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CITIZENSHIP IN SCIENCE INTEGRATED SCIENCE, TECHNOLOGY, SOCIETY: MIDDLE SCHOOL TEACHERS' PERCEPTIONS OF LEARNING TOOLS

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Abstract :
This study aims to analyze teachers' perceptions of the development of Citizenship-based learning devices in science integrated with the Science, Technology, and Society approach to make students have critical thinking skills, science process skills, and students' curiosity in learning energy material. A mixed method approach was used, combining qualitative and quantitative data. The study involved five schools, with qualitative data obtained through teacher interviews and classroom observations, while quantitative data were collected through teacher perception questionnaires. The findings showed that the developed devices were positively received and considered effective in making students have critical thinking skills, science process skills, and students' curiosity in learning energy material and can connect scientific concepts with social and environmental issues. Furthermore, the devices were found to support the development of scientific attitudes and awareness of the social impacts of science and technology. Overall, the learning devices were considered suitable for contextual and meaningful science education.

Keywords: Citizenship in Science, Perception, Science, Society, Technology

INTRODUCTION

Science learning in schools should not only focus on memorizing concepts, formulas, or theories, but should also help students understand how science is used in everyday life (Fransiska et al., 2018; Nissen et al., 2021; Wilcox & Lewandowski, 2018). Currently, we live in an era filled with various technological developments and social challenges, including in terms of energy use (Husamah et al., 2022; Khusniati et al., 2023; Nielsen et al., 2018). Science learning needs to be directed so that students are not only academically smart, but also can think critically, care about the environment, and be responsible as citizens (Madu, 2020; Pamungkas et al., 2017; Supriadi & Hignasari, 2019). One approach that can be used to achieve this is Citizenship in Science, which is an approach to science learning that encourages students to become science-conscious citizens and active in social issues related to science.

According to PISA 2018 data, although about two-thirds of students globally reported reducing energy consumption at home to protect the environment, only about 44% participated in environmental protection activities, and more than a quarter of students did not engage in actions such as boycotting products or signing environmental petitions. The topic of energy is one of the most important materials in science learning, especially because energy is directly related to everyday human activities. Starting from the use of electricity at home, vehicles, to global issues such as climate change, all of these are related to energy. (Alimin & Effendi, 2020; Fauzi, 2024; Maison et al., 2019). Unfortunately, in practice, learning about energy is often limited to explaining forms of energy, energy changes, or renewable and non-renewable energy sources (Bosch et al., 2018; Novas et al., 2021). In fact, learning about energy can be a gateway to discussing various social and environmental issues, such as energy waste, the impact of power plants on the environment, or how individual decisions can affect the sustainability of natural resources.

To bridge science with real life, an integrative approach is needed. The Science, Technology, and Society (STS) approach emphasizes the importance of the relationship between science, technology, and community life (Dewi & Atun, 2019; Gobo & Marcheselli, 2023; Yoon & Olsen, 2023). Through this approach, students are invited to understand that science does not stand alone, but is always related to technological developments and has an impact on social life. If the STS approach is combined with Citizenship in Science, science learning will be more meaningful. Students not only understand scientific concepts, but are also invited to think about how the concepts are used, their impact on society, and what they can do as responsible citizens.

Citizenship in Science is a learning approach that integrates science education with citizenship values, aiming to form students who not only understand scientific concepts, but also have social awareness, environmental responsibility, and the ability to make science-based decisions (Adamou et al., 2021; Hoover, 2020; Widodo et al., 2021). Meanwhile, the Science, Technology, and Society (STS) approach emphasizes the importance of the relationship between science, technological developments, and their impact on society (Martín-Gutiérrez et al., 2017; Nugraheni & Wuryandani, 2018; ÖZDEN, 2020). When these two approaches are combined in the learning process, students are invited to understand science concepts more contextually, criticize the impact of technology on everyday life, and play an active role as citizens who care about global issues such as climate change, sustainable energy, and the ethics of technology use (Chanchangi et al., 2023; Kumar et al., 2021; Stirling, 2007). This approach is very relevant in forming a generation that is not only academically intelligent, but also wise and responsible in facing future challenges.

The role of teachers is very important because they are the main implementing teachers in the classroom and determine the success of a learning approach. Therefore, it is important to know how teachers view or perceive energy learning devices based on Citizenship in Science and the STS approach. Do teachers find this approach easy to implement? Do teachers see the benefits for students? Do they have challenges in using it? These questions need to be answered so that we can find out what the conditions are in the field and what needs to be improved.

This research is in line with studies conducted by (Zendrato & Sarumaha, 2018), which examined teachers' perceptions of learning devices in improving students' critical thinking skills. Although the study was only conducted in one school, the results showed that student engagement in the learning process increased when the devices were designed with a contextual approach that was relevant to everyday life. This finding is in line with the results of the current study which showed that the integration of the Citizenship in Science approach with Science, Technology, and Society was able to significantly foster students' critical thinking skills, curiosity, and science process skills. Both studies emphasize the importance of the role of teachers in directing learning that encourages active participation, as well as the need for learning devices that not only emphasize mastery of concepts, but also the formation of students' scientific attitudes and social responsibility.

