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Development of Teaching Materials with a Socio-Scientific Issues Context on the Nuclear Power Plant Theme

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Abstract: Indonesia plans to construct Nuclear Power Plants (NPPs) to meet energy demands and align with the government's commitment to Net Zero Emission (NZE). However, this development faces numerous challenges, including public resistance. Most of this opposition stems from concerns and negative stigma surrounding nuclear energy, exacerbated by the public's limited knowledge, including students, about nuclear energy and its application in NPPs. Therefore, the development of teaching materials with a Socio-Scientific Issues (SSI) context on the theme of NPPs will be undertaken. The purpose of this research is to determine the feasibility of SSI-based teaching materials on the theme of NPPs to facilitate students' critical thinking skills. This study adopts a Research and Development (RnD) model, with the development of teaching materials following the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. In this study, the procedure is limited to the development stage. The validation results for the content achieved a score of 77.81% in the "feasible" category, while the media validation scored 79.16%, also in the "feasible" category. The results of the student response questionnaire showed an average score of 74.33%, classified as "interesting". Based on these results, the developed teaching materials are categorized as "feasible" and suitable for use in 12th-grade high school physics learning.

Keywords: Teaching Material, Socio-Scientific Issues (SSI), Nuclear Power Plants (NPP).

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Introduction

In the 21st century, education is required to prepare students to master various skills to face future challenges (Santika et al., 2018), These 21st-century skills are crucial given the rapid technological advancements in various fields. 21st-century thinking emphasizes students' ability to think more critically (Hasibuan & Prastowo, 2019).

Critical thinking is closely related to decision-making (Diharjo et al., 2017), Students who master critical thinking skills can formulate arguments, confirm the credibility of information sources, or make decisions (Khovivah et al., 2022). However, based on the 2022 survey results from the Programmed for International Student Assessment (PISA) (OECD,

2023, 2024) which assessed students in reading, mathematics, and science (Yusmar & Fadilah, 2023). it was found that Indonesian students' thinking skills are still below the international average score. Therefore, critical thinking skills must be implemented in student learning activities to enable students to master and become accustomed to critical thinking (Cahyani & Putri, 2019).

The use of teaching materials in the learning process can make learning more effective, structured, practical, and engaging (Azizah et al., 2022). Teaching materials are a collection of information, media, and texts utilized by teachers to prepare and evaluate the implementation of learning (Eliyanti, 2016). Teaching materials that can promote critical thinking aspects are Socio-Scientific Issues (SSI) teaching materials. The use of SSI teaching materials can prepare students to become skilled in taking roles in issues related to socio-scientific contexts (Santika et al., 2018).

Socio-scientific issues (SSI) are representations of issues or problems in social life that are closely related to science, often presenting solutions that are relative or have no definite answers (Kusumaningtyas et al., 2020). According to research conducted by Sunu and Dwandaru (2023) the use of SSI in learning, particularly in physics education, can train students' critical thinking skills. Several examples of SSI themes include global warming , air pollution (Yulinawati et al., 2019), energy sources (Saefullah et al., 2020), climate change (Arjaya & Surata, 2024), and nuclear power plants (Jho et al., 2014).

The Socio-scientific Issues (SSI) approach shares similarities with the Problem-Based Learning (PBL) approach. In the PBL learning process, issues or problems are systematically presented by the teacher in the form of questions, whereas in the SSI approach, students must develop issues or problems by considering various aspects (Wulandari, 2022). Therefore, the SSI approach in the learning process requires students to actively participate throughout the learning process. Additionally, the issues raised in SSI are science-based, controversial, and open-ended (Nubita & Istianah, 2024; Wardani et al., 2024). One of the controversial socio-scientific issues is Nuclear Power Plants (NPPs). In Indonesia, SSI on the nuclear power plant (NPP) theme is not yet available, as NPPs are still in the planning stage.

