answered correctly by participants are summarized in Table 6, illustrating the distribution of items across easy, moderate, and complex categories.

Table 6. Instrument Difficulty Test Results

Item Number	Difficulty Level	Category
1	0.74	Easy
2	0.71	Easy
3	0.51	Medium
4	0.51	Medium
5	0.80	Easy
6	0.77	Easy
7	0.26	Difficult
8	0.29	Difficult
9	0.37	Medium
10	0.69	Medium
11	0.83	Easy
12	0.57	Medium
13	0.57	Medium
14	0.37	Medium
15	0.43	Medium

Table 6 shows the results of the instrument difficulty test with easy (f = 5), medium (f = 8), and difficult (f = 2). This distribution reflects an ideal balance in item difficulty, ensuring a fair spread of scores and accommodating students with varying abilities. The test instrument is well-constructed in terms of difficulty level. The presence of easy, medium, and difficult items ensures that the instrument can differentiate between high- and low-achieving students while still providing accessible entry points for all learners. This balance is crucial in accurately and equitably measuring cognitive learning outcomes.

The last test on the instrument is the differentiating power test; the results of this test are shown in Table 7.

Table 7. Instrument Differentiability Test Results

Item Number	Differentiating Power	Criteria
1	0.5	Good
2	0.5	Good
3	0.8	Very good
4	0.6	Good
5	0.4	Good
6	0.6	Good
7	0.6	Good
8	0.8	Very good
9	0.6	Good
10	0.4	Good
11	0.5	Good
12	0.5	Good
13	0.5	Good
14	0.6	Good
15	0.7	Very good

Table 7 presents the results of the differentiating power test, categorized as good (f = 12) and very good (f = 3).

These results indicate that the majority of the test items have strong differentiating power, meaning they are effective in distinguishing between students with high and low levels of understanding. This is crucial in evaluating learning outcomes, particularly in identifying which students have truly mastered the material. Items with good and excellent discrimination levels can effectively differentiate between students who understand the concepts deeply and those who do not, thereby supporting valid conclusions about learning effectiveness.

Data analysis techniques for the feasibility of the media developed using the percentage formula (formula 1), the cognitive learning outcomes test instrument was analyzed with the Pearson product moment coefficient for the validity test (formula 2), Cronbach alpha correlation for the reliability test (formula 3), comparison of correct answers for the difficulty level of the question (formula 4), and the discrimination index for the differentiator test (formula 5).

Feasibility test formula

$$NP = \frac{R}{SM} \times 100\% \qquad (1)$$

with

PV : Percentage value

T : Total score obtained

MN : Maximum number of scores

Media and material eligibility criteria refer to Riduwan (2015).

$81\% - 100\%$: Very feasible

$61\% - 80\%$: Feasible

$41\% - 60\%$: Feasible enough

$21\% - 40\%$: Less feasible

$0\% - 20\%$: Not feasible

Validity test formula

$$r_{\text{xy}} = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}} \qquad (2)$$

with

r_{xy} : Pearson product-moment coefficient

$\bar{X}$: Average score of those who answered correctly

$\bar{Y}$: Average score of all test takers

X : The score of students answering correctly

Y : The score of students answering incorrectly

The validity criteria are based on whether the p-value is less than 0.05 and the Pearson correlation is positive.

Reliability test formula

$$r_i = \left[\frac{k}{(k-1)}\right]\left[1 - \frac{\sum S_{\mathrm{i}}}{S_{\mathrm{t}}}\right] \quad (3)$$

with

r_i : Cronbach Alpha Value
k : Number of items
$\sum S_{\mathrm{i}}$: Number of score variances for each item
S_{t} : Total variance

Reliability criteria refer to Guilford in Mudanta, Astawan, and Jayanta (2020).

$0.80 < \mathrm{r_i} \leq 1.00$: Very high
$0.60 < \mathrm{r_i} \leq 8.00$: High
$0.40 < \mathrm{r_i} \leq 0.60$: Medium
$0.20 < \mathrm{r_i} \leq 0.40$: Low
$\mathrm{r_i} \leq 0.20$: Very Low

The formula for the level of difficulty test

$$P = \frac{B}{JS} \quad (4)$$

with

P : Difficulty level
B : Number of students who answered correctly
JS : Total number of students

The criteria for the level of difficulty refer to Guilford in Sudjana (2005).

$\mathrm{P} > 0.70$: Easy
$0.30 \leq \mathrm{P} \leq 0.70$: Medium
$\mathrm{P} < 0.30$: Difficult

Differentiating the power formula

$$D = \frac{BA}{JA} - \frac{BB}{JB} \quad (5)$$

with

D : Differentiating power
BA : Number of upper group students who answered correctly
BB : Number of lower group students who answered correctly
JA : Number of upper group students
JB : Number of lower group students

The criteria for the level of difficulty refer to Guilford in Fitriani (2021).

$\mathrm{D} \geq 0.70$: Very good
$0.40 \leq \mathrm{D} < 0.70$: Good
$0.20 \leq \mathrm{D} < 0.40$: Medium
$\mathrm{D} < 020$: Bad

Data analysis techniques for assessing student interest in learning and cognitive learning outcomes include the Shapiro-Wilk test for normality (Formula 6), the Levene test for homogeneity (Formula 7), the N-Gain test (Formula 8), and the Independent Sample t-test (Formula 9).

Normality test formula

$$W = \frac{\sum(a_i x_i)^2}{\sum(x_i - \bar{x})^2} \quad (6)$$

with

W : Shapiro-Wilk normality test value
x_{i} : Respondent score
$\bar{x}$: Average value of x_{i}

Normality test criteria refer to Guilford in Hajaroh and Raehanah (2021).

$\mathrm{W} < 0.05$: Normally distributed
$W > 0.05$: Not normally distributed

Homogeneity test formula

$$W = \frac{(n-k)\sum_{i=1}^{k} n_i\,(\bar{Z}_\iota - \bar{Z}..)^2}{(k-1)\sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(Z_{ij} - \bar{Z}_\iota\right)^2} \quad (7)$$

with

n : Number of observations
k : Number of groups
$\bar{Z}_\iota$: Average value of group Z_i
$\bar{Z}..$: Overall average value of Z_{ij}

The criterion is based on whether the p-value is greater than or equal to 0.05; in this case, the variance between groups is considered homogeneous.

N-Gain test formula

$$\langle \mathrm{g} \rangle = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Ideal score} - \text{Pretest score}} \quad (8)$$

Normality test criteria refer to Guilford in Sukarelawan et al. (2024).

