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Analysis of teachers' understanding of epistemic beliefs and implications for learning science based-on SSI

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Abstract

The 21st century is becoming a century of globalization. Still, the 2022 PISA survey states that Indonesian students have low science literacy, ranked 64 out of 81 countries. Hence, it is necessary to develop scientific knowledge and epistemic beliefs not to be left behind by the times. This study aims to analyze the characteristics and level of teacher understanding of epistemic beliefs and implications for learning science based on socio-scientific issues. The research used a qualitative study, and data were collected through interviews, observations, and tests. Eight science teachers responded to be analyzed using the constant comparison method by applying Nvivo media to support data analysis. The results showed relatively few teachers have an epistemic understanding of science learning. Hence, teachers generally believe that scientific inquiry must begin with questions and that the perceptions and biases of researchers strongly influence scientific conclusions. The novelty of this research lies in the research design and efforts that can be applied to improve the epistemic understanding of teachers, namely by presenting programs for pre-service and in-service teachers, providing regular workshops, and offering internships or research experiences to science teachers.

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Introduction

The world community is currently facing various changes in the 21st century. The global community, including Indonesian society, has developed into a new era where changes occur faster in various fields, including education. Due to the rapid changes, the demands of the times are increasingly competitive(Tri et al., 2019). Therefore, the implementation of science is needed in learning activities, especially in science education. Science education in Indonesia is one of the main concerns in science because it contains many elements of application activities in everyday life to introduce nature to students. According to Agung, science education is very important for students in facing the challenges of the 21st century (Agung et al., 2022). Society uses scientific knowledge and skills to evaluate every decision-making process, including technological, social, and economic development.

Science education has an important role in the education system and to be able to measure the level of education of students can be seen through the results of the world survey through the Program Internationale for Student Assessment (PISA) survey. The data results from the PISA survey can provide an overview of the level of understanding and literacy of

students in Indonesia. The results of the 2022 Programme Internationale for Student Assessment (PISA) survey, stated that Indonesian students have low science literacy because they are ranked 64 out of 81 countries that the Ministry of Education and Culture seeks curriculum changes so that science learning can realize increased understanding and literacy (Vasalampi et al., 2023).

The curriculum change from the revised K-13 curriculum to the independent curriculum is an effort made by the Ministry of Education, Culture, and Research to change the Indonesian learning system (Javadikasgari et al., 2018; Suyitno et al., 2023). These efforts allowed students to learn calmly, comfortably, enjoyably, stress-free, and pressure-free to explore students natural talents and improve science literacy and understanding. Curriculum changes are made to overcome various obstacles experienced when implementing the revised K-13 Curriculum because the revised K-13 curriculum causes teachers to focus more on administrative preparation before starting learning, provides a considerable academic burden to students, and teachers' lack of understanding of science knowledge concepts in the curriculum (Ahmed Alismail, 2023; Widyastuti, 2020). Dramatically affects the learning process that will be carried out so that from the various problems caused, a new curriculum is formalized to support learning to be more effective, efficient, and able to support learning loss recovery after the COVID-19 pandemic (Handayani, 2020; Iqbal & Sari, 2022). The changes that occur are significant enough to affect the student learning process with the assistance of a teacher.

Teachers and students become an essential element in the sustainability of science learning by going through the process of understanding the theory to be directly involved in implementing learning activities in the classroom to everyday life so that teachers are required to direct and provide understanding related to existing facts. Meanwhile, students must understand how the basis, reasoning process, and scientific action are specifically in the core concepts in the discipline and across science disciplines, supplying chances for pupils to learn about the cosmos while applying science and the scientific method. Requires teachers to have a deep understanding of the epistemic foundations of science learning and a strong knowledge of science concepts and understanding. Previous research revealed that "teachers will find it difficult to incorporate science activities into the lessons they deliver unless they are confident that they understand the activities to be carried out." Therefore, some scholars have formulated theories regarding a framework for improving teachers' professional development and their epistemic comprehension of teaching science (Lunn et al., 2021). When teachers understand the eight epistemic procedures related to the knowledge development process, they can build classroom environments and curricula that bring science learning closer to comprehension for students.

Background of the Study

Science learning must develop science literacy; one crucial aspect is the ability to utilize scientific understanding to make decisions and solve problems related to social issues (Pratiwi et al., 2019). Socio-scientific issues (SSI) based understanding efforts are an effort given as an approach to learning in order to cultivate student's ability to explore problems to be further developed in various fields of life so that they are significantly able to represent social issues related to science from a community perspective (Rifa et al., 2022). Introducing Socio-Scientific Issue-based science learning to all students is essential to prove the application of

social problems in the realm of science education in Indonesia. In order to gain scientific understanding, understanding how natural science is created, communicated, and demonstrated is essential, in addition to using scientific practices, methods, and content. In preparing students for the application of life in society and enabling them to make decisions on socio-scientific issues, science education should emphasize more on science knowledge, including knowledge of the nature of science and scientific knowledge (Espeja & Lagarón, 2015; S. Rahayu, 2019). They explained the importance of epistemic beliefs, considering that students who are knowledgeable in science must continue to the next level with a rich understanding of knowledge related to the epistemology of science.