Indonesia plans to establish Nuclear Power Plants (NPPs), which are still in the planning stage. The construction is subject to several requirements as stated in Law No. 17 of 2007 regarding the National Long-Term Development Plan (Ruslan, 2021). The development of NPPs in Indonesia has been planned for a long time but has continuously faced delays. According to the National Research and Innovation Agency (BRIN), if the target is met, NPPs are expected to operate in Indonesia by 2032 (BRIN, 2024). However, the development faces several challenges, one of which is public acceptance, which must be addressed(A. Yanto, 2023). Most opposition is based on concerns and the widespread stigma associating nuclear energy with bombs (Wijaya, A. I., Ariana, P., & Hidayah, 2022). This issue is exacerbated by the public's limited knowledge, including that of students, about nuclear energy, particularly its application in Nuclear Power Plants (NPPs).

Based on these issues, the development of Socio-Scientific Issues (SSI)-based teaching materials on the Nuclear Power Plant (NPP) theme will be conducted to facilitate students' critical thinking. This study is expected to educate and facilitate students' critical thinking about issues or problems, particularly those related to Nuclear Power Plants (NPPs).

Method

The procedure for developing teaching materials in this study uses the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. In this study, the procedure is limited to the Development stage, as the objective is to develop a teaching material. The development process requires a series of evaluations by experts, trials on research subjects individually or on a limited scale, and revisions to refine the final product (Cahyadi, 2019).

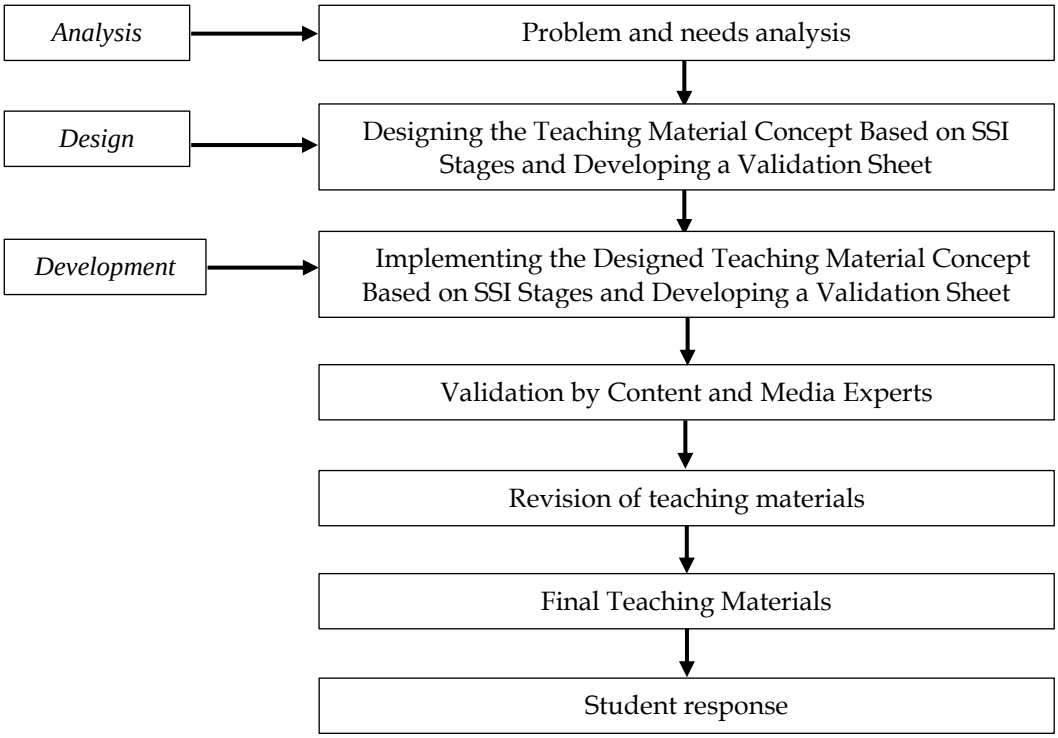

Figure 1. Stages of Teaching Material Development

Analysis

The first step in the Analysis stage is "problem analysis", which involves examining the issues that serve as the foundation or background for developing teaching materials. Besides that, "teaching material analysis" is equally important to identify the need for instructional support, specifically teaching materials. This needs analysis can be conducted through observations or literature studies. Furthermore, literature studies are also useful for gathering information and conceptualizing ideas before designing the teaching materials.