$0.70 \leq \langle \mathrm{g} \rangle \leq 1.00$: High
$0.30 \leq \langle \mathrm{g} \rangle < 0.70$: Medium
$0.00 < \langle \mathrm{g} \rangle < 0.30$: Low
$\langle \mathrm{g} \rangle = 0.00$: Fixed
$-1.00 \leq \langle \mathrm{g} \rangle < 0.00$: Decrease

T-test formula

$$T_{\mathrm{h}} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (9)$$

with

n_1 : Number of first data (experimental class)
n_2 : Number of seconds of data (control class)
$\bar{x}_1$: Mean value of the first data (experimental class)
$\bar{x}_2$: Mean value of the second data (control class)
S_1^2 : Variance of the first data (experimental class)
S_2^2 : Variance of the second data (control class)

Normality test criteria refer to Guilford in Muhid (2019).

$T_{\mathrm{h}} > T_{\mathrm{tabel}}$: H_0 rejected
$T_{\mathrm{h}} < T_{\mathrm{tabel}}$: H_0 accepted

RESULT AND DISCUSSION

The analysis stage is the initial stage in the ADDIE model. This stage is conducted to collect and identify initial information that serves as the basis for developing digital teaching materials. The analysis stage involves analyzing needs through direct interviews with physics teachers and observations of classroom learning. It is found that students' interest in learning physics remains low, as evidenced by the low level of attention in the classroom and the lack of enthusiasm among students. Physics material is abstract for students to understand, with monotonous delivery only sourced from the teacher (teacher-centered), with the same media in the form of textbooks, making students passive and less involved in the teaching and learning process. Monotone learning media cannot facilitate an active learning process for students, both inside and outside the classroom, resulting in low student interest that impacts cognitive learning outcomes. Interactive and flexible learning media are needed with material that is linked to students' daily lives. These findings provide a strong rationale for the development of digital teaching materials that are not only interactive and contextual but also designed using a student-centred approach. Addressing these issues early in the *analysis* stage ensures that the instructional design will be more targeted, relevant, and responsive to the real needs of students and teachers in the field.

The results of interviews and observations support this conclusion. Teachers reported that students often appeared disengaged, especially when the material involved abstract concepts. One teacher explained that students rarely asked questions during class, and only a small number actively responded to explanations. Classroom observations also showed that many students did not take notes, struggled to maintain focus, and were hesitant to participate in discussions. These patterns suggest that the current instructional approach does not sufficiently capture students' attention or promote meaningful engagement with the subject matter, ultimately limiting the depth of their understanding and the quality of their learning experience.

The results of the analysis stage served as the basis for designing a digital teaching material prototype that incorporates real-world SSI contexts and adopts the flipped classroom model to address the identified issues. Integrating SSI into instruction allows students to engage with science through relevant, real-life problems, which has been shown to promote critical thinking, scientific literacy, and meaningful engagement with (Zeidler & Nichols, 2009). To further strengthen this instructional design, the flipped classroom model enables students to study the material before attending class. This way, classroom sessions can focus on discussions, group work, and problem-solving, which helps students build a stronger understanding and improve their learning outcomes. (Bergmann & Sams, 2012)This integration is expected to stimulate students' curiosity, increase their engagement with the content outside of class hours, and ultimately improve their understanding and learning outcomes. Therefore, the analysis stage not only identified problems but also became a critical step in determining the direction and relevance of the content and learning model to be developed in subsequent stages.

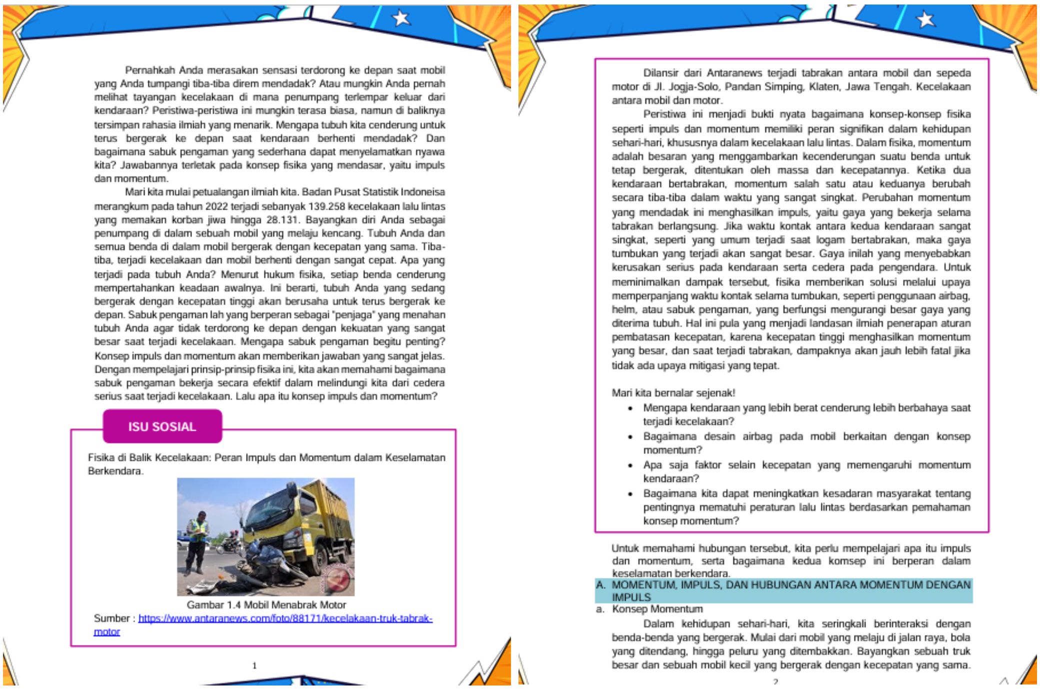
The next stage is design, which involves creating digital teaching materials and research instruments. The design process involves formulating learning objectives that align with cognitive and affective outcomes, compiling digital materials related to the topic of impulse and momentum, designing the interface and interactivity of the media, selecting a development platform, creating a learning flow based on the flipped classroom model, and constructing evaluation tools.

The learning objectives were structured to enhance both students' conceptual understanding and their interest in physics. Digital content was developed using contextual SSI, such as vehicle safety, road accidents, and airbag technology, all of which are directly related to the principles of impulse and momentum. This contextualization helps make abstract physics concepts more tangible and meaningful to students.

The learning flow was designed to support pre-class learning through interactive digital media, including videos and simulations. Digital media in pre-class activities increases student motivation and learning effectiveness in flipped classroom settings. (Haetami, Boateng, & Martinez, 2025). In-class activities focused on problem-solving, experiments, and guided discussions, which emphasize that active, collaborative engagement fosters critical thinking and deep conceptual understanding (Pilu, Jabu, Sulaiman, Wijayanti, & Misnawati, 2025). Post-class activity designed to reinforce learning through reflection, independent assignments, or online quizzes, support metacognition and self-regulated learning, leading to better knowledge internalization and lifelong learning skills (Purba, 2025)—the Evaluation instruments, including a cognitive test and a student interest questionnaire. The cognitive tests were developed with reference to the Revised Bloom's Taxonomy, which categorizes cognitive processes into six hierarchical levels: remembering, understanding, applying, analyzing, evaluating, and creating. (Anderson & Krathwohl, 2001). Meanwhile, the student interest questionnaires were constructed based on Slameto (2010), Who identifies indicators such as feelings of pleasure, student involvement, interest, and student attention.