This study aims to explore more deeply the teachers' perceptions towards energy teaching tools developed with Citizenship in Science and STS approaches. The results of this study are expected to be the basis for developing learning tools that are not only in accordance with the curriculum, but also relevant to real-world challenges. Thus, students can learn science not only to pass exams, but also to become citizens who are aware, caring, and ready to face global issues related to energy and the environment. Citizenship in science encourages students to see science not just as a collection of facts, but as a tool for understanding and solving real problems in society. For example, issues of global warming, renewable energy, or air pollution are science topics that are highly relevant to their role as citizens.

The urgency of this research lies in the need to strengthen science learning that is more relevant to real-life contexts, especially amidst increasing global challenges such as the energy crisis and climate change. Science education in schools has great potential to shape a young generation that is not only cognitively intelligent, but also has social and environmental concerns (Arent et al., 2020; Madu, 2020; Mutlu, 2020). Unfortunately, there are not many teaching tools that are specifically designed to integrate the Citizenship in Science and STS approaches, especially on the topic of energy (González-García et al., 2021; Hoover, 2020). In addition, teachers' understanding of the importance of science education based on citizenship and society is still very varied. By exploring teachers' perceptions, this study is an important initial step to determine the extent to which this approach can be applied in the field and what needs and support are needed so that these teaching tools can run effectively (Azhari & Safrina, 2022; Wulandari, 2020). The findings of this study are expected to provide real contributions to policy development, teacher training, and the design of science learning that is more contextual, critical, and oriented towards building students' character as science-conscious citizens.

The novelty of this research lies in its focus on combining two important approaches in science learning, namely Citizenship in Science and Science, Technology, and Society (STS), which have so far rarely been applied simultaneously in the context of education in Indonesia, especially in energy material. This research does not only try to develop products, but emphasizes more on teachers' understanding and views on innovative teaching tools designed with these approaches. By placing teachers as the main subject, this research offers a new perspective that is important for the development of sustainable learning tools that are in accordance with the needs in the field. In addition, the integration of science, technology, society, and civic values in one teaching tool unit provides a unique contribution in the effort to create a more contextual, critical, and effective science education for the formation of students' characters as responsible citizens.

RESEARCH METHOD

Research Design

This study was designed using a mixed methods approach, which combines quantitative and qualitative methods simultaneously to obtain a more complete picture of the object being studied. Quantitative methods are used to collect and analyze numerical data that is measurable (Fikriyah & Sukmawati, 2022; Planinic et al., 2019; Schoonenboom, 2019). In this case, a four-point Likert scale is used to assess teachers' perceptions of the learning tools developed. This quantitative method allows researchers to process data statistically, identify patterns, and test previously formulated hypotheses objectively and systematically (Elvanisi et al., 2018; Kamar et al., 2020; Ubaidillah & Efendi, 2022). In this study, qualitative methods are used as a complement that aims to dig deeper into the meaning behind the numbers, through observation and in-depth interviews. With this approach, researchers can understand the context, experiences, and subjective views of the teachers who were respondents in this study. The combination of these two methods allows researchers to not only see general trends based on numbers, but also to gain a richer and more comprehensive understanding of the dynamics that occur in the application of the Citizenship in Science and STS approaches in energy learning.

Research Target/Subject

The population in this study consisted of 9 teachers who were actively teaching in five schools in Jambi Province namely SMPN 19 Kota Jambi, SMPN 12 Kota Jambi, SMPN 11 Batanghari, SMPN 10 Tungkal Ulu, Pondok Modern Al-Mishbah Jambi. These schools were carefully selected to represent the diversity of educational backgrounds, teaching experiences, and different characteristics of the school environment. This research was conducted from June 2024 to February 2025. The sample in this study was taken purposively, considering that the teachers involved had direct relevance to the research topic, especially in terms of the implementation of science learning and energy materials. The selection of teachers as respondents aimed to obtain in-depth and contextual data, especially regarding how they understand and respond to the Citizenship in Science approach integrated with the Science, Technology, and Society (STS) approach (Rosidin et al., 2020; Tiara & Sari, 2019; Wahlund & Palm, 2022). In addition, in the sample selection process, the researcher also considered variations in the learning methods used by teachers, the level of technology utilization in the teaching and learning process, and their readiness to face learning innovations.

Research Procedure

The first stage begins with the distribution of questionnaires and conducting interviews with teachers as an effort to collect quantitative and qualitative data regarding their perceptions of the learning devices developed. Furthermore, the data obtained is analyzed through the process of analyzing questionnaires and interview sheets to identify the tendencies of teacher perceptions and aspects that support or hinder the implementation of learning devices. The results of the analysis are then compiled and presented in the form of research findings. The final stage of this process is drawing conclusions based on the results obtained, which aims to answer the formulation of the problem and evaluate the effectiveness of learning devices in developing critical thinking skills, science process skills, and students' curiosity. The following is a presentation of the research procedure which can be seen in Figure 1.

