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Development of Physics Teaching Materials Based on Science Process Skills and Their Influence on Critical Thinking

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Abstract: This study aims to analyze the content validity of the developed Science Process Skills (SPS)-based physics instructional materials; analyze the responses of educational practitioners regarding the quality and practicality of the materials; and analyze the effect of the developed SPS-based physics instructional materials. The research employed the Research and Development (R&D) method with the 4D model (Define, Design, Develop, and Disseminate). The developed product was validated by three experts, its practicality was assessed by ten physics teachers, and it was tested on 36 tenth-grade students. The instruments used in this study included a validation sheet for the instructional materials, a practitioner response questionnaire, and a validated critical thinking skills test for students. The results showed that the SPS-based physics instructional materials were validated using Aiken's V index, with an average score of 0.81 for content feasibility, 0.82 for presentation, 0.82 for language, and 0.81 for graphical aspects. The overall average score was 0.82. The hypothesis testing showed that t_{count} = 8.006 ≥ t_{table} = 1.994, indicating a significant difference in critical thinking ability between students taught using the SPS-based physics materials and those taught using conventional materials. Based on these findings, the developed SPS-based physics instructional materials are valid according to experts, practical based on teachers' assessments, positively received, and effective in improving students' critical thinking skills, thus feasible for implementation in physics learning as a supportive medium to enhance students' critical thinking abilities.

Keywords: Critical thinking skills; Development; Physics instructional materials; Science Process Skills (SPS)

Introduction

Education is instruction that is generally conducted in schools as formal educational institutions; in other words, education is the process of teaching and learning activities in the classroom. Education is a conscious effort carried out by families, communities, and the government through guidance, teaching, and training activities that take place in schools and outside schools throughout life to prepare learners so that they are able to play roles in various living environments in a stable manner for the future (Bonsapi et al., 2023). Education is also a conscious effort to prepare learners through guidance, teaching, and training activities so that they can carry out their roles in the future. Education is considered a process that gradually changes individual attitudes and behaviors through teaching and training so that individuals can achieve maturity in social and cognitive functions (Siregar et al., 2024). In line with the findings of Habsy et al. (2025), education is a process of individual maturation manifested in changes in behavior, cognition (knowledge), and self-awareness, with the aim of developing the potentials possessed by individuals in accordance with prevailing socio-cultural values.

Education in the modern era demands critical thinking skills as one of the 21st-century competencies that students must possess. In physics learning, critical thinking skills are important for understanding abstract concepts and preventing complex problems related to

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natural phenomena (Ennis, 2011). Education can be understood as a systematic process to develop students' potential holistically—not only in the aspect of knowledge (cognitive), but also in thinking skills and self-awareness of learning (metacognitive) (Desi et al., 2024).

Physics is a fundamental science needed to build thinking skills in order to solve problems in everyday life. However, physics is often perceived as a subject that is difficult to understand (Nurnaifah et al., 2022). Physics is a branch of science that studies the fundamental properties of the universe through observation, experimentation, and mathematical modeling to explain phenomena from microscopic to macroscopic levels. Physics plays an important role in the development of modern technology and in solving real-world problems in various fields such as energy, communication, and health (Ma, 2020). Physics learning helps students develop conceptual understanding and scientific thinking skills through distinctive scientific language as well as the use of digital-based learning technologies (Geelan, 2013). Physics also plays a fundamental role in educational innovation and research, as described by Annalen der Physik as a center of excellence for global physics research (Hildebrandt, 2023). Effective physics learning also emphasizes the relationship between theoretical concepts and their applications in real life, enabling students to understand physics as part of everyday experience (Kotsis, 2024). In addition, physics serves as a primary foundation for technological innovations that drive developments in industry, communication, and energy (Adorno et al., 2025). This is why physics is very important to study, as evidenced by the inclusion of physics as a subject at all levels of education.

Quality learning requires instructional tools that can help students understand and master physics material effectively. The implementation of this statement implies that for teachers to teach well, they must prepare learning tools before the teaching and learning activities begin. Thus, instructional tools play an important role in the success of the learning process to support the smooth implementation of teaching and learning activities (Ayuningtyas et al., 2017). Physics education aims to train students to master knowledge, concepts, and principles of physics, to be able to analyze natural phenomena in their surroundings, and to possess scientific skills; therefore, students must also have process skills, critical thinking skills, and creative thinking skills.