The develop stage is carried out by making digital teaching materials based on a previously compiled design, digital teaching materials that have been made are entered into Google Sites as a container consisting of the Home section, instructions for use, learning instructions, learning videos, materials, simulations, practice questions, and inspirational figures. At this stage, research instruments were also developed, including the Material and Media Feasibility Questionnaire, the Student Interest Questionnaire, and the Cognitive Learning Outcomes Test. Experts validated all of these instruments to ensure clarity, relevance, and alignment with the study objectives.

One of the results of developing digital teaching materials in the subtopic "Impulse, momentum, and the relationship between impulse and momentum" is the integration of SSI contexts relevant to real life. In this material, a traffic accident involving a car and a motorcycle that occurred on the Jogja-Solo Road in Klaten, Central Java, as reported by Antara News, is presented as a contextual example. The incident is illustrated in Figure 2, showing the aftermath of the collision, including severe vehicle damage and the potential for serious injury. This real-life event serves as a powerful analogy for the physics concepts of momentum and impulse.



Pernahkah Anda merasakan sensasi terdorong ke depan saat mobil yang Anda tumpangi tiba-tiba direm mendadak? Atau mungkin Anda pernah melihat tayangan kecelakaan di mana penumpang terlempar keluar dari kendaraan? Peristiwa-peristiwa ini mungkin terasa biasa, namun di baliknya tersimpan rahasia ilmiah yang menarik. Mengapa tubuh kita cenderung untuk terus bergerak ke depan saat kendaraan berhenti mendadak? Dan bagaimana sabuk pengaman yang sederhana dapat menyelamatkan nyawa kita? Jawabannya terletak pada konsep fisika yang mendasar, yaitu impuls dan momentum.

Mari kita mulai petualangan ilmiah kita. Badan Pusat Statistik Indoneisa merangkum pada tahun 2022 terjadi sebanyak 139.258 kecelakaan lalu lintas yang memakan korban jiwa hingga 28.131. Bayangkan diri Anda sebagai penumpang di dalam sebuah mobil yang melaju kencang. Tubuh Anda dan semua benda di dalam mobil bergerak dengan kecepatan yang sama. Tiba-tiba, terjadi kecelakaan dan mobil berhenti dengan sangat cepat. Apa yang terjadi pada tubuh Anda? Menurut hukum fisika, setiap benda cenderung mempertahankan keadaan awalnya. Ini berarti, tubuh Anda yang sedang bergerak dengan kecepatan tinggi akan berusaha untuk terus bergerak ke depan. Sabuk pengaman lah yang berperan sebagai "penjaga" yang menahan tubuh Anda agar tidak terdorong ke depan dengan kekuatan yang sangat besar saat terjadi kecelakaan. Mengapa sabuk pengaman begitu penting? Konsep impuls dan momentum akan memberikan jawaban yang sangat jelas. Dengan mempelajari prinsip-prinsip fisika ini, kita akan memahami bagaimana sabuk pengaman bekerja secara efektif dalam melindungi kita dari cedera serius saat terjadi kecelakaan. Lalu apa itu konsep impuls dan momentum?

ISU SOSIAL

Fisika di Balik Kecelakaan: Peran Impuls dan Momentum dalam Keselamatan Berkendara.

Gambar 1.4 Mobil Menabrak Motor

Sumber : https://www.antaranews.com/foto/88171/kecelakaan-truk-tabrak-motor

1

Dilansir dari Antaranews terjadi tabrakan antara mobil dan sepeda motor di Jl. Jogja-Solo, Pandan Simping, Klaten, Jawa Tengah. Kecelakaan antara mobil dan motor.

Peristiwa ini menjadi bukti nyata bagaimana konsep-konsep fisika seperti impuls dan momentum memiliki peran signifikan dalam kehidupan sehari-hari, khususnya dalam kecelakaan lalu lintas. Dalam fisika, momentum adalah besaran yang menggambarkan kecenderungan suatu benda untuk tetap bergerak, ditentukan oleh massa dan kecepatannya. Ketika dua kendaraan bertabrakan, momentum salah satu atau keduanya berubah secara tiba-tiba dalam waktu yang sangat singkat. Perubahan momentum yang mendadak ini menghasilkan impuls, yaitu gaya yang bekerja selama tabrakan berlangsung. Jika waktu kontak antara kedua kendaraan sangat singkat, seperti yang umum terjadi saat logam bertabrakan, maka gaya tumbukan yang terjadi akan sangat besar. Gaya inilah yang menyebabkan kerusakan serius pada kendaraan serta cedera pada pengendara. Untuk meminimalkan dampak tersebut, fisika memberikan solusi melalui upaya memperpanjang waktu kontak selama tumbukan, seperti penggunaan airbag, helm, atau sabuk pengaman, yang berfungsi mengurangi besar gaya yang diterima tubuh. Hal ini pula yang menjadi landasan ilmiah penerapan aturan pembatasan kecepatan, karena kecepatan tinggi menghasilkan momentum yang besar, dan saat terjadi tabrakan, dampaknya akan jauh lebih fatal jika tidak ada upaya mitigasi yang tepat.

Mari kita bernalar sejenak!

- Mengapa kendaraan yang lebih berat cenderung lebih berbahaya saat terjadi kecelakaan?
- Bagaimana desain airbag pada mobil berkaitan dengan konsep momentum?
- Apa saja faktor selain kecepatan yang memengaruhi momentum kendaraan?
- Bagaimana kita dapat meningkatkan kesadaran masyarakat tentang pentingnya mematuhi peraturan lalu lintas berdasarkan pemahaman konsep momentum?

Untuk memahami hubungan tersebut, kita perlu mempelajari apa itu impuls dan momentum, serta bagaimana kedua komsep ini berperan dalam keselamatan berkendara.

A. MOMENTUM, IMPULS, DAN HUBUNGAN ANTARA MOMENTUM DENGAN IMPULS

a. Konsep Momentum

Dalam kehidupan sehari-hari, kita seringkali berinteraksi dengan benda-benda yang bergerak. Mulai dari mobil yang melaju di jalan raya, bola yang ditendang, hingga peluru yang ditembakkan. Bayangkan sebuah truk besar dan sebuah mobil kecil yang bergerak dengan kecepatan yang sama.