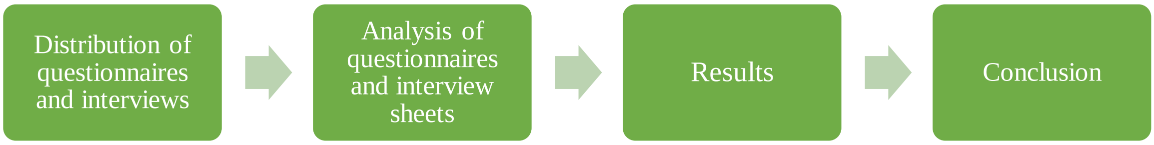

Figure 1. Research Procedure

Instruments, and Data Collection Techniques

The data collection technique in this study was carried out using two main types of instruments, namely teacher perception questionnaires and interview sheets. The questionnaire was used to collect quantitative data regarding teachers' views on learning devices based on *Citizenship in Science* and integrated with the STS approach. Data from this questionnaire allows researchers to analyze teacher perceptions more systematically and measurably through statistical analysis. The questionnaire used in this study consisted of 19 statement items that had been declared valid and represented various aspects or indicators of teacher perception. Each statement was designed to describe teacher perceptions of the effectiveness, relevance, ease of use, and usefulness of teaching devices in the energy learning process.

The scale used in this questionnaire is a Likert scale with four levels of answer choices, namely: 4 for "strongly agree", 3 for "agree", 2 for "disagree", and 1 for "strongly disagree". This scale is used to facilitate the interpretation of the tendency of teacher attitudes or perceptions towards each statement in the questionnaire. Each statement in the questionnaire is arranged based on predetermined indicators and listed in the instrument grid. The grid aims to ensure that all indicators of teacher perception. The grid of the teacher perception questionnaire instrument is shown in table 1.

Table 1. Grid of Teacher Perception Questionnaire Instruments for the Development of Citizenship in Science Learning Tools Integrated with Science, Technology, and Society

Aspect	Variables	No. Statement Items
Science Teacher Perception	Critical Thinking Skills	1,2,3,4,5
	Science Process Skills	6,7,8,9,10,11,12,13,14,15,16
	Curiosity Character	17,18,19
Total		19

The categories of teacher perception questionnaires regarding the development of citizenship in science learning tools can be seen in Table 2 below.

Table 2. Categories of Teacher Perception Questionnaire on the Development of Citizenship in Science Learning Tools

Category	Variable Interval		
	Critical Thinking Skills	Science Process Skills	Character Curiosity
Strongly Disagree	5.00-8.75	11.00-19.25	3.00-5.25
Don't agree	8.76-12.50	19.25-27.50	5.26-7.50

Agree	12.50-16.25	27.51-35.75	7.51-9.75
Strongly agree	16.26-20.00	35.76-44.00	9.76-12.00

Meanwhile, in-depth interviews were conducted with several teachers selected as informants, with the aim of further exploring their direct experiences, understandings, and reflections during the use or assessment of the developed learning devices. Through these interviews, researchers can obtain more detailed and contextual qualitative information, which cannot be fully described through questionnaire data. The combination of quantitative data from questionnaires and qualitative data from interviews is expected to provide a complete picture of teacher perceptions, both in terms of numbers and from the narrative side of teacher experiences. The outline of the teacher interview guide instrument for learning devices is shown in Table 3 below.

Table 3. Teacher Interview Guide Instrument Grid

Variables	Indicator	No Statement
Teachers' Perceptions of Students' Critical Thinking Skills	Basic Clarification	1
	Basic Support	2
	Inference	3
	Further Clarification	4
	Strategy and Tactics	5
Teachers' Perceptions of Students' Science Process Skills	Observation	6
	Classification	7
	Communication	8
	Measurement	9
	Designing Experiments	10
	Analyzing Experiments	11
	Conducting Experiments	12
	Collecting and Processing Data	13
	Prediction	14
	Creating a Data Table	15
	Conclusion	16
Teachers' Perceptions of Students' Curiosity Characteristics	Students ask teachers or friends about the lesson material	17
	Students try to find learning resources about the concepts being studied.	18
	Students ask about something related to the subject matter but outside of what is discussed in class.	19
	Total	19

Data analysis technique

In this study, data analysis techniques were carried out using two approaches, namely descriptive statistical analysis for quantitative data, and qualitative analysis for non-numerical interview data. For questionnaire data collected from teacher perceptions, researchers used descriptive statistical methods to obtain an overview of the tendency of teacher perceptions (Amrhein et al., 2019; Astalini et al., 2021). This analysis includes calculating the percentage, average value (mean), mode, and distribution of scores for each item in the questionnaire. By using descriptive statistics, researchers can see the extent to which teachers agree or disagree with statements related to the effectiveness, ease, and usefulness of the learning tools that have been prepared. The results of this analysis provide a quantitative basis that can help interpret the extent to which the learning tools are accepted by teachers.

Meanwhile, qualitative data obtained through interviews were analyzed using thematic analysis techniques based on the stages in qualitative analysis, namely: data reduction, data presentation, and drawing conclusions. In the data reduction stage, researchers sort and simplify information from interview results that are considered relevant to the focus of the study. Furthermore, data presentation is carried out in the form of narratives or important quotes from respondents that represent a particular theme. The final stage is drawing conclusions, namely identifying patterns, tendencies, or important findings from teachers' answers that can be used to support or enrich the results of quantitative analysis.