Weak thinking skills can lead to errors in understanding learning properly, and critical thinking becomes a pattern that students must possess (Darmaji et al., 2020). Entering learning in the current era, students are expected to have critical thinking abilities in educational activities as competencies to be achieved as well as tools needed to construct knowledge (Maulina et al., 2022). Critical thinking is a very important ability to be developed in physics learning because it trains students to analyze information, evaluate arguments, and make rational decisions (Musniar et al., 2025). Critical thinking is not merely remembering or understanding concepts, but also the ability to assess the truth of information and relate it to real-life contexts (Yersi et al., 2025). Critical thinking does not simply involve memorizing concepts, but includes analytical and reflective thinking based on scientific processes (Alia et al., 2017).

In senior high school learning, one alternative approach is to package thinking skills in science subjects through science process skills. This is because science process skills support individuals in thinking scientifically. In other words, science process skills are skills of thinking, reasoning, and acting logically to investigate and construct scientific concepts that are important in the problem-solving process, and they reflect the elements of the scientific method in science learning (Fauziah, 2022). Science process skills also include thinking skills and scientific habits used by scientists in scientific inquiry; therefore, the development of science process skills is closely related to scientific thinking and problem solving.

Science process skills are a learning approach designed to enable learners to discover facts and construct concepts and theories in the learning they receive. Learners are directed to actively engage in scientific activities during the learning process (Nurtang, 2020). In reality, in the teaching and learning process of physics in schools, teachers still tend to emphasize physics as a product to be delivered, and students attempt to memorize it. Teachers tend to conduct learning by assigning independent tasks with the assistance of instructional materials such as textbooks and self-study books; teachers have not yet delivered material through science process skills and do not conduct scientific experiments (Andriyani et al., 2023). Consequently, science process skills, abilities, and attitudes are very important because they can enable individuals to have high flexibility in facing changes in their surroundings, including in social interactions, work, and institutions or organizations. Individuals who are trained in science process skills will develop honest, responsible, and meticulous personalities, enabling them to socialize more easily within society. Science process skills are very important for learners and play a significant mediating role in improving students' learning achievement in the learning process (Chandola & Tiwari, 2024).

The quality of science education in Indonesia still faces major challenges at the international level. Based on the latest report from the Programme for International Student Assessment (PISA) 2022, Indonesian students' scientific literacy achieved an average score of 383, which remains below the global average score of 485 (OECD, 2023). These results reflect a concerning condition, in which students' abilities to identify scientific problems, explain phenomena scientifically, and use scientific evidence to draw conclusions have not yet met the expected standards. Although Indonesia's global ranking position has improved due to declining scores in many other countries as a result of the pandemic, the absolute score of Indonesian scientific literacy still confirms the existence of a significant gap in the mastery of concepts and scientific reasoning. This condition indicates that the education system in Indonesia still requires deep innovation, particularly in physics learning, which relies heavily on science process skills and critical thinking abilities.

Based on observations and interviews with one educator at SMA Negeri 2 Makassar, it was found that some teachers still use conventional learning methods with lecture-based and assignment-oriented approaches. The instructional materials used are generally limited to textbooks that are not designed to train science process skills. As a result, students are less actively involved in learning and tend to receive information passively, without engaging in exploration or critical thinking. In addition, the prospective researcher also conducted interviews with a physics teacher and several students. Teachers stated that they experience difficulties in developing instructional materials that actively engage students and train science process skills. Conversely, students reported that the learning process was less interesting and that they found it difficult to understand the material being taught.

In general, the low level of students' science process skills is caused by the lack of optimization of student-centered learning. The learning process shows that students are less skilled and less active in participating in learning activities; students tend to remain silent and merely pay attention to the material being delivered. This condition is influenced by weak scientific backgrounds, limited laboratory facilities, learning resources, instructional tools, as well as the competence and quality of teaching personnel (Rahmasiwi et al., 2015). One effort to improve students' science process skills is through the implementation of instructional materials that contain structured learning activity steps and content oriented toward science process skills. By using instructional materials based on science process skills, students are trained to develop and discover the concepts being learned.