2

Figure 2. Development of Digital Teaching Materials on Momentum and Impulse through the Context of Traffic Accidents

The case invites students to critically examine not only the physical causes of the accident but also the broader socio-scientific dimensions involved. Discussions cover factors such as vehicle speed, driver reaction time, and adherence to traffic regulations, as well as the ethical responsibility of drivers to ensure the safety of themselves and others. Students are encouraged to consider the societal impacts of such accidents, including medical costs, loss of productivity, and the psychological trauma experienced by victims and their families. By analyzing the event from legal, ethical, and social perspectives, learners can appreciate that traffic safety is not solely a matter of individual behaviour but a shared responsibility that affects the wider community.

Building on this socio-scientific awareness, students are then guided to explore the underlying physics principles that explain variations in injury severity and damage. As illustrated in Figure 3, this forms the basis for developing digital teaching materials in the subtopic "Introduction to Physics Concepts," focusing on impulse and momentum as a quantitative framework for understanding collision mechanics.

Meskipun keduanya bergerak dengan kecepatan yang sama, namun truk besar akan lebih sulit untuk dihentikan dibandingkan dengan mobil kecil. Hal ini disebabkan oleh perbedaan massa antara keduanya. Konsep momentum akan membantu kita memahami mengapa hal ini terjadi.

Gambar 1.1 Mobil Menabrak Rumah

Setiap benda yang bergerak akan memiliki momentumnya, momentum ini dapat didefinisikan sebagai tingkat kesukaran untuk menghentikan gerak suatu benda. Perhatikan gambar berikut ini!

Gambar 1.2 Mobil dan Sepeda Menabrak Pohon

Mari kita bayangkan sebentar! Anggap bahwa kecepatan mobil dan sepeda sama ($\vec{v}_m = \vec{v}_s$), dapat dilihat bahwa mobil memiliki kerusakan yang lebih parah dari sepeda ketika menabrak pohon. Hal ini membuktikan bahwa mobil dengan massa yang lebih besar dari sepeda ($m_m > m_s$) akan menyebabkan gerak benda menjadi sulit untuk dihentikan, sehingga dapat disimpulkan bahwa:

$$\vec{p} \sim m$$

Momentum yang dimiliki oleh suatu benda akan sebanding dengan massa yang dimiliki oleh benda tersebut. Perhatikan gambar berikut!

3

Gambar 1.3 Mobil yang Sedang Melaju

Anggap dua mobil identik dengan massa yang sama ($m_1 = m_2$), tetapi tetapi kedua mobil melaju dengan kecepatan berbeda ($\vec{v}_1 > \vec{v}_2$), maka mobil dengan kecepatan yang lebih besar akan menimbulkan kerusakan yang lebih parah dibandingkan mobil dengan kecepatan yang lebih kecil, sehingga dapat disimpulkan bahwa:

$$\vec{p} \sim \vec{v}$$

Momentum yang dimiliki suatu benda akan sebanding dengan kecepatan yang dimilikinya, momentum termasuk besaran vektor dengan arahnya searah dengan kecepatan benda, jadi momentum ($\vec{p}$) merupakan tingkat kesukaran untuk menghentikan gerak suatu benda dengan persamaan yang ditulis sebagai berikut:

$$\vec{p} = m.\vec{v}$$

Keterangan :

$\vec{p}$ = Momentum $(kg.m/s)$
m = Massa benda (kg)
$\vec{v}$ = Kecepatan benda (v)

CONTOH SOAL

Suatu benda bermassa $40\,kg$ dan bergerak dengan kecepatan $5\,m/s$. Tentukan momentum yang dimiliki oleh benda tersebut!
Pembahasan:
Diketahui
$m = 40\ kg$
$\vec{v} = 5\ m/s$
Ditanya
$\vec{p} = ?$
Dijawab

4

Berdasarkan persamaan momentum dapat dituliskan sebagai berikut:
$p = m.v$
$p = 40 \times 5$
$p = 200\ kg.m/s$

VIDEO PEMBELAJARAN

Untuk lebih mendalami pengetahuan anda mengenai konsep momentum. Anda dapat mempelajari lebih lanjut melalui link berikut ini.

b. Konsep Impuls

Pernahkah kamu melihat rekaman kecelakaan lalu lintas di mana sebuah mobil menabrak kendaraan lain dalam sekejap? Atau mungkin pengendara sepeda motor yang selamat setelah kecelakaan karena menggunakan helm? Di balik peristiwa tersebut, terdapat sebuah kekuatan dahsyat yang bekerja dalam sekejap mata. Kekuatan sekejap mata inilah yang kita sebut sebagai impuls. Bayangkan seperti ini, impuls adalah seperti benturan keras yang terjadi dalam sekejap mata.

Konsep impuls ini sangat dekat dengan kehidupan kita sehari-hari! Banyak hal yang tidak kita sadari merupakan contoh dari implementasi konsep impuls. Perhatikan gambar berikut ini!

5

Figure 3. Development of Digital Teaching Materials for Introducing the Concept of Impulse and Momentum

To deepen their understanding of the momentum and impulse concepts in the context of the Klaten car-motorcycle collision, students engage in inquiry-based activities using the PhET

"Collision Lab" simulation as a virtual laboratory. The simulation enables learners to manipulate variables such as vehicle mass, initial velocity, and collision time, allowing them to observe the effects on momentum changes and impact forces. Students are tasked with recreating simplified versions of the accident, testing scenarios both with and without safety devices, and recording their observations. By comparing the simulated outcomes to the actual incident, they develop stronger connections between theoretical concepts and real-world applications in road safety. Figure 4 illustrates the development of this simulation activity, showing how the virtual environment can be adapted to reflect the conditions of the real-life incident. Figure 5 illustrates the development of this simulation activity, showing how the virtual environment can be adapted to reflect the conditions of the real-life incident.

Figure 4. Development of Digital Teaching Materials Incorporating the PhET Simulation

In the evaluation stage, students complete multiple-choice and short essay questions based on real-life collision cases to assess their understanding of impulse and momentum. Their attitudes toward traffic safety and their skills in applying physics concepts are also evaluated through project rubrics and observation during activities. Figure 5 shows an example of the evaluation interface developed for the digital teaching materials.