RESULTS AND DISCUSSION

A. Qualitative Results

1. Results of Initial Observations of Teachers' Needs for Learning Tools

The initial study was conducted through observation and informal discussions with science teachers in several schools that were the subjects of the study (Irawati & Saifuddin, 2018). The results of the observation showed that most teachers had an urgent need for learning tools that not only focused on cognitive aspects, but were also able to develop the values of social concern, environmental responsibility, and critical thinking skills of students. Teachers said that so far the learning tools used tended to be theoretical and had not touched on many contextual aspects that were relevant to students' daily lives.

In addition, teachers also revealed that energy material is often taught separately from the social and technological contexts that accompany it. This causes students to be less able to see the relationship between the scientific concepts they learn and the realities of life in society. Therefore, teachers feel the need for learning tools that can integrate scientific materials with current issues such as energy utilization, sustainable technology, and their impacts on society and the environment. They hope that these tools can encourage students to think reflectively and act as citizens who are aware of their role in maintaining the sustainability of energy and the environment.

From a technical perspective, teachers also highlighted the importance of the availability of systematically arranged devices, complete with student worksheets, learning implementation instructions, and reflection and discussion guides that can stimulate active student involvement. Adaptive and flexible devices with school conditions are also the hope of teachers, considering that not all schools have adequate facilities and infrastructure, especially in terms of digital media or laboratories.

Overall, the results of this initial study show that teachers are in dire need of learning tools that not only support students' achievement of basic competencies, but also shape their character and social awareness. Citizenship in Science- based tools integrated with the STS approach are considered a potential solution to answer these needs, because they are considered capable of providing a more contextual, relevant, and meaningful learning experience.

2. Results of teacher interviews regarding teacher perceptions of the learning tools that have been developed.

Conducting interviews with teachers to determine their perceptions of learning tools is a very important step in assessing the extent to which the tools are effective and relevant to be implemented in the classroom. As parties who play a direct role in the learning process, teachers have real experience in observing how students respond to the materials and methods used. Therefore, interviews provide more in-depth information about the ability of learning tools to encourage students to think critically, foster curiosity, and develop science process skills.

In addition to providing an overview of the success of the device in achieving learning objectives, interviews also serve as a tool to explore various challenges faced by teachers during the implementation process. These challenges can be in the form of limited facilities, lack of time, or obstacles to students' understanding of certain concepts. This information is very useful as input for evaluating, improving, and developing learning devices in a better direction and in accordance with needs in the field. Thus, interviews are an important component in obtaining a complete and realistic picture of the implementation of Citizenship in Science- based learning that is integrated with the Science, Technology, and Society approach. The following presents the results of interviews regarding teacher perceptions of the learning devices that have been developed, which can be seen in Table 4.

Table 4. Teachers' perceptions of the learning tools that have been developed

No	Aspect	Brief Description of Findings
1	Critical thinking	All teachers agreed that the learning tools were able to develop the five aspects of critical thinking: Elementary Clarification, Basic Support, Inference, Advanced Clarification, and Strategy and Tactic. Students were trained to

		understand basic concepts, draw conclusions, evaluate arguments, and design real solutions related to energy issues.
2	Science Process Skills	Teachers assessed that this device greatly supports the development of science process skills such as: observation, classification, communication, measurement, designing and conducting experiments, data analysis, and scientific prediction. Students are also active in creating data tables and drawing conclusions based on scientific evidence.
3	Curiosity Character	The device encourages students to actively ask questions, both to teachers and friends, to search for learning resources independently, and to relate the material to phenomena outside the classroom. Project-based and inquiry-based learning makes students more critical and explorative. All teachers stated that students' curiosity increased during the learning process.

Based on the interview results summarized in the table, it is known that teachers have a very positive perception of the ability of learning devices in developing students' critical thinking skills. The five critical thinking aspects of Elementary Clarification, Basic Support, Inference, Advanced Clarification, and Strategy and Tactic appear to be well integrated in the learning scenario. The teacher said that students are not only invited to understand the basic concepts of energy, but also invited to think deeply, draw conclusions based on data, and analyze and evaluate arguments that arise in class discussions. The most prominent is how students are trained to design real solutions to energy problems in everyday life, such as saving electricity at home. This shows that learning devices not only emphasize the cognitive aspect, but also direct students to become citizens who think reflectively and are responsible for science and technology issues.

In addition to critical thinking, teachers also highlighted the success of the device in developing students' science process skills (Casquilho et al., 2023a, 2023b; Worachak et al., 2023). Learning activities are designed to directly engage students in scientific activities such as observation, classification, measurement, and experimentation. Students are not only recipients of information, but also active participants in the scientific process through direct practice in the classroom. They are trained to design simple experiments, collect and process data, and draw conclusions based on observation results. These skills are essential to prepare students to face global challenges that increasingly demand scientific thinking skills and data-based problem solving. In the context of science education, this approach also forms a deeper conceptual understanding and makes the learning process more meaningful because it is directly related to students' real lives.