Various studies indicate that the development of physics instructional materials based on science process skills is effective in improving senior high school students' critical thinking abilities. Guided inquiry–based instructional materials train students to discover concepts through scientific stages, thereby enhancing critical thinking skills (Nisa et al., 2018). Electronic physics modules that integrate scientific activities such as observing and drawing conclusions have also been proven to improve critical thinking abilities and students' learning motivation. In addition, physics learning tools based on the scientific approach that emphasize observation, experimentation, and scientific reflection significantly develop students' higher-order thinking skills (Wenno et al., 2022). Project-Based Learning models grounded in science process skills have also been shown to effectively encourage students to think systematically and analytically and to solve real-world problems (Hasanah et al., 2018). Thus, the integration of science process skills into physics instructional materials can serve as an effective strategy for developing the critical thinking abilities of Grade X senior high school students.

Several previous studies have shown that the development of physics instructional materials integrated with science process skills has a significant effect on improving senior high school students' critical thinking abilities. Research conducted by Lembang et al. (2025) developed concept elaboration–based instructional materials using the 4D model and found that the resulting product was valid, practical, and capable of improving students' critical thinking abilities at a moderate level. Similar results were reported by Viskaali et al. (2025) who developed physics learning modules based on discovery learning and found a significant increase in critical thinking abilities through students' active involvement in scientific processes. Furthermore, research by Usman et al. (2025) instructional materials based on Project-Based Learning (PjBL) and demonstrated that this model effectively increased students' critical thinking abilities by up to 45% compared to conventional learning. This approach emphasizes scientific activities and real-world problem solving, which align with the development of science process skills. In addition, research by Nisa et al. (2018) showed that guided inquiry–based physics instructional materials were valid, practical, and effective in improving students' critical thinking abilities, with an n-gain score of 0.64 (moderate–high category).

From these research findings, it can be concluded that the use of physics instructional materials grounded in science process skills—through concept elaboration, discovery learning, project-based learning, or guided inquiry approaches—consistently contributes to the improvement of students' critical thinking abilities. However, most previous studies still focus on the development of specific models or approaches without explicitly integrating science process skills as the primary foundation for instructional material development. Therefore, this research is important to conduct, and the researcher is interested in carrying out a study entitled "Development of Physics Instructional Materials Based on Science Process Skills and Their Effect on the Critical Thinking Ability of Grade X Students at SMA Negeri 2 Makassar.