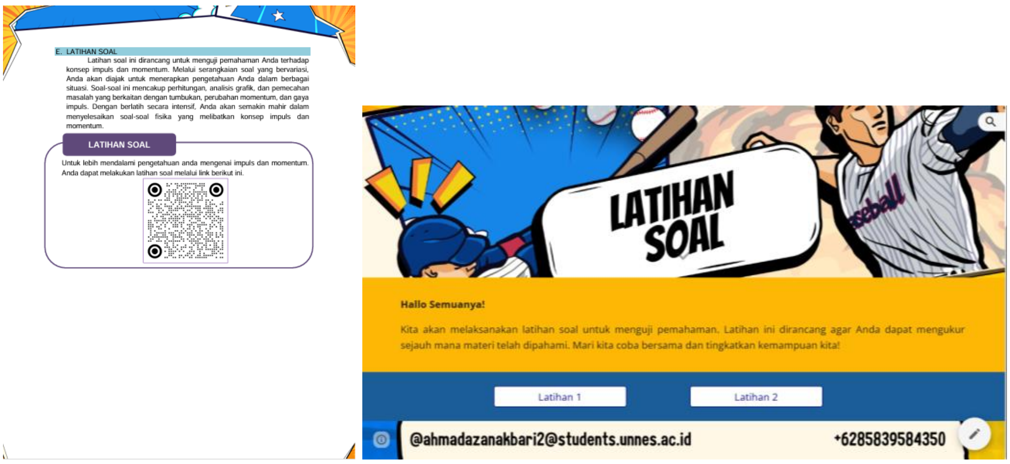
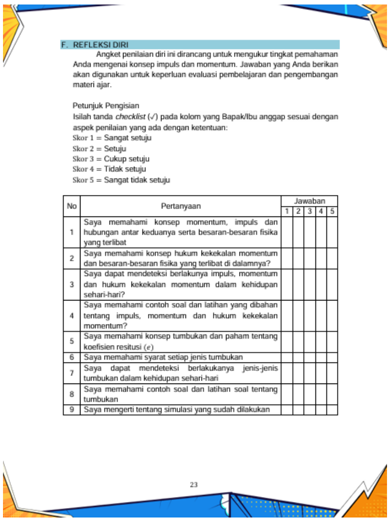


Figure 5. Development of Digital Teaching Materials for the Evaluation

Following the evaluation, the overall learning process concludes with a summary of key concepts and a discussion on how the knowledge of impulse and momentum can be applied in everyday life to enhance safety and social responsibility. In the reflection stage, students are encouraged to think critically about the social and ethical aspects of traffic safety after learning about impulse and momentum. Figure 6 illustrates the digital tools used for the reflection activity, including an online discussion board and a poster creation platform.



F. REFLEKSI DIRI

Angket penilaian diri ini dirancang untuk mengukur tingkat pemahaman Anda mengenai konsep impuls dan momentum. Jawaban yang Anda berikan akan digunakan untuk keperluan evaluasi pembelajaran dan pengembangan materi ajar.

Petunjuk Pengisian

Isilah tanda *checklist* (✓) pada kolom yang Bapak/Ibu anggap sesuai dengan aspek penilaian yang ada dengan ketentuan:

Skor 1 = Sangat setuju
Skor 2 = Setuju
Skor 3 = Cukup setuju
Skor 4 = Tidak setuju
Skor 5 = Sangat tidak setuju

No	Pertanyaan	Jawaban				
		1	2	3	4	5
1	Saya memahami konsep momentum, impuls dan hubungan antar keduanya serta besaran-besaran fisika yang terlibat					
2	Saya memahami konsep hukum kekekalan momentum dan besaran-besaran fisika yang terlibat di dalamnya?					
3	Saya dapat mendeteksi berlakunya impuls, momentum dan hukum kekekalan momentum dalam kehidupan sehari-hari?					
4	Saya memahami contoh soal dan latihan yang dibahan tentang impuls, momentum dan hukum kekekalan momentum?					
5	Saya memahami konsep tumbukan dan paham tentang koefisien resitusi (e)					
6	Saya memahami syarat setiap jenis tumbukan					
7	Saya dapat mendeteksi berlakukanya jenis-jenis tumbukan dalam kehidupan sehari-hari					
8	Saya memahami contoh soal dan latihan soal tentang tumbukan					
9	Saya mengerti tentang simulasi yang sudah dilakukan					

23

Figure 6. Development of Digital Teaching Materials for the Reflection

This teaching material invites students to take a closer look at something we often hear about: traffic accidents, and to understand how physics concepts, such as momentum, impulse, and collision, play a role in these events. When a vehicle moves, it carries momentum, which depends on both its mass and its velocity. In the event of a collision, the momentum of one or both vehicles changes suddenly within a very short period, producing a strong force known in physics as impulse. This force is responsible for the damage to vehicles and injuries to the people involved. The higher the velocity and mass of the vehicles, the greater the momentum, and the more severe the impact can be. This is why safety measures, such as velocity limits, airbags, helmets, and seatbelts, are so important. These tools are designed to increase the time over which the collision occurs, thereby reducing the force experienced by the body. By learning about these principles, students gain not only a deeper understanding of physics but also realize how science connects to real-life safety and decision-making. This makes the learning process more meaningful, as it encourages students to think critically, develop empathy, and apply scientific thinking to everyday situations.

The digital teaching material products that have been developed are then tested for product feasibility. The feasibility test is conducted to assess the feasibility level of the product before it is implemented. The feasibility test is divided into two, namely the media expert feasibility test and the material expert feasibility test. The results of the material expert feasibility test, conducted by four material experts and one physics teacher, are presented in Table 8. The feasibility test, conducted by four media experts, is presented in Table 9.

Table 8. Material Expert Feasibility Analysis Results

Validator	Score
Material Expert 1	71
Material Expert 2	62
Material Expert 3	66
Material Expert 4	71
Material Expert 5	61
Total Score	331
Maximum Score	400
Percentage (%)	82.75
Category	Very Feasible

Table 9. Media Expert Feasibility Analysis Results

Validator	Score
Media Expert 1	95
Media Expert 2	78
Media Expert 3	93
Media Expert 4	97
Total Score	363
Maximum Score	440
Percentage (%)	82.5
Category	Very Feasible

Table 8 presents the results of the material feasibility data analysis, with a percentage value of 82.75%, indicating that it falls into the very feasible category. This indicates that the content of the digital teaching materials has met the criteria of relevance, accuracy, clarity, and contextual alignment with SSI. The high feasibility score suggests that the material is suitable for supporting students' understanding of physics concepts within real-life contexts, as expected in SSI-based learning.

Table 9 presents the results of the media feasibility data analysis, with a percentage value of 82.5%, indicating a very feasible category. This demonstrates that the digital teaching materials are not only informative but also technically appropriate, visually appealing, interactive, and user-friendly, which supports the flipped classroom model. The feasibility of the media is crucial because it ensures students can access and interact with the learning content effectively, both inside and outside the classroom.

The next stage is implementation. The media that has been developed is tested on class XI students of SMA Negeri 12 Semarang, using the Flipped Classroom model. The first meeting is held in 3JP, and the second meeting is held in 2JP, focusing on impulse and momentum material. Learning syntax meetings 1 and 2 are presented in Tables 10 and 11, respectively.