Design

The Design stage involves determining the content or initial concept of the teaching materials before development. The content and design of the teaching materials are aligned with the stages of Socio-Scientific Issues (SSI) and critical thinking indicators, as identified in the previous Analysis stage. In addition to developing the teaching material concept, this stage also includes preparing research instruments, such as evaluation instruments for content and media expert, as well as student readability or response questionnaires for the teaching materials.

Development

The Development stage involves realizing the teaching material concept, validating the teaching materials, revising them, and conducting limited student trials. Validation is carried out by four experts in content and media. After validation, revisions are made based on feedback and suggestions from the validators. Finally, the teaching materials are tested on a

limited scale with 20 students at a high school in Pandeglang Regency to gather student responses to the developed materials.

The instruments used in this study include content validation instruments, media validation instruments, and student readability or response questionnaires. According to the National Education Standards Agency (BSNP), there are four aspects of feasibility assessment: content feasibility, language feasibility, presentation feasibility, and graphical feasibility. Language feasibility is further evaluated based on clarity, communicativeness, dialogic and interactive qualities, appropriateness, and adherence to linguistic rules (Wandira Yulis et al., 2022; Zaharah et al., 2023).

These assessment aspects were modified to produce a content validation instrument with three evaluation criteria: content feasibility, presentation feasibility, and contextual feasibility. Meanwhile, the media validation instrument includes graphical aspects (teaching material size, cover design, and content layout) and language aspects (clarity, communicativeness, dialogic and interactive qualities, appropriateness to student development, and adherence to linguistic rules).

For the student readability or response questionnaire, four evaluation aspects are considered: content, language, interest, and graphical design (Badiah et al., 2024). The research instruments used in this study utilize a Likert scale, as shown in Table 1.

Table 1. Assessment Criteria for Material and Media Feasibility Testing

Score	Criteria
5	Very Good
4	Good
3	Fair
2	Poor
1	Very Poor

(Purwanto, 2019)

Meanwhile, the student response questionnaire for the teaching materials uses a Likert scale with criteria ranging from strongly disagree to strongly agree. The complete criteria can be seen in Table 2.

Table 2. Student Response Score Criteria

Score	Criteria
5	Strongly Agree
4	Agree
3	Neutral
2	Disagree
1	Strongly Disagree

(Udin, 2021)

The data analysis technique used in this study is quantitative analysis with descriptive statistics to assess the feasibility of the teaching materials. Descriptive statistics is a branch of statistics that focuses on collecting, processing, presenting, and analyzing quantitative data descriptively. It is used to summarize and simplify data, making the information contained within easier to understand (Nurul Huda Panggabean et al., 2020).

The collected data are processed into percentages using the following equation:

$$Perscentage = \frac{Total\ score\ obtained}{Maximum\ score} \quad (1)$$

After the content and media validation data are processed into percentages, they can be interpreted as shown in Table 3.

Table 3. Interpretation Criteria for Material and Media Validation Percentage Data

Percentage%	Criteria
80.01% - 100%	Very Feasible
60.01% - 80.00%	Feasible

40.01% - 60.00%	Fairly Feasible
20.01% - 40.00%	Not Feasible
0.00% - 20.00%	Very Not Feasible

(Nurul Huda Panggabean et al., 2020; Purwanto, 2019)

Meanwhile, the student response data for the teaching materials, after being processed and interpreted, are presented in Table 4.

Table 4. Interpretation Criteria for Student Readability Questionnaire or Response Percentage Data

Percentage%	Criteria
80.01% - 100%	Very Interesting
60.01% - 80.00%	Interesting
40.01% - 60.00%	Fairly Interesting
20.01% - 40.00%	Not Interesting
0.00% - 20.00%	Very Not Interesting

(Nurul Huda Panggabean et al., 2020; Purwanto, 2019)

Results and Discussion

Analysis

The utilization of nuclear energy in Indonesia, particularly in the energy sector, faces challenges in implementation. Indonesia has long planned to build a Nuclear Power Plant (NPP) as a low-carbon electricity supplier, aligning with the government's commitment to achieving net zero emissions by 2060. One of the biggest challenges comes from public opposition, largely driven by negative stigma and limited knowledge about nuclear energy. This negative perception is not only prevalent among the general public but also among students. Therefore, students are expected to think critically about the issues or stigmas circulating in society.