Method

Type of Research

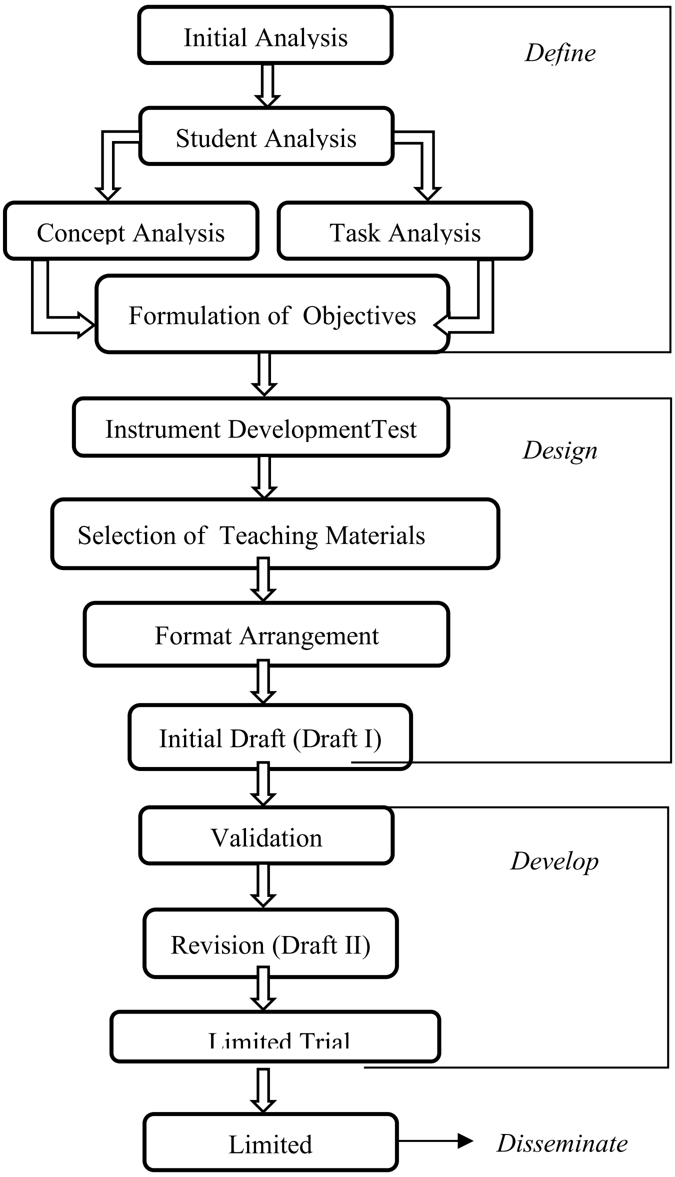

Figure 1. Four-D (4-D) model development design

This study is a Research and Development (R&D) project that refers to the 4-D development model developed by Thiagarajan (1974), which consists of four stages: Define, Design, Develop, and Disseminate. The stages carried out in this research procedure can be seen in Figure 1.

The initial–final analysis aims to identify the products needed in the field. At this stage, a preliminary study was conducted through direct classroom observations to identify problems and determine students' needs in the learning process. The preliminary study was carried out at SMA Negeri 2 Makassar.

SMA Negeri 2 Makassar is one of the schools that has implemented the Merdeka Curriculum. Based on the analysis, it was found that physics learning is currently conducted only in classrooms. The availability of laboratory space does not adequately support students in conducting experiments due to limited laboratory equipment. In addition, it was found that physics learning activities rarely involve science process skills. Therefore, this study designs structured instructional materials that facilitate experimentation and collaboration. The developed instructional materials are designed to be easy for both teachers and students to use, namely physics instructional materials based on Science Process Skills (SPS). The development of SPS-based physics instructional materials in schools requires adequate supporting facilities and infrastructure. Each classroom at SMA Negeri 2 Makassar has been equipped with a smartboard or interactive whiteboard, which plays an important role in supporting the classroom learning process.

Define Stage

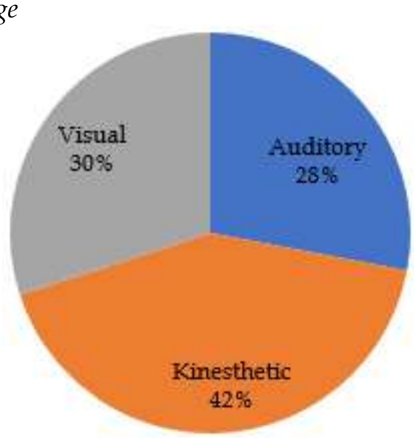

Figure 2. Learning styles of grade X students at SMA Negeri 2 Makassar

The analysis stage was also conducted on the students. According to Jean Piaget, students at this age are capable of abstract thinking, developing hypotheses logically, and drawing conclusions from available information. Students are able to solve problems and construct arguments as their operational competence develops into a more complex level. At the formal operational stage, students are able to communicate, exchange ideas, and collaborate in solving problems through SPS-based physics instructional materials. These SPS-based physics instructional materials serve as learning tools that enable students to engage in independent learning and more easily understand physics concepts that can be applied in everyday life.

In terms of students' learning styles, each student has a unique way of understanding physics material. The distribution of learning styles among Grade X students is presented in Figure 2.

Design

After identifying the problems at the definition stage, the next step is the design stage. This stage aims to develop physics instructional materials based on science process skills that can be used in physics learning. The design stage includes the selection of instructional materials and learning content, the selection of instructional material formats, and the development of the initial design of the instructional materials.

Development

The development stage aims to produce physics instructional materials based on Science Process Skills (SPS). At this stage, validation of the research instruments, design revision, and product trials were conducted. In the content validity phase, validation was carried out on the instructional materials, the teacher response questionnaire, and the students' critical thinking ability test instrument. Based on the results of evaluations, corrections, and suggestions from experts, improvements were subsequently made to the SPS-based physics instructional materials. After conducting content validation based on expert judgments, the revision results were used to refine the SPS-based physics instructional materials.

Following the revision of the instructional materials, a limited product trial was conducted to determine the outcomes of implementing the SPS-based physics instructional materials in classroom learning and to examine the improvement in students' critical thinking abilities after using the SPS-based physics instructional materials.