The character of students' curiosity also received special attention from teachers. The interview results showed that Citizenship-based science learning succeeded in creating a classroom atmosphere that encouraged students to actively ask questions, explore material further, and connect learning topics with phenomena outside the classroom. Teachers noted that students were encouraged to seek additional information from various sources, including the internet and the surrounding environment, especially when working on research-based projects. This attitude is an important indicator of meaningful student-centered learning, where students are internally motivated to learn and understand issues that are relevant to their lives. With increased curiosity, students not only expand their knowledge but also develop the confidence to engage in critical discussions and express opinions or questions. This is in line with the main objective of Citizenship-based science learning, namely to form a young generation that is critical, caring, and active in facing social and environmental challenges. The following presents the quantitative results of teacher perception data on the learning tools developed.

B. Quantitative Results

The following describes the results of teachers' perceptions of the learning tools developed on the variables of critical thinking skills, science process skills, and curiosity character. The description of the results of teachers' perceptions in Jambi Province on the variable of students' critical thinking skills is described in the following table 5.

Table 5. Description of Teachers' Perceptions of Students' Critical Thinking Ability Variables

Interval	Category	%	Mean	Med	Max	Min
5.00-8.75	Strongly Disagree	0	3.08	3.00	4.00	2.00

8.76-12.50	Don't agree	11.1
12.50-16.25	Agree	66.7
16.26-20.00	Strongly agree	22.2

Based on the results of the data analysis obtained, it can be concluded that teachers' perceptions of students' critical thinking ability variables generally show a positive tendency. Most teachers, namely 66.7%, gave responses in the Agree category, which indicates that they believe that this learning device is able to encourage students to develop critical thinking skills, especially in understanding the concept of energy in depth. In addition, there are 22.2% of teachers who stated Strongly Agree, which means they have a very strong belief in the effectiveness of this device in shaping students' more analytical and reflective thinking. Conversely, only 11.1% of teachers are in the Disagree category, and no teachers stated Strongly Disagree. These findings indicate that the majority of teachers gave a positive response to the use of this learning device in building students' critical thinking skills.

In terms of statistical analysis, the average value (mean) obtained was 3.08, with a median value of 3.00. This indicates that teachers' perceptions are relatively consistent in the Agree category. The highest (maximum) value recorded was 4.00 or Strongly Agree, while the lowest (minimum) value was 2.00 or disagree. The variation in scores indicates that although most teachers support this learning approach, there are still differences of opinion among them. However, in general, the positive tendency still dominates.

Table 6. Description of Teachers' Perceptions on Students' Science Process Skills Variables

Interval	Category	%	Mean	Med	Max	Min
11.00-19.25	Strongly Disagree	0	3.18	3.00	4.00	3.00
19.25-27.50	Don't agree	0				
27.51-35.75	Agree	55.6				
35.76-44.00	Strongly agree	44.4				

The results of the data analysis showed that teachers' perceptions of students' critical thinking skills were very positive. Most teachers gave responses in the Agree (55.6%) and Strongly Agree (44.4%) categories. This indicates that teachers consider Citizenship in Science -based learning tools integrated with the Science, Technology, and Society (STS) approach to be able to improve students' critical thinking skills, especially in understanding energy material. No teachers gave responses in the Disagree or Strongly Disagree categories, which means that this tool is fully accepted by teachers as an effective learning tool in encouraging students to think analytically and reflectively about energy and technology issues in everyday life.

Statistically, the mean value of 3.18 and the median value of 3.00 indicate that teachers' perceptions are generally in the Agree category. The maximum value obtained is 4.00 (Strongly Agree), and the minimum value is 3.00 (Agree), which indicates that none of the teachers gave a negative response to this learning tool. In other words, all teachers involved in this study agreed that the Citizenship in Science approach integrated with STS can help students develop their critical thinking skills. This finding provides a positive indication of the implementation of this learning tool, because it is considered capable of supporting a deeper and contextual understanding of the concept of energy.

Table 6. Description of Teachers' Perceptions on the Character Variable of Students' Curiosity

Interval	Category	%	Mean	Med	Max	Min
3.00-5.25	Strongly Disagree	0	3.25	3.00	4.00	2.00
5.26-7.50	Don't agree	11.1				
7.51-9.75	Agree	55.6				
9.76-12.00	Strongly agree	33.3				

Based on the results of data analysis, it is known that teachers' perceptions of students' critical thinking skills in the context of Citizenship in Science -based learning integrated with the Science, Technology, and Society (STS) approach show a positive tendency. Most teachers are in the Agree category (55.6%), followed by the Strongly Agree category (33.3%). This indicates that the majority of teachers acknowledge that this learning tool contributes to improving students' critical thinking skills, especially in understanding issues related to energy and technology. Meanwhile, only 11.1% of teachers are in the Disagree category, and none of the teachers chose the Strongly Disagree category. This shows that although there is still a little doubt, in general the teachers consider this learning tool to be quite effective in helping students think more analytically and reflectively about issues related to science and technology in everyday life.

From the statistical calculation results, the average value (mean) was obtained at 3.25 and the median value was 3.00, which indicates that teachers' perceptions are relatively stable in the Agree category. The maximum value recorded was 4.00 (Strongly Agree), while the minimum value was 2.00 (Disagree), which means that there is little variation in teachers' views on this tool, although most responses remain positive. This finding strengthens previous results stating that the Citizenship in Science approach integrated with STS is able to provide real benefits for students, especially in developing their critical thinking skills contextually.