One way to enhance students' critical thinking is by using a Socio-Scientific Issues (SSI) approach, which can be implemented through teaching materials. The SSI approach on the topic of NPPs has been widely applied in several countries (Evren Yapıcıoğlu & Aycan, 2018). However, in Indonesia, SSI on the NPP theme is still unavailable, as the NPP development is still in the planning stage.

Therefore, teaching materials with a Socio-Scientific Issues (SSI) context on the Nuclear Power Plant (NPP) theme will be developed to facilitate students' critical thinking skills.

Design

In the design phase, the content of the initial concept for the teaching materials is determined before development. The content and concept of the teaching materials are aligned with the stages of Socio-Scientific Issues (SSI) and critical thinking indicators, as identified in the previous analysis phase.

The developed teaching materials are divided into four chapters. Chapter I focuses on presenting nuclear physics materials taught in high school, aiming to provide students with information and knowledge about nuclear energy. Chapter II explains energy and Nuclear Power Plants (NPPs), discussing their potential, working principles, and different types of NPPs. Chapter III covers radioactivity and its impacts, which are closely related to nuclear utilization. Chapter IV focuses on mitigation and waste management, teaching how to prevent the negative effects of nuclear energy in NPPs by understanding existing nuclear waste management methods.

The development of the teaching materials aligns with critical thinking indicators and SSI stages. The critical thinking indicators used consist of five components: providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and strategizing and tactics. These five critical thinking indicators are applied to the five SSI stages: Problem analysis, Clarification of the science, Refocus on the socio-scientific dilemma, Role-playing task, and Meta-reflective activity (Rohmah et al., 2021).

Development

After completing the design phase, which produced the initial concept and blueprint of the teaching materials, the concept was then realized into teaching materials using Canva. As outlined in the design phase, the organization of the teaching materials aligns with critical thinking indicators and SSI stages. Details of these SSI stages are provided in the user guide for the teaching materials, as shown in Figure 2.

Figure 2. Guidelines for Usage and Stages of Socio-Scientific Issues (SSI)

At the beginning of each chapter, issues related to the chapter's discussion are presented to encourage students to analyze arguments related to these issues and to introduce them to the material covered in the chapter. This can be seen in Figure 3.

(a) (b)

Figure 3. (a) Chapter Cover Design, and (b) Social Issues Discussed

Chapter IV discusses a current issue regarding Japan's plan to discharge nuclear waste from the damaged Fukushima plant into the ocean, caused by a disaster. This issue aligns with the main topic of Chapter IV, which is nuclear waste mitigation and management. By examining this issue, students can learn how Japan manages and handles nuclear waste under such circumstances, serving as a preventive measure if a similar situation occurs once a Nuclear Power Plant is established. Additionally, Chapter IV also covers nuclear waste categories and their management, as illustrated in Figure 4.

(a) (b)

Figure 4. (a) Categories of Nuclear Waste, and (b) Nuclear Waste Management

The teaching materials that have been developed are presented as an initial product that will undergo content and media validation by validators to assess their feasibility. The validation process involves 4 validators, consisting of 2 physics education lecturers and 2 high school physics teachers. The results of the content validation are shown in Table 5 and Figure 5.

Table 5. Material Validation Results by Each Validator

Name	Content Feasibility	Presentation Feasibility	Contextual Feasibility	Average Validator Rating
Validator 1	88.57%	88.00%	95.00%	90.52%
Validator 2	85.71%	64.00%	60.00%	69.90%
Validator 3	65.71%	60.00%	55.00%	60.24%
Validator 4	85.71%	96.00%	90.00%	90.57%
Average Validator Rating	81.43%	77.00%	75.00%	77.81%