Dissemination

After completing the limited trial, the next stage was the dissemination of the physics instructional materials. In this study, dissemination was conducted on a limited scale to physics teachers at SMA Negeri 2 Makassar, SMA Negeri 3 Makassar, SMA Negeri 13 Makassar, and SMA Darul Marhamah. The purpose of this stage was to promote the instructional materials and obtain evaluations from practitioners or physics teachers to determine the practicality level of the SPS-based physics instructional materials. The evaluation was conducted using a validated questionnaire instrument and involved four physics teachers from SMA Negeri 2 Makassar, one teacher from SMA Negeri 3 Makassar, one teacher from SMA Negeri 13 Makassar, and two teachers from SMA Darul Marhamah.

Trial Subjects

The trial subjects in this study were students of classes X.2 and X.6 MIPA at SMA Negeri 2 Makassar in the 2025/2026 academic year. The product trial was conducted on 36 students of class X.2 (experimental class) and 36 students of class X.6 (control class). The research trial design employed a Posttest Only Control Design, as shown in the following table.

Table 1. Posttest-only control design

	Group	Treatment	Posttest
R	Experimental	X	0_1
R	Control	-	0_2

Notes:
0_1 : Posttest in the experimental class.
0_2 : Posttest in the control class.
R : Random assignment (Rambang).
X : Implementation of Science Process Skills (SPS) based instructional materials.
- : Use of standard textbooks (Conventional method).

Data Analysis

Analysis of Instructional Material Validity

To determine the level of relevance based on evaluations by three experts, the content validity coefficient (Aiken's V) was utilized. The Aiken's V formula is used to calculate the content validity coefficient based on the assessment results from each expert for a specific item, as shown in Equation (Azwar, 2012).

$$V = \frac{\sum S}{n(c-1)} \quad (1)$$

Notes:
V : Index of expert agreement on item validit
S : Difference between the score given by each expert and the lowest score in the category used
I_0 : Lowest rating score
n : Number of raters (validators)
c : Number of rating categories

According to the Aiken validity criterion, if V ≥ 0.4, the expert agreement index is considered valid.

Practicality Test Result Analysis

Practicality analysis is based on data obtained through questionnaires completed by practitioners/teachers. The practitioners' assessment of the science process skills-based physics instructional materials, as stated in the questionnaire sheets, is analyzed using Equation 2 according to Apriandi et al. (2023) as follows:

$$PRS = \frac{\Sigma_A}{\Sigma_B} \times 100\% \quad (2)$$

Notes:

PRS : Percentage of practitioners responding to the categories stated in the instrument

Σ_A : Total score obtained for each category stated in the questionnaire

Σ_B : Maximum possible score for each category responding to the questionnaire

Calculating the percentage of practitioner assessments for each question, based on the criteria determined through scaling procedures, yields values at the following measurement levels.

Table 2. Practitioner assessment score criteria

Percentage (%)	Criteria
80–100	Very Practical
61–80	Practical
41–60	Moderately Practical
21–40	Not Practical
0–20	Very Impractical

Source: Hendriani et al. (2023)

Based on the practicality analysis above, the developed science process skills-based physics instructional materials are considered practical if the practitioner questionnaire result is greater than 60%.

The Effect of Using Teaching Materials Based on Science Process Skills (SPS) on Students' Critical Thinking Ability

The data obtained from administering the critical thinking ability test (posttest) were analyzed using inferential analysis. Inferential analysis was used to determine whether there was an effect of using SPS-based physics teaching materials on students' critical thinking skills; therefore, a t-test was conducted. The prerequisites for the t-test are that both groups must come from populations that are normally distributed and have homogeneous variances, namely:

Normality Test

The normality test is conducted as a prerequisite analysis to determine whether the research data is normally distributed. This test was performed using the Lilliefors test to assess whether the critical thinking skills test results for both the experimental and control classes followed a normal distribution.

Homogeneity Test

The homogeneity test is used to determine whether the research samples originate from populations with homogeneous variance. The variance homogeneity of a data group can be tested using the F-test as follows:

$$F = \frac{\text{Largest Variance}}{\text{Smallest Variance}} \quad (3)$$

The data used for the homogeneity test are the critical thinking skills test scores from both the experimental and control classes.