This study is in line with the findings of (Zendrato & Sarumaha, 2018)which also examined teachers' perceptions of learning devices. The main difference lies in the scope of the schools studied if the previous study only involved one school, then this study was conducted in five different schools to obtain a broader and more representative picture. This allows researchers to see the consistency of the application of learning devices in various school contexts. However, the development of learning devices is still limited to energy material only. Therefore, it is recommended that further research expand the development to other science topics so that the benefits can be more comprehensive and applicable in the science curriculum.

The implications of this study indicate that the developed learning tools are able to encourage the growth of a culture of critical and explorative thinking in students. With the stimulus to ask questions, seek additional information, and relate learning concepts to everyday life, students become more independent in learning and more active in participating in class discussions. This not only strengthens their understanding of the learning material, but also forms a scientific attitude that is important for everyday life and the future. In addition, teachers also have an important role to continue to adjust learning strategies that foster students' curiosity so that the learning process remains dynamic and relevant to the times.

The novelty of this learning tool lies in the Citizenship in Science approach that not only focuses on mastering scientific concepts, but also instills social awareness and responsibility in science-based decision making. By integrating the Science, Technology, and Society (STS) perspective, this tool encourages students to think critically about the impact of science in real life, such as issues of energy conservation and environmental sustainability. Furthermore, active and exploration-based learning methods provide space for students to build their own understanding through discussion, experimentation, and independent information seeking, so that the learning process becomes more contextual, meaningful, and empowering.

CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the Citizenship in Science- based learning device integrated with the Science, Technology, and Society approach is effective in making students have critical thinking skills, science process skills, and students' curiosity character. Teachers' perceptions of this device are very positive, indicated by the dominant responses in the agree and strongly agree categories. Through exploratory activities, discussions, experiments, and information gathering from various sources, students become more active, reflective, and able to link scientific concepts with real issues in everyday life, especially related to energy. This device is also able to encourage the formation of scientific attitudes and social awareness in science-based decision making. Thus, this device has great potential to be applied widely to create science learning that is contextual, meaningful, and relevant to the challenges of the times.

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REFERENCES

Adamou, A., Georgiou, Y., Paraskeva-Hadjichambi, D., & Hadjichambis, A. C. (2021). Environmental citizen science initiatives as a springboard towards the education for environmental citizenship: A systematic literature review of empirical research. In *Sustainability (Switzerland)* (Vol. 13, Issue 24). https://doi.org/10.3390/su132413692

Alimin, A., & Effendi, H. (2020). Pengembangan Modul Pembelajaran Berbasis Daring Pada Mata Diklat Instalasi Penerangan Listrik Kelas XI di Sekolah Menegah Kejuruan. *Ranah Research : Journal of Multidisciplinary Research and Development*, *2*(4), 133–138. https://jurnal.ranahresearch.com/index.php/R2J/article/view/314

Amrhein, V., Trafimow, D., & Greenland, S. (2019). Inferential Statistics as Descriptive Statistics: There Is No Replication Crisis if We Don't Expect Replication. *American Statistician*, *73*(sup1), 262–270. https://doi.org/10.1080/00031305.2018.1543137

Arent, E., Sumarmi, Utomo, D. H., & Ruja, I. N. (2020). Improving Students' Environmental Care Character Through Positive Character Camp (Pcc) Program. *Journal for the Education of Gifted Young Scientists*, *8*(4), 1329–1343. https://doi.org/10.17478/jegys.771681

Astalini, A., Darmaji, D., Kurniawan, D. A., & Wulandari, M. (2021). Students' Perceptions of the Physics-Mathematical E-Module on Partial Differential Material Based on Gender. *Jurnal Pendidikan Dan Pengajaran*, *54*(3), 529–538. https://doi.org/10.23887/jpp.v54i3.35338

Azhari, B., & Safrina, K. (2022). The Development Of Learning Tools For Students With Comorbid Dyscalculia-Dyslexia. *Jurnal Ilmiah Peuradeun*, *10*(3). https://doi.org/10.26811/peuradeun.v10i3.724

Bosch, J., Staffell, I., & Hawkes, A. D. (2018). Temporally explicit and spatially resolved global offshore wind energy potentials. *Energy*, *163*. https://doi.org/10.1016/j.energy.2018.08.153

Casquilho, J. P., Sinaga, F. P., Septiani, N., Oktavia, S. W., Qoidah, N. N., & Rini, E. F. S. (2023a). The Influence Of Critical Thinking Ability On Students' Science Learning Outcomes. *Edufisika: Jurnal Pendidikan Fisika*, *8*(2), 116–124. https://doi.org/10.59052/edufisika.v8i2.24865

Casquilho, J. P., Sinaga, F., Septiani, N., Oktavia, S. W., Qoidah, N. N., & Rini, E. F. S. (2023b). Pengaruh Kemampuan Berpikir Kritis Terhadap Hasil Belajar IPA Siswa. *EduFisika: Jurnal Pendidikan Fisika*, *8*(2). https://doi.org/10.59052/edufisika.v8i2.24865

Chanchangi, Y. N., Adu, F., Ghosh, A., Sundaram, S., & Mallick, T. K. (2023). Nigeria's energy review: Focusing on solar energy potential and penetration. In *Environment, Development and Sustainability* (Vol. 25, Issue 7). https://doi.org/10.1007/s10668-022-02308-4