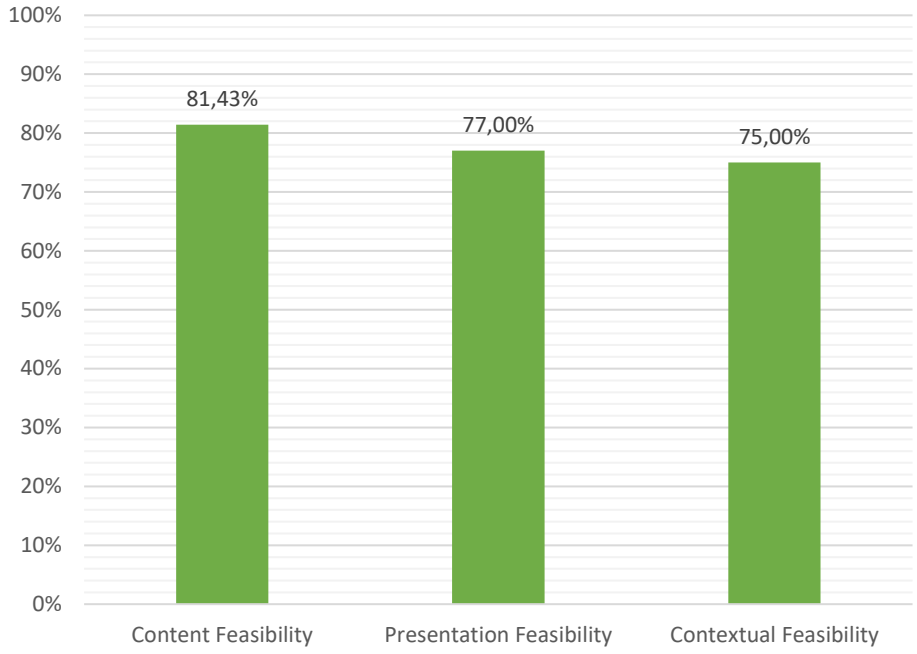

Figure 5. Diagram of Material Validation Results

The results of the content validation indicate that the feasibility of the content received an average score of 81.43%, which falls under the "very feasible" category. The aspect of presentation feasibility received an average score of 77.00%, categorized as "feasible." Meanwhile, the contextual feasibility aspect received an average score of 75.00%, also categorized as "feasible."

The lowest average rating was found in the contextual feasibility aspect. This is likely due to the topic of nuclear power plants (NPPs) being relatively unfamiliar in Indonesia, making it challenging for students to relate it to their daily lives.

Media validation results were evaluated based on four aspects: the size of the teaching material, the cover design, the content design, and the language used. The results of the media validation are presented in Table 6 and Figure 6.

Table 6. Media Validation Results by Each Validator

Name	Teaching material size	Cover desain	Content design	Lenguage	Average Validator Rating
Validator 1	100%	96.00%	88.57%	80.00%	91.14%
Validator 2	70%	64.00%	65.71%	57.78%	64.37%
Validator 3	70%	76.00%	74.29%	55.56%	68.96%
Validator 4	90%	92.00%	100.00%	86.67%	92.17%
Average Validator Rating	83%	82.00%	82.14%	70.00%	79.16%