Hypothesis Testing

Hypothesis testing is conducted using the Independent Sample t-test formula, as it aims to test two samples or compare the control and experimental groups. The Independent Sample t-test formula used is as follows:

$$t = \frac{X_1 - X_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \quad (4)$$

Notes:

X_1 = Mean of the experimental group

X_2 = Mean of the control group

S = Pooled standard deviation

N_1 = Number of members in the experimental class

N_2 = Number of students in the control group

To calculate the value of S, the following formula is used.

$$S = \sqrt{\frac{(n_1 - 1)s_1 2 + (n_2 - 1)s_2 2}{(n_1 + n_2) - 2}} \quad (5)$$

Notes:

S_1^2 = Variance of the experimental group.

S_1^2 = Variance of the control group

n_1 = Number of students in the experimental group

n_2 = Number of students in the control group

The purpose of the hypothesis test is to compare whether the two data sets (variables) are the same or different. What is compared in this hypothesis test is the posttest score between the experimental and control groups as a whole regarding students' critical thinking ability.

Result and Discussion

Results of the Development of Physics Teaching Materials Based on Science Process Skills

Based on the needs analysis conducted in grade 10 of SMA Negeri 2 Makassar, the researcher developed a draft of physics teaching materials based on Science Process Skills (SPS), covering the topic of renewable energy. The selected development format was printed teaching materials. This choice was made considering its support for learning activities, especially during face-to-face classroom instruction. This confirms that systematically, interactively, and contextually designed physics teaching materials—those that are relevant to daily life—can serve as a strategic solution to improve the quality of learning and physics learning outcomes at various levels of education (Miftahurrahmi et al., 2021).

Figure 3. Cover of physics teaching materials based on Science Process Skills (SPS)

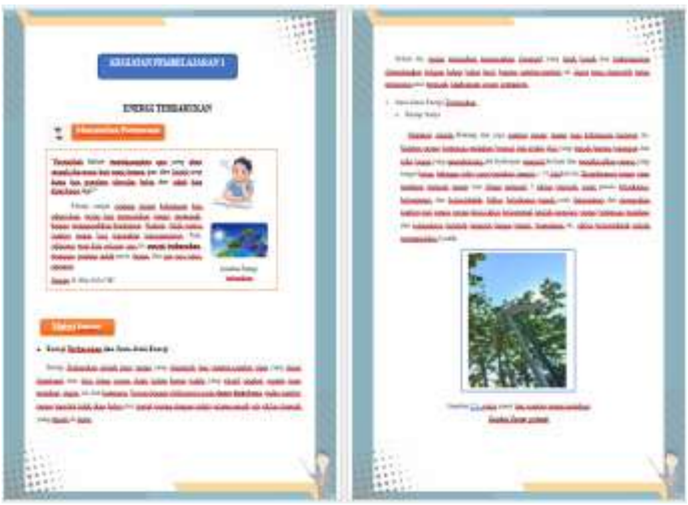

Figure 4. Integration of Science Process Skills (SPS) and critical thinking

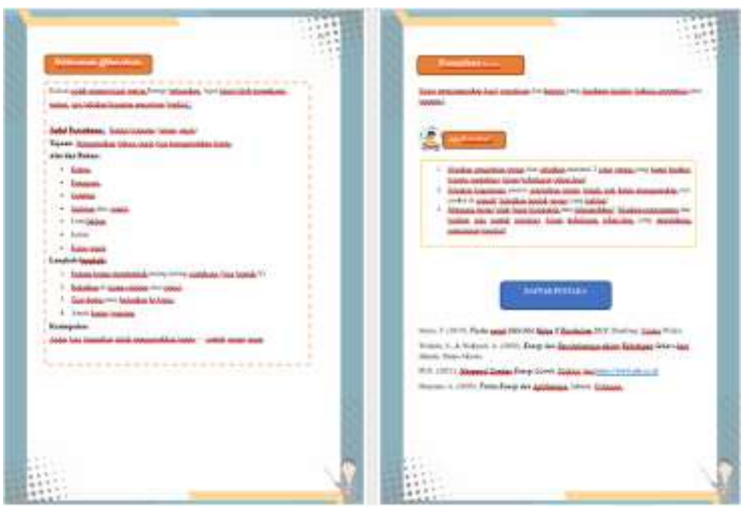

Figure 5. Integration of Science Process Skills (SPS) aspects

The development of SPS-based physics teaching materials includes several components: The introductory section of the material consists of the cover and introduction, which contain general information about the SPS-based physics teaching materials being developed. The cover is designed to be as attractive as possible, featuring fonts, illustrations/images, and colors that align with the characteristics of the developed materials. The content section of the teaching material is systematically organized by integrating Science Process Skills (SPS) indicators into each sub-topic. The narrative within the teaching material not only presents theoretical explanations but also guides students through the stages of SPS indicators.