Dewi, N. P. L. C., & Atun, S. (2019). The Effect Of Science Technology Society (STS) Learning On Students' Science Process Skills. *Jurnal Ilmiah Peuradeun*, *7*(1). https://doi.org/10.26811/peuradeun.v7i1.288

Elvanisi, A., Hidayat, S., & Fadillah, E. N. (2018). Analisis keterampilan proses sains siswa sekolah menengah atas Skills analysis of science process of high school students. *Jurnal Inovasi Pendidikan IPA*, *4*(20), 245–252. https://journal.uny.ac.id/index.php/jipi/article/view/21426/12225

Fauzi, A. (2024). Perilaku boros energi listrik di kalangan siswa SDN Pacar Keling V Surabaya. *Jurnal Janacitta*, *12*(1), 112–125. https://jurnal.unw.ac.id/index.php/janacitta/article/view/3314/2428

Fikriyah, A. N., & Sukmawati, W. (2022). Pengembangan Media Pembelajaran Learning Management System (LMS) Berbasis Moodle pada Materi Perubahan Energi. *Ideas: Jurnal Pendidikan, Sosial, Dan Budaya*, *8*(3), 799. https://doi.org/10.32884/ideas.v8i3.869

Fransiska, L., Subagia, I. W., & Sarini, P. (2018). Pengaruh Model Pembelajaran Guided Discovery Terhadap Keterampilan Proses Sains Siswa Smp Negeri 3 Sukasada. *Jurnal Pendidikan Dan Pembelajaran Sains Indonesia (JPPSI)*, *1*(2), 68. https://doi.org/10.23887/jppsi.v1i2.17214

Gobo, G., & Marcheselli, V. (2023). Science, Technology and Society: An Introduction. In *Science, Technology and Society: An Introduction*. https://doi.org/10.1007/978-3-031-08306-8

González-García, F. J., Blanco-López, Á., España-Ramos, E., & Franco-Mariscal, A. J. (2021). The Nature of Science and Citizenship: a Delphi Analysis. *Research in Science Education*, *51*(3). https://doi.org/10.1007/s11165-018-9817-5

Hoover, E. (2020). Whose citizenship in “citizen science”? In *Toxic truths*. https://doi.org/10.7765/9781526137005.00027

Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022). Sustainable development research in Eurasia Journal of Mathematics, Science and Technology Education: A systematic literature review. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(5). https://doi.org/10.29333/ejmste/11965

Irawati, H., & Saifuddin, M. F. (2018). Analisis Kebutuhan Pengembangan Bahan Ajar Mata Kuliah Pengantar Profesi Guru Biologi Di Pendidikan Biologi Universitas Ahmad Dahlan Yogyakarta. *Bio-Pedagogi*, *7*(2), 96. https://doi.org/10.20961/bio-pedagogi.v7i2.27636

Kamar, K., Asbari, M., Purwanto, A., Nurhayati, W., & Sudiyono, R. N. (2020). Membangun Karakter Siswa Sekolah Dasar Melalui Praktek Pola Asuh Orang Tua Berdasarkan Genetic Personality. *Jurnal Inovasi Pembelajaran*, *6*(c), 75–86. https://doi.org/10.22219/jinop.v6i1.10196

Khusniati, M., Heriyanti, A. P., Aryani, N. P., Fariz, T. R., & Harjunowibowo, D. (2023). Indigenous science constructs based on Troso woven fabric local wisdom: a study in ethnoscience and ethnoecology. *Journal of Turkish Science Education*, *20*(3), 549–566. https://doi.org/10.36681/tused.2023.031

Kumar, A., Krishnamurthi, R., Bhatia, S., Kaushik, K., Ahuja, N. J., Nayyar, A., & Masud, M. (2021). Blended Learning Tools and Practices: A Comprehensive Analysis. *IEEE Access*, *9*. https://doi.org/10.1109/ACCESS.2021.3085844

Madu, B. C. (2020). Scientific Explanation of Phenomenon, Imagination and Concept Formation as Correlates of Students' Understanding of Physics Concepts. *Journal of Natural Sciences Research*, *11*(16), 17–28. https://doi.org/10.7176/jnsr/11-16-03

Maison, M., Lestari, N., & Widaningtyas, A. (2019). Identifikasi Miskonsepsi Siswa Pada Materi Usaha Dan Energi. *Jurnal Penelitian Pendidikan IPA*, *6*(1), 32. https://doi.org/10.29303/jppipa.v6i1.314

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual technologies trends in education. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(2), 469–486. https://doi.org/10.12973/eurasia.2017.00626a

Mutlu, A. (2020). Evaluation of students' scientific process skills through reflective worksheets in the inquiry-based learning environments. *Reflective Practice*, *21*(2), 271–286. https://doi.org/10.1080/14623943.2020.1736999

Nielsen, J. W., Nigg, D. W., & Norman, D. R. (2018). Extension of the advanced test reactor operating envelope via enhanced reactor physics validation techniques. *Nuclear Technology*, *201*(3), 228–246. https://doi.org/10.1080/00295450.2017.1356647