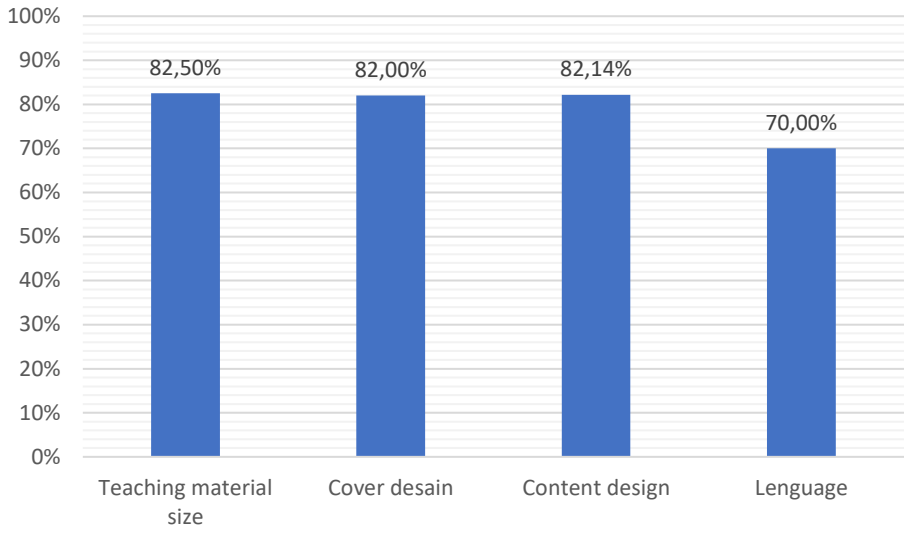

Figure 6. Diagram of Media Validation Results

Figure 6 presents the results of the media validation, which include the categories of teaching material size, cover design, teaching material content design and language. The evaluation of the material size received a percentage of 82.50%, categorized as "very feasible." The cover design received a percentage of 82.00%, also categorized as "very feasible." The content design was rated at 82.14%, falling under the "very feasible" category as well. However, the language aspect received a percentage of 70.00%, categorized as "feasible."

Among these four categories, language received the lowest average rating. This was partly due to spelling and sentence structure errors found in the initial product that was validated. Based on these validation results, suggestions for improvement were provided, particularly focusing on correcting the writing errors, as it was the lowest-rated aspect among all validation criteria.

After the initial product was validated and feedback was gathered for revisions, the teaching material was then revised accordingly before conducting a limited trial to evaluate students' responses. The limited trial was conducted at a public high school in Pandeglang Regency with 20 students participating. The results of this trial are presented in Figure 7.

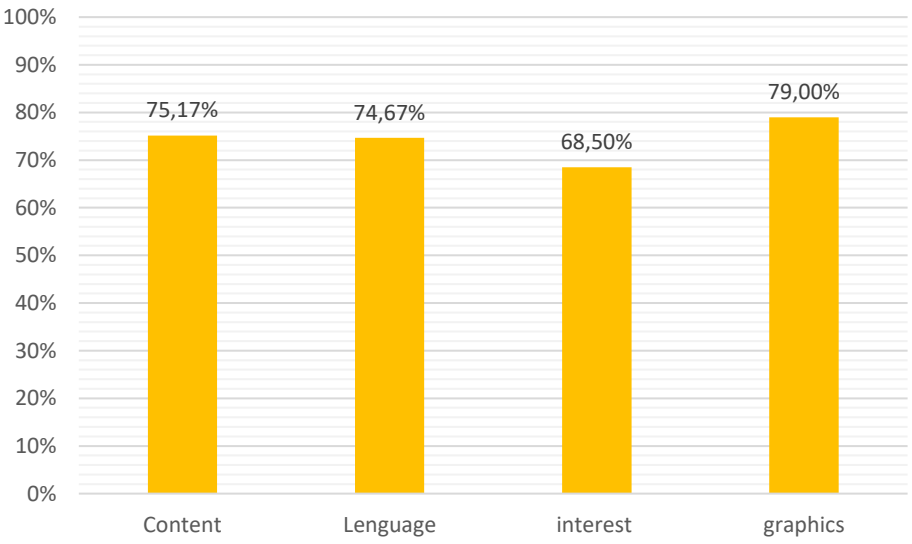

Figure 7. Diagram of Limited Trial Results on Students

Figure 7 shows the results of the limited trial on students' responses to the developed teaching material, categorized into four aspects. The average percentage rating for the content aspect was 75.17%, which falls into the "feasible" category. The language aspect received an average of 74.67%, also categorized as "feasible." For the interest aspect, the average rating was 68.50%, while the graphics aspect received 79.00%, both categorized as "feasible."

The limited trial process faced constraints, particularly in terms of time allocation. The time limitations hindered the optimal explanation of the teaching materials and their content. As a result, some students commented that certain terms and abbreviations within the materials were difficult to understand. This may have contributed to the relatively lower student responses in terms of interest aspect and language aspects.