Table 10. Learning Syntax Meeting 1

Syntax	Learning Activity	
Pra-Class Activity	a. Teachers send media and guides via WhatsApp. b. Students study the learning materials and videos. c. Students work on Exercise 1.	
In-Class Activity	Introduction	a. The teacher greets, invites prayer, asks how the students are, and checks the students' attendance. b. The teacher explains the learning flow, objectives, and assessment. c. The teacher gives apperception and motivation to the students.
	Core Activities	a. Students take the pretest and fill in the learning interest questionnaire. b. The teacher and students discuss Exercise 1 previously done. c. The teacher guides the students to discuss the social issue: “Momentum in Traffic Rules” d. The teacher facilitates discussion, questions, and answers about the issue. e. The teacher directs the discussion to stay focused on the concept of momentum. f. The teacher and students discuss example problems about momentum. g. The teacher guides students to discuss social issues: "Impulses in Fights”. h. The teacher facilitates discussion, questions, and answers about the issue.

Syntax	Learning Activity		
		i.	The teacher directs the discussion to focus on the concept of impulse and its relationship with momentum.
		j.	The teacher and students discuss sample problems about impulse and its relationship with momentum.
	Closing	a.	The teacher allows students to ask questions and summarize the learning.
		b.	The teacher appreciates students' participation.
		c.	The teacher closes the lesson with a prayer together.
Post-Class Activity	The teacher gives simulation assignments at home through digital learning media.		

Table 11. Learning Syntax Meeting 2

Syntax	Learning Activity		
Pra-Class Activity	a. Students study materials and videos about the law of conservation of momentum and collision.		
	b. Students work on Exercise 2 in the digital learning media.		
In-Class Activity	Introduction	a.	The teacher greets, invites prayer, asks how the students are, and takes attendance.
		b.	The teacher conveys the learning flow, objectives, and assessment.
		c.	The teacher gives apperception and motivation.
	Core Activities	a.	The teacher and students discuss Exercise 2.
		b.	The teacher guides students to the social issue: "Collisions in Expressing Opinions".
		c.	The teacher facilitates discussion, questions, and answers related to the issue.
		d.	The teacher directs the discussion to focus on the concept of the law of conservation of momentum and collision. The teacher and students discuss sample problems related to the material
		e.	Students take the post-test and fill in the learning interest questionnaire.
	Closing	a.	The teacher allows students to ask questions and summarize the learning.
		b.	The teacher appreciates students' engagement.
		c.	The teacher closes the class with a prayer together.
Post-Class Activity	a. Students work on the "Let's Try" section.		
	b. Students fill in the "Self Evaluation" section.		

The final stage of evaluation assesses the media that has been implemented based on students' interest and cognitive learning outcomes. This stage involved comparing the pretest and posttest results to assess changes in student interest in learning that occurred after receiving treatment in the experimental class. The N-Gain test is used to see the increase in learning interest that occurs before and after using the developed digital teaching materials. The results of the N-Gain Test, which measures students' interest in learning, are presented in Table 12.

Table 12. N-Gain Test Results of Student Learning Interest

Class	Average score		$\langle g \rangle$	Criteria
	Pretest	*Posttest*		
Control	52.20	63.49	0.020	Low
Experiment	54.74	74.15	0.355	Medium

Table 12 presents the results of the N-Gain analysis, which showed an increase in student interest in the control class by 11.29 and in the experimental class by 19.41. The normalized gain of the control class was 0.020 in the low category, and the normalized gain test of the experimental class was 0.355 in the medium category. Overall, the use of digital teaching materials has increased student interest in learning.

The results of the N-Gain analysis for each indicator of student interest in learning by (Slameto, 2010) Can be seen in Figure 8. These indicators include good feelings*,* student engagement*,* interest*, and* student attention.

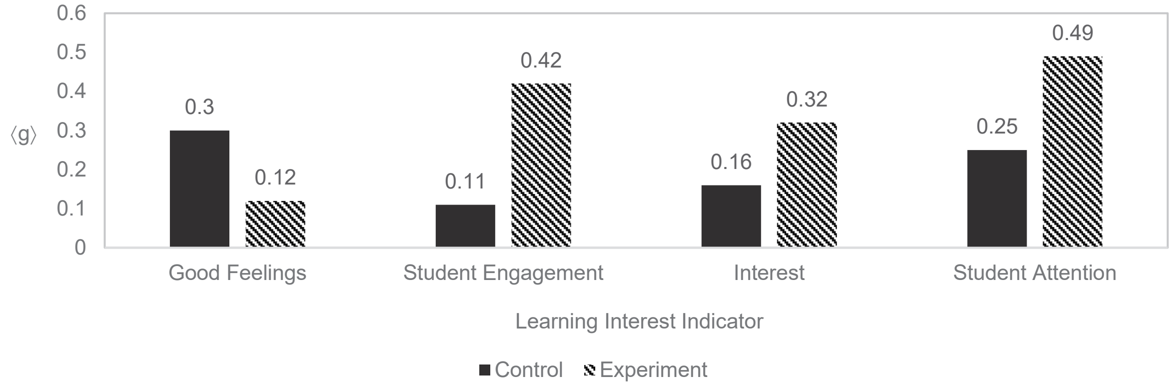


Figure 7. N-Gain Test Analysis Results for Each Learning Interest Indicator

The results of the N-Gain test analysis of learning interest for indicators of feelings of pleasure in the control class of 10.15 and the experimental class of 11.77 with a normalized gain of the control class of 0.30 in the medium category, and the normalized gain test of the experimental class of 0.12 in the low category, for indicators of student involvement in the control class of 12.21 and the experimental class of 21.62 with a normalized gain of the control class of 0.11 in the low category, and the normalized gain test of the experimental class of 0,42 in the moderate category, for the interest indicator in the control class of 11.91 and the experimental class of 19.85 with a normalized gain of 0.16 in the low category, and the normalized gain test of the experimental class of 0.32 in the moderate category, for the student attention indicator in the control class of 10.88 and the experimental class of 24.41 with a normalized gain of 0.25 in the low category, and the normalized gain test of the experimental class of 0.49 in the moderate category. The indicator of feeling happy is the indicator with the smallest increase, with a normalized gain in the low category. Flipped Classroom learning requires students to learn independently in class; the feeling of being forced to do independent learning is a strong reason for the slight increase in student interest in learning, as indicated by feelings of pleasure. The feeling of being forced to learn is an indication of low interest; feeling happy raises the enthusiasm to continue learning things he likes (Adnyana & Yudaparmita, 2023).

A t-test was conducted to determine whether the improvement between the control and experimental classes was significant. The results of the t-test analysis for the control and experimental classes, examining student learning interest, yielded a p-value of 0.008, which is less than 0.05. Therefore, H0 was rejected, indicating a significant difference between the average value of the control class and the experimental class. This indicates that the use of digital teaching materials based on SSI has a more positive impact on increasing student interest in learning compared to conventional learning methods.