Nissen, J. M., Her Many Horses, I., & Van Dusen, B. (2021). Investigating society's educational debts due to racism and sexism in student attitudes about physics using quantitative critical race theory. *Physical Review Physics Education Research*, *17*(1), 10116. https://doi.org/10.1103/PhysRevPhysEducRes.17.010116

Novas, N., Garcia, R. M., Camacho, J. M., & Alcayde, A. (2021). Advances in solar energy towards efficient and sustainable energy. *Sustainability (Switzerland)*, *13*(11). https://doi.org/10.3390/su13116295

Nugraheni, A. A., & Wuryandani, W. (2018). The Effect Of Science Technology And Society Models On Science Process Skills. *Informasi*, *48*(2). https://doi.org/10.21831/informasi.v48i2.21359

ÖZDEN, M. (2020). Science Education for Citizenship: A Case Study. *Anadolu Journal of Educational Sciences International*, *10*(1). https://doi.org/10.18039/ajesi.682020

Pamungkas, A., Subali, B., & Linuwih, S. (2017). Implementasi model pembelajaran IPA berbasis kearifan lokal untuk meningkatkan kreativitas dan hasil belajar siswa. *Jurnal Inovasi Pendidikan IPA*, *3*(2), 118. https://doi.org/10.21831/jipi.v3i2.14562

Planinic, M., Boone, W. J., Susac, A., & Ivanjek, L. (2019). Rasch analysis in physics education research: Why measurement matters. *Physical Review Physics Education Research*, *15*(2), 20111. https://doi.org/10.1103/PhysRevPhysEducRes.15.020111

Rosidin, U., Maulina, D., & Suane, W. (2020). Pelatihan Pengelolaan Laboratorium Dan Penggunaan Alat Peraga IPA Bagi Guru-Guru IPA Di SMP/MTS Se-Kota Bandar Lampung. *Jurnal Pengabdian Masyarakat MIPA Dan Pendidikan MIPA*, *4*(1), 52–60. https://doi.org/10.21831/jpmmp.v4i1.34075

Schoonenboom, J. (2019). A Performative Paradigm for Mixed Methods Research. *Journal of Mixed Methods Research*. https://doi.org/10.1177/1558689817722889

Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society Interface*, *4*(15). https://doi.org/10.1098/rsif.2007.0213

Supriadi, M., & Hignasari, L. V. (2019). Pengembangan Media Virtual Reality Pada Muatan Pelajaran IPA Kelas VI Sekolah Dasar. *JTP - Jurnal Teknologi Pendidikan*, *21*(3), 241–255. https://doi.org/10.21009/jtp.v21i3.13025

Tiara, S. K., & Sari, E. Y. (2019). Analisis Teknik Penilaian Sikap Sosial Siswa Dalam Penerapan Kurikulum 2013 Di Sdn 1 Watulimo. *EduHumaniora | Jurnal Pendidikan Dasar Kampus Cibiru*, *11*(1), 21–30. https://doi.org/10.17509/eh.v11i1.11905

Ubaidillah, U., & Efendi, R. N. (2022). Perbandingan Antara Karakter Toleransi Terhadap Perkembangan Budaya Lokal Atau Ciri Khas Suatu Daerah Pada Muatan Pembelajaran IPS di Sekolah Dasar. *Journal of Basic Education Research*, *3*(2), 48–56. https://doi.org/10.37251/jber.v3i2.254

Wahlund, M., & Palm, J. (2022). The role of energy democracy and energy citizenship for participatory energy transitions: A comprehensive review. In *Energy Research and Social Science* (Vol. 87). https://doi.org/10.1016/j.erss.2021.102482

Widodo, B., Muchtar, S. Al, & AR, E. D. (2021). Strengthening Digital Citizenship through Citizenship Education Based on Science, Technology and Society in Era 4.0. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, *4*(3). https://www.bircu-journal.com/index.php/birci/article/view/2153

Wilcox, B. R., & Lewandowski, H. J. (2018). A summary of research-based assessment of students' beliefs about the nature of experimental physics. *American Journal of Physics*, *86*(3), 212–219. https://doi.org/10.1119/1.5009241

Worachak, S. P., Damnoen, P. S., Hong, D. A. C., & Putri, S. E. (2023). Analysis of critical thinking skills in problem-based learning and inquiry learning models. *EduFisika: Jurnal Pendidikan Fisika*, *8*(3), 286–299. https://doi.org/10.59052/edufisika.v8i3.29442

Wulandari, A. (2020). Implementation of the 2013 Curriculum Based on a Scientific Approach (Case Study at SD Cluster II Kintamani). *International Journal of Elementary Education*, *4*(3), 422. https://doi.org/10.23887/ijee.v4i3.28172

Yoon, J., & Olsen, A. (2023). Promoting Science Affinities through a Video Project in a Science, Technology, and Society (STS) Learning Approach. *International Journal of Education in Mathematics, Science and Technology*, *11*(4). https://doi.org/10.46328/ijemst.3049

Zendrato, W., & Sarumaha, A. (2018). Persepsi Guru Mata Pelajaran Peminatan Sosial Terhadap Implementasi Kurikulum 2013 Revisi Di Sma Negeri 1 Telukdalam. *Jurnal Education*

Development, *6*(1), 52–59. https://doi.org/10.37081/ed.v6i1.654