During the limited trial period, students were asked questions to assess their understanding of the subject matter, particularly their knowledge of nuclear-related topics. When asked, "*What do you know about nuclear?*", most students responded with terms such as "bomb," "radiation," and "large energy." These responses indicate that while some students had a basic understanding of nuclear science, others held misconceptions, likely influenced by the negative stigma surrounding nuclear energy.

The final feasibility level of the teaching material, which utilizes the Socio-Scientific Issues (SSI) approach on the topic of nuclear power plants (PLTN), can be determined from the overall average of all aspects evaluated in the content and media validations. These results are shown in Figure 8.

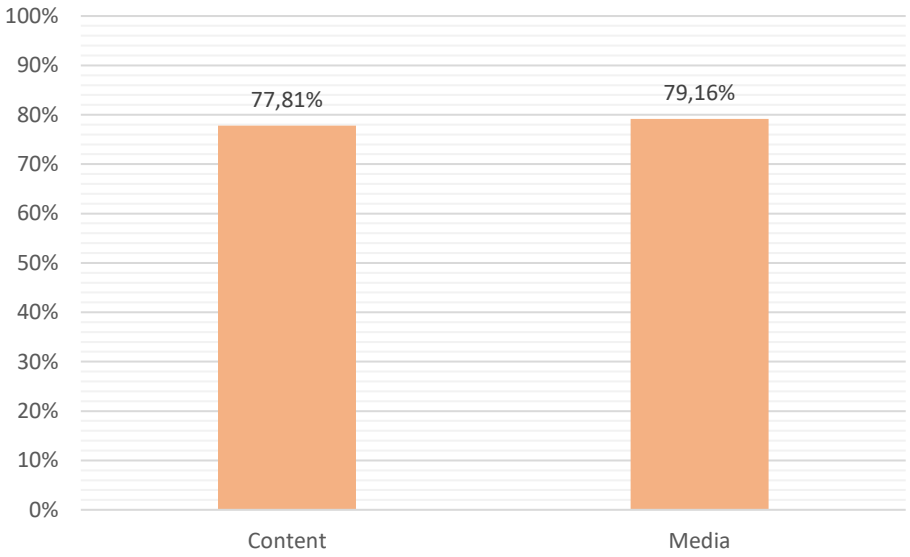

Figure 8. Diagram of Teaching Material Feasibility Results

Based on the overall percentage results from the validation of content and media, the content received a score of 77.81%, categorized as "feasible," while the media received a score of 79.16%, also categorized as "feasible." Therefore, the teaching material developed using the Socio-Scientific Issues (SSI) approach on the topic of nuclear power plants is considered suitable for use in teaching physics to twelfth-grade high school students. These findings are consistent with previous research conducted by Septiningrum, which concluded that SSI-based teaching materials are feasible for use in learning activities. (Septiningrum et al., 2021).

Conclusion

The development of teaching materials with the context of Socio-Scientific Issues (SSI) on the topic of nuclear power plants (NPP) to facilitate students' critical thinking skills has been successfully carried out using the ADDIE model, which consists of five stages: Analysis,

Design, Development, Implementation, and Evaluation. However, in this study, the procedure was limited to the development stage, in line with the research objective of developing teaching materials.

The theme of Nuclear Power Plants (NPP) is a controversial socio-scientific issue (SSI). Additionally, this NPP theme is correlated with the subject matter of Nuclear Physics and Radioactivity, which is taught in 12th-grade high school. There are various other SSI themes besides NPP that can be explored and correlated with different subject matters and educational levels.

The validation results for the content received a score of 77.81%, categorized as "feasible", and the media validation received a score of 79.16%, also categorized as "feasible". Student responses to the teaching materials were collected through questionnaires given to 20 students, yielding an average score of 74.33%, which falls under the category of "interesting". Based on these results, the developed teaching materials are deemed "feasible" and can be used in physics learning for 12th-grade high school students.

Several suggestions are offered for future research. Further investigation is needed on the development of teaching materials from this study, as the use of the ADDIE model was limited to the development stage. Future research is expected to continue the remaining two stages, namely implementation and evaluation. Moreover, SSI-based teaching materials are not limited to this topic or NPP, future research is encouraged to explore other issues or themes that can be implemented across various educational levels.

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