The results of the t-test analysis for each learning interest indicator are presented in Table 13.

Table 13. T-test Results for Each Indicator of Student Learning Interest

Indicator	*P-Value*	Description
Good Feelings	0.891	H_0 Retrieved
Student Engagement	0.001	H_0 rejected
Interest	0.003	H_0 rejected
Student Attention	0.001	H_0 rejected

Table 13 shows the results of the t-test analysis for the indicator of feelings of pleasure found a p-value of 0.891> 0.05 then H_0 accepted so that there is no significant difference between the average value of the control class and the experimental class, for the indicator of student involvement p-value of 0.001< 0.05 then H_0 rejected so that there is a significant difference between the average value of the control class and the experimental class, for the interest indicator p-value of 0.003< 0.05 then H_0 is rejected so that there is a significant difference between the average scores of the control class and the experimental class. For the student's attention indicator, the student's p-value is 0.001, which is less than 0.05, indicating that H0 is rejected. This suggests a significant difference between the average scores of the control and experimental classes.

An analysis of students' cognitive learning outcomes was conducted using the N-Gain test to assess the increase in cognitive learning outcomes that occurred between the pre- and post-treatment periods. The results of the N-Gain Test, which assesses students' cognitive learning outcomes, are presented in Table 14.

Table 14. N-Gain Test Results for Student Cognitive Learning Outcomes

Class	Average score		$\langle g \rangle$	Criteria
	Pretest	*Posttest*		
Control	49.41	73.92	0.46	Medium
Experiment	55.10	80.31	0.55	Medium

The results of the N-Gain test analysis for cognitive learning outcomes showed an increase in student cognitive learning outcomes in the control class (24.51) and the experimental class (25.21). The normalized gain of the control class was 0.46 in the moderate category, and the normalized gain of the experimental class was 0.55 in the moderate category. The control class and experimental class are both in the moderate category; however, there is an increase in the experimental class when viewed in terms of the change in average posttest and pretest scores. Digital teaching materials in the form of videos, comics, and others encourage student involvement, understanding of relevant concepts, and facilitate meaningful learning (Damopolii, Lumembang, & İlhan, 2021).

The results of the t-test analysis for the control and experimental classes, examining student cognitive learning outcomes, showed a p-value of 0.038, which is less than 0.05. Therefore, H0 was rejected, indicating a significant difference between the average value of the control class and the experimental class using Flipped Classroom learning with digital teaching materials based on SSI.

This finding aligns with previous research indicating that integrating SSI into learning can increase interest in learning by making science relevant to real life, and encourage both concept understanding and impact understanding (Badeo & Duque, 2022; Sanchez, Picardal, Fernandez, & Caturza, 2024; Sari, Saputro, & Sajidan, 2025). The application of the Flipped Classroom model provides students with the opportunity to access and explore materials independently before face-to-face sessions in the classroom, thereby facilitating active involvement in the learning process and enhancing cognitive mastery of concepts. (Haetami, Boateng, & Martinez, 2025; Khatoon, 2024; Zheng, Bhagat, Zhen, & Zhang, 2020). The digital teaching materials developed in this study synergistically combine the two approaches, resulting in a learning strategy that not only attracts student interest but also proves effective in improving cognitive learning outcomes through a more in-depth, reflective, and meaningful process of concept internalization.

CONCLUSION

Based on the research results, it can be concluded that digital teaching materials developed using the Socio-Scientific Issues (SSI) approach on topics related to impulse and momentum are feasible, practical, and effective for implementation in physics learning. These materials have the potential to enhance students' interest and cognitive learning outcomes by presenting learning content that is relevant to real-world issues. Further studies are recommended to explore the use of SSI-based digital teaching materials on a broader scale and across diverse student populations, ensuring broader applicability and maximizing their impact in science education.

REFERENCES

Adnyana, K. S., & Yudaparmita, G. N. A. (2023). Peningkatan Minat Belajar IPAS Berbantuan Media Gambar pada Siswa Sekolah Dasar. *Edukasi: Jurnal Pendidikan Dasar*, *4*(1), 61–70.

Agustina, S., Arief, M., & Fitri, R. (2022). Pengaruh Minat dan Pemanfaatan Sumber Belajar terhadap Prestasi Belajar Siswa. *Jurnal Pendidikan Manajemen Perkantoran*, *7*(2), 202–213.

Amarulloh, R. R. (2022). Pengembangan Media Pembelajaran Fisika Dasar Berbasis Literasi Sains dengan Menggunakan Google Sites. *Jurnal Inovasi dan Pembelajaran Fisika*, *9*(2), 154–164.

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Longman.

Annajmi, A., & Kuswandi, D. (2024). Flipped Classroom: Inovasi Pengaturan Lingkungan Belajar dalam Pembelajaran Matematika. *DIAJAR: Jurnal Pendidikan dan Pembelajaran*, *3*(1), 116–124.

Arslan, A. (2020). Instructional Design Considerations for Flipped Classroom. *International Journal of Progressive Education*, *16*(6), 33–59.

Badeo, J. M., & Duque, D. A. (2022). The Effect of Socio-Scientific Issues (SSI) in Teaching Science: A Meta-Analysis Study. *Journal of Technology and Science Education*, *12*(2), 291–302.

Bergmann, J., & Sams, A. (2012). *Flip Your Classroom: Reach Every Student, Every Class, Every Day*—international society for technology in education.

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach* (Vol. 722). Springer.

Damayanti, H., Rizky, N. N., & Sofiyah, K. (2024). Pengaruh Apresiasi dan Motivasi dalam Meningkatkan Minat Belajar Siswa Madrasah Ibtidaiyah Kelas Rendah. *LANCAH: Jurnal Inovasi dan Tren*, *2*(2b), 829–834.

Damopolii, I., Lumembang, T., & İlhan, G. O. (2021). Digital Comics in Online Learning During COVID-19: Its Effect on Student Cognitive Learning Outcomes. *Int. J. Interact. Mob. Technol.*, *15*(19), 33.

Data, N. (2022). Maximum Utilization of Google Sites (MUGS) in Teaching English for Academic and Professional Purposes. *AJARCDE (Asian Journal of Applied Research for Community Development and Empowerment)*, *6*(3), 68–72.

Fakhri, M. M., Andayani, D. D., Kaswar, A. B., Adistia, A. Z., & Fadhilatunisa, D. (2023). Dampak Penerapan Flipped Classroom terhadap Pengetahuan, Keterampilan, dan Keterlibatan Mahasiswa dalam Pembelajaran. *Jurnal Ilmiah Edutic: Pendidikan dan Informatika*, *9*(2), 127–138.

Haetami, A., Boateng, A., & Martinez, R. (2025). Flipped Classroom Models: Revolutionizing Learning in Higher Education. *International Journal of Educational Narratives*, *3*(1), 1–11.