Physics Teaching Materials Based on Science Process Skills (SPS) Validation Results

The Science Process Skills (SPS)-based physics instructional materials developed in this study were validated by three experts to assess their validity before the limited field trial. The aspects assessed during the validation process included content suitability, presentation, language, and graphics. The scores from the content validity analysis using the Aiken's V expert agreement index are presented in Table 3.

Table 3. Content validity analysis of science process skills-based physics instructional materials

Aspect	V	Category
Content Suitability	0.81	Valid
Presentation	0.82	Valid
Language	0.82	Valid
Graphical	0.81	Valid

Validity, derived from the term *validity*, refers to the extent to which a product accurately performs its intended function (Kartini et al., 2019). Validity indicates how feasible the developed teaching material is for use, based on expert evaluations of its content, language, presentation, and alignment with learning objectives (Wahyuni et al., 2024). Content validity is determined by expert consensus in assessing the designed product; each expert is asked to evaluate the product to identify its strengths and weaknesses (Retnawati, 2016).

Based on the table above, all assessed aspects fall into the valid category. The content feasibility aspect obtained an Aiken's V index of 0.81, which is classified as valid. The presentation feasibility achieved a score of 0.82, language feasibility 0.82, and graphical feasibility 0.81, all within the valid category. The overall mean validity index was 0.82.

These findings are consistent with previous scientific studies, such as those by Suryanti & Festiyed (2023) and Firdaus et al. (2024) which found that teaching materials based on Science Process Skills were declared valid based on validation results. Similarly, Haerani et al. (2023) reported that the worksheets developed met valid, practical, and effective criteria, indicating that their use helps students actively develop science process skills through experimental activities. The developed physics teaching materials enhance students' understanding through conceptual, intellectual, and hands-on learning experiences. Furthermore, research by Nuvitalia et al. (2021) stated that the materials were feasible for use based on aspects of content, presentation, language, science process skills, and students' critical thinking abilities. Expert validation showed high scores across all aspects, indicating that the teaching materials are ready for use in learning activities that promote students' critical thinking skills.

Practitioners' Evaluation of Physics Teaching Materials Based on Science Process Skills (SPS)

Practitioners' evaluation of the physics teaching materials based on Science Process Skills (SPS) was obtained through questionnaires completed by physics teachers. The evaluation questionnaire was filled out by four physics teachers from SMA Negeri 2 Makassar, two from SMA Negeri 3 Makassar, and two from SMA Negeri 13 Makassar. The practitioners' evaluation questionnaire consisted of 21 statements related to the content scope of the teaching materials, the suitability of the materials in assessing critical thinking ability, the advantages of the materials, and the practicality of the developed materials. The teachers' responses regarding the practicality of the SPS-based physics teaching materials are presented in Table 4.

Table 4. Practitioners' evaluation results of SPS-based physics teaching materials

Assessment Aspect	Percentage (%)	Criteria
Suitability of Instructional Materials with Science Process Skills	91	Very practical
Instructional Materials in Measuring Critical Thinking Skills	87	Very practical
Practicality of Instructional Materials	89	Very practical
Advantages of Instructional Materials	95	Very practical
Mean	91	Very practical

Based on the practitioners' assessment analysis shown in the table above, the average percentage score of the practitioners' evaluation of the teaching materials was 91%, indicating that the physics teaching materials based on Science Process Skills are categorized as very practical for classroom use. The aspect of suitability with Science Process Skills obtained a percentage of 91%, the aspect of measuring critical thinking ability scored 87%, the practicality aspect scored 89%, and the advantages aspect scored 95%. The cumulative interpretation of these percentage scores shows that all aspects fall within the very practical category.