Hu, X. (2020). Coping with University Students' Boredom in Classroom: A Behavioral Perspective. International Research in Education, 8 (2), 33. *International Research in Education*, *8*(2). https://doi.org/http://dx.doi.org/10.5296/ire.v8i2.17648.

Jumadi, J., & Dwandaru, W. S. B. (2023). Socio-Scientific Issues in Physics Learning to Improve Students' Critical Thinking Skills. *Revista Mexicana de Física E*, *20*(1 Jan-Jun), 10201–10202.

Khatoon, S. (2024). Flipped Learning: A Paradigm Shift in Education. *International Journal of Emerging Knowledge Studies*, *3*(11), 916–922.

Khikmawati, D. K., Alfian, R., Nugroho, A. A., Susilo, A., Rusnoto, R., & Cholifah, N. (2021). Pemanfaatan E-Book untuk Meningkatkan Minat Belajar Siswa Sekolah Dasar di Kudus. *Buletin KKN Pendidikan*, *3*(1), 74–82.

Macalalag Jr, A. Z., Kaufmann, A., Van Meter, B., Ricketts, A., Liao, E., & Ialacci, G. (2024). Socioscientific Issues: Promoting Science Teachers' Pedagogy on Social Justice. *Disciplinary and Interdisciplinary Science Education Research*, *6*(1), 28.

Mudanta, K. A., Astawan, I. G., & Jayanta, I. N. L. (2020). Instrumen Penilaian Motivasi Belajar dan Hasil Belajar IPA Siswa Kelas V Sekolah Dasar. *Mimbar Ilmu*, *25*(2), 262–270.

Murphy, L., Eduljee, N. B., & Croteau, K. (2021). Teacher-Centered Versus Student-Centered Teaching: Preferences and Differences Across Academic Majors. *Journal of Effective Teaching in Higher Education*, *4*(1), 18–39.

Murtikaningrum, P. S., Rahayu, F. M. K., Arinda, A., Charisma, P. N. D., Miranda, F. D., Astuti, B. P., & Anggrasari, L. A. (2024). Pengembangan Media Digital Web Learning Giko Berbasis Aplikasi Google Sites pada Materi IPAS Siswa Sekolah Dasar. *Seminar Nasional Sosial, Sains, Pendidikan, Humaniora (SENASSDRA)*, *3*(2), 247–256.

Muzayanah, U. (2020). Penggunaan Bahan Ajar Interaktif POSDAHUT untuk Meningkatkan Efektivitas Belajar IPS di Kelas VII-D Semester Gasal SMPN 2 Wedarijaksa Tahun 2018/2019. *Forum Ilmu Sosial*, *47*(1), 46–54.

Nababan, D., Marpaung, A. K., & Koresy, A. (2023). Strategi Pembelajaran Project Based Learning (PJBL). *Jurnal Pendidikan Sosial dan Humaniora*, *2*(2), 706–719.

Nur, S. M. (2023). Analisis Penerapan Pendekatan Berbasis Socio-Scientific Issues (SSI) dalam Pembelajaran Materi Biologi. *Prosiding Seminar Nasional Biologi: Inovasi Sains & Pembelajarannya*, *11*(1).

Nurillahwaty, E. (2022). Peran Teknologi dalam Dunia Pendidikan. *Seminar Nasional Program*

Pascasarjana Universitas PGRI Palembang, *1*, 81–85.

Osman, N., Noor, S. S. M., Hat, N. C., Rouyan, N. M., & Saad, K. N. M. (2023). Students' Acceptance of Flipped Learning Through Google Application. *Online Journal of Communication and Media Technologies*, *13*(4), e202360.

Pilu, R., Jabu, B., Sulaiman, I., Wijayanti, R., & Misnawati, M. (2025). Flipped Learning and Its Challenges: Understanding Students' Struggles in Indonesian EFL Contexts from Teachers' Viewpoint. *Frontiers in Education*, *10*, 1575385.

Purba, S. E. E. (2025). Flipped Classroom: A Pathway to Increase Self-Regulated Learning. *Jambura Economic Education Journal*, *7*(2), 586–597.

Purwanto, A., & Risdianto, E. (2022). Analisis Kebutuhan Pengembangan Bahan Ajar Digital Matakuliah Geofisika Berbasis Platform LMS Moodle untuk Menunjang Implementasi Kurikulum MBKM. *Jurnal Kumparan Fisika*, *5*(1), 7–14.

Putri, & Eka, N. M. F. (2022). *Peran Guru dalam Teknologi dan Tantangan Perkembangan Teknologi Pendidikan di Era Digital*.

Riduwan. (2015). *Skala Pengukuran Variabel-Variabel Penelitian*. Alfabeta.

Sánchez, J. M., Picardal, M., Fernández, S., & Caturza, R. R. (2024). Socio-Scientific Issues in Focus: A Meta-Analytical Review of Strategies and Outcomes in Climate Change Science Education. *Science Education International*, *35*(2), 119–132.

Sari, D. R., Saputro, S., & Sajidan, S. (2025). A Systematic Review on Integrating SSI into Science Education: Its Impact on 21st Century Skills (2014-2024). *Educational Studies and Research Journal*, *2*(1), 1–14.

Slameto. (2010). *Belajar dan Faktor-Faktor yang Mempengaruhinya*. Rineka Cipta.

Sulistyawati, N. L. G., Suarjana, I. M., & Wibawa, I. M. C. (2022). Pengembangan Media Website Berbasis Google Sites pada Materi Statistika Kelas IV Sekolah Dasar. *Jurnal Pendidikan Dan Konseling (JPDK)*, *4*(4), 895–904.

Sunami, M. A., & Aslam, A. (2021). Pengaruh Penggunaan Media Pembelajaran Video Animasi Berbasis Zoom Meeting terhadap Minat dan Hasil Belajar IPA Siswa Sekolah Dasar. *Journal of Basic Education*, *5*(4), 1940–1945.

Suratnu, R. (2023). The Adoption of the ADDIE Model in Designing an Instructional Module: The Case of Malay Language Learners. *IJIET (International Journal of Indonesian Education and Teaching)*, *7*(2), 262–270.

Wulandari, A., Hakim, L., Sulistyowati, R., & Mian, Y. (2022). Interactive Multimedia Development Using Google Sites to Improve Student Learning Outcomes and Energy. *EDUSAINS*, *14*(2), 188–201.

Zeidler, D. L., & Nichols, B. H. (2009). Socio-Scientific Issues: Theory and Practice. *Journal of Elementary Science Education*, *21*(2), 49–58.

Zheng, L., Bhagat, K. K., Zhen, Y., & Zhang, X. (2020). The Effectiveness of The Flipped Classroom on Students' Learning Achievement and Learning Motivation. *Journal of Educational Technology & Society*, *23*(1), 1–15.