This finding is supported by research conducted by Pohan et al. (2020) which found that teaching materials were rated as very practical for use in learning. The validation results indicated a very good feasibility score, and students' responses toward the materials were high, showing that students felt supported and motivated during the learning process. Similarly, Yetri et al. (2019) concluded that physics teaching materials had a high level of practicality, as they could be easily used by teachers, well understood by students, and effectively improved both science process skills and critical thinking abilities. Furthermore, students reported that the materials encouraged active participation and a better understanding of physics concepts, particularly through activities that honed critical thinking skills such as analyzing, evaluating, and drawing conclusions. Therefore, these materials were considered highly practical, easy to implement in class, and effective in supporting physics learning that fosters students' critical thinking skills (Marlina & Sriyanti, 2020). In addition, Pathoni et al. (2020) found that the implementation of science process skills was both practical and effective in improving students' critical thinking abilities and could be easily adapted across different educational levels.

Differences in Students' Critical Thinking Skills with and without Science Process Skills (SPS)

Table 5. Results of normality test analysis

Data	L_{count}	L_{table}	Description
Experimental Class	0.114	0.147	Normal
Control Class	0.128	0.148	Normal

After the validity and practitioner assessments were conducted, the developed physics teaching materials were then tested. This aimed to determine whether the SPS-based physics teaching materials had an effect on students' critical thinking ability. Therefore, to observe the effect, a trial was conducted using the True Experimental method with a Posttest Only Control Design model. The trial was carried out in two classes, namely the experimental class and the control class. Both classes were not given a pretest but were given a posttest after the treatment. The experimental class received treatment using the developed SPS-based physics teaching materials, while the control class used conventional teaching materials commonly used in schools. After the learning process, both classes were given a critical thinking test.

Table 6. Hasil Analisis Uji Homogenitas

Data	Number of student (n)	df	Variants (S^2)
Experiment Class	36	35	4.139683
Control Class	36	35	7.246825
F_{count}			1.750574
F_{table}			1.757

After the normality test was conducted, the next step was the homogeneity test. The homogeneity test was conducted to determine whether the variances between the experimental class and the control class were homogeneous. The homogeneity test was performed using the F-test. The results of the homogeneity test of critical thinking ability in the experimental and control classes are shown in Table 6.

Based on Table 6, the variance of the experimental class is 4.139683 and that of the control class is 7.246825 resulting in an F_{count} of 1.750574. The F_{count} value was then compared with the F-table value at a significance level of 5% with degrees of freedom df_1 = 35 and df_2 = 35, which is 1.757 Since $F_{count} < F_{table}$, it can be concluded that both groups have homogeneous variances. Thus, the homogeneity assumption required for conducting a parametric test (t-test) is fulfilled. The results of the t-test analysis (Independent Sample t-test) can be seen in Table 7.

Table 7. t test (Independent Sample t-test)

Data	Number of student (n)	df	Average ($\bar{X}$)	Variants (S^2)
Experiment Class	36	35	16.444444	4.139683
Control Class	36	35	11.916666	7.246825
df				70
t_{count}				8.006
t_{table}				1.994

Based on Table 7, the average score of the critical thinking test for the experimental class is 16.444444 with a variance of 4.139683, while the control class obtained an average score of 11.916666 with a variance of 7.246825. The obtained t_{count} value is 8.006. Meanwhile, the t_{table} value at a 5% significance level with degrees of freedom (df = 70) is 1.994. Since $t_{count} > t_{table}$, it can be concluded that there is a significant difference between the critical thinking test results of the experimental and control classes. The SPS-based physics teaching materials have a significant effect on improving students' critical thinking ability.

Conclusion

The development of these Science Process Skills (SPS)-based physics instructional materials was conducted using the 4D model (Define, Design, Develop, Disseminate). Analysis results show that the instructional materials have met the feasibility criteria. First, based on expert assessment, the content validity proved valid and feasible for use, supported by an Aiken's V coefficient greater than 0.4. Second, assessment results from practitioners/teachers indicate the "Very Feasible" and "Feasible" categories, reflecting the practicality of the materials in the field. Third, effectiveness testing using a Posttest-Only Control Design found a significant difference in critical thinking skills between the experimental class and the control class (t_{count} = 8.006 > t_{table} = 1.994). The highest improvement was observed in the Interpretation and Analysis indicators, strongly proving that SPS-based physics instructional materials are effective in building students' critical thinking skills.

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The authors declare no conflict of interest.

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