Epistemic Understanding for Socio-Scientific Issue-based Science Learning

Science learning activities that involve students directly with socio-scientific issue-based teaching methods can be applied to help students develop a deep understanding of the implications of learning activities by providing opportunities to find out how science in social life is applied. The study proves that students who participate in socio-scientific issue-based learning activities will have a better epistemic understanding of science, so the more time spent studying science, the better the results of students' understanding of science epistemic beliefs (Areepattamannil et al., 2020). Implementing classroom learning activities and teachers' epistemic understanding of science are two areas in which the Ministry of Education, Culture, Research, and Technology (MoECT) has long been interested in conducting research.

Teachers' Epistemic Understanding of the Implications of Socio-Scientific Issue (SSI)-Based Science Learning

This research explains that teachers need knowledge to integrate argumentation into the science learning process, so that teachers can develop learning models to facilitate student understanding in classroom learning activities (Ludyasari et al., 2022; Nursela et al., 2022). In previous research, the results of the analysis were obtained related to several things that affect the level of epistemic beliefs and it has been explained that the level of epistemic beliefs of a teacher is influenced by several indicators, namely the level of education and life experience. If the level of education is high and has adequate life experience, the epistemic beliefs tend to be higher and more complex, this applies vice versa (Justin & Abhiyoga, 2021; Sugiyono, 2016). In addition to knowing the educational background and experience, there are several things that need to be done to determine the level of epistemic beliefs and become novelty in this study, namely located on indicators and efforts that can be applied in increasing teacher epistemic beliefs.

This study uses three main indicators, namely exploring, understanding, and analyzing. As for the efforts that can be applied to improve teachers' epistemic understanding, namely by presenting programs for pre-service and in-service teachers, providing regular workshops, and offering internships or research experiences to science teachers. it is important to do because it can improve teacher professionalism in shaping a teaching system that can lead students to a more directed understanding based on a clear foundation, namely the epistemic beliefs of science learning. Considering this, teachers can intensify the development of epistemic knowledge and exploratory studies. Exploratory study activities are carried out to build basic cognitive understanding of teachers as a foundation for understanding the cognitive nature of epistemic knowledge (Guilfoyle et al., 2020; Learning & Didik, 2022).

Method

This research uses a qualitative method, with the data collection process using interviews, observations, and tests directly to science teachers in Ponorogo Regency whose interview results will be analyzed from NVivo and the constant comparison method. This research is exploratory to be able to provide evidence related to various insights into the epistemic knowledge of each teacher so that researchers apply direct data collection and are analyzed using the application in order to provide a high level of data validity from respondents and it is hoped that the direct method can provide honest responses according to their epistemic beliefs (Kite et al., 2020; Nasivo, 2020; Nasrudin, 2022). In the process of carrying out this research using open questions in the form of multiple choices to provide variables to teachers in dealing with a problem, there are questions in the form of descriptions used to determine the teacher's response to the problem presented, and finally questions in the form of socioemotional which are used as indicators of teacher understanding and accuracy in making decisions.

Science Teacher Epistemic Beliefs Research Instrument

Research on teachers' epistemic beliefs is carried out in 8 stages and includes several types of questions related to the epistemic beliefs of teachers (Sari et al., 2019; Suherman et al., 2019). The interview activity began with questions about self-identity and implementation in the learning process applied in the teacher's teaching location school; as many as 13 questions were developed. The next activity uses observation of the teacher's teaching process in the field, and the last activity uses a test by applying 3 indicators, namely exploring, understanding, and analyzing to be able to determine the level of teacher understanding of epistemic beliefs on the theme of natural disasters, where the test contains 6 multiple choice questions, 3 description questions and 6 socioemotional questions that are used as a medium for understanding and analyzing the most appropriate answers from several correct answers. The research process was carried out using several stages, namely in Figure 1 below:

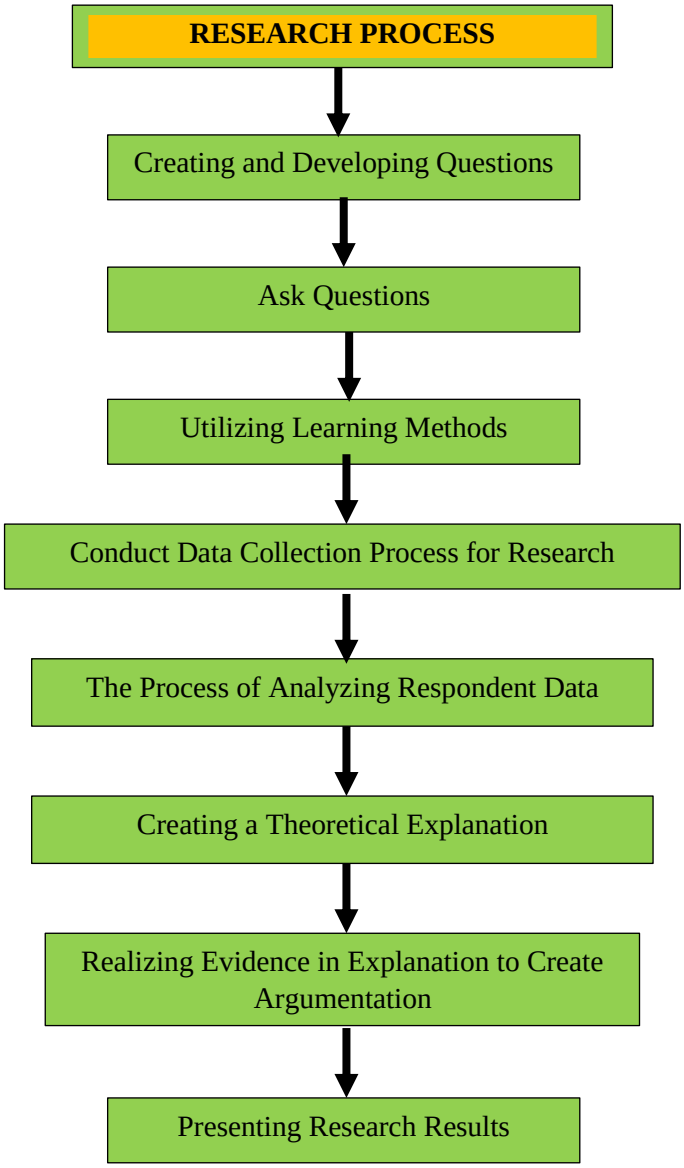

Figure 1. Stages of Teacher Epistemic Belief Survey

This study aims to analyze the characteristics of teachers' understanding of epistemic beliefs by utilizing knowledge that is currently being discussed. This research uses open questions in the form of multiple choices to provide variables to teachers in dealing with a problem. There are questions in the form of descriptions that are used to determine the teacher's response to the problem presented, and finally, questions in the form of socioemotional which are used as indicators of teacher understanding and accuracy in making decisions. In addition, the survey process also provides several questions to produce valid evidence that can be identified in detail. In addition, the survey process also provided several questions to generate valid evidence and be able to be identified in detail. The questionnaire went through various revisions and then focused on collecting data in the form of a survey to teachers going through the teaching phase at the school, as many as 8 science teachers. The analysis results can be seen in Table 1, which contains all the components used in the research activities.

Table 1. Activity Questions for Implementing Science Learning Based on Social Science Issues

Question	Source	Science Learning Implementation Target
Q1. The earthquake caused a lot of damage and losses to the community; how can appropriate and effective efforts be applied in order to anticipate disasters for the long term?	Developed by researchers	Obtaining Evidence
Q2. After such a devastating disaster, an evaluation is needed so that the impact of the disaster can be minimized. How can to minimize material losses and casualties due to the eruption of Mount Merapi?	Developed by researchers	Building Description
Q3. Forest fires are very detrimental to the ecosystem of living things, because the situation will worsen environmental conditions, especially during the dry season. How can we prevent forest fires?	Developed by researchers	Analyzing and Interpreting Data
Q4. what learning media do you use?	Developed by researchers	Using scientific thinking
Q5. What learning model do you use?	Developed by researchers	Developing and Using Models
Q6. What are the obstacles you face when teaching in class?	Developed by researchers	Asking Questions
Q7. What are the results of the learning that you have applied to students? (student activeness in receiving material, etc.)	Developed by researchers	Plan and carry out investigations.
Q8. On average, what is the percentage of students' understanding of the lessons you have delivered?	Developed by researchers	Engage in Argument from Evidence

Participants

Data were collected through interviews, observations, and tests directly from science teachers who teach at the junior high school level in Ponorogo District. A total of eight teachers have completed the research stages completely and thoroughly. In addition, various research information related to teachers has been summarized in Table 2 in detail. Each teacher who has

gone through the analysis process does not have an identity number but uses an initial name that has been approved.

Data Analysis

In the data collection process that has been carried out, the first two research results are obtained with a significant difference between respondents 1 and 2, which is 32% of 6 multiple choice questions, so that it focuses on the main discussion and data concentration (Social et al., n.d.; Widiyatmoko et al., 2022).

Table 2. Demographic Characteristics of Study Participants (n=8)

Gender	87% Female
	13% Male
Ethnicity	**100% Java**
Value Taught	13% Madrasah Aliyah
	37% Junior High School
	50% Madrasah tsanawiyah
Education Level	87% S1 science education
	13% S1 Biology Education

In the data analysis process, intervals are needed to determine the category on the results of data analysis which can be seen in table 3 below:

Table 3. Epistemic Confidence Completion Interval

No	Interval	Category
1.	0-39%	Very Low
2.	40-59%	Low
3.	60-74%	Medium
4.	75-84%	High
5.	85-100%	Very High

Based on Table 2, it is stated that all respondents including teachers have graduated from the undergraduate level (S1), have teaching experience with scientific teaching methods and in accordance with the standards of understanding of science educators. The research process used instruments that have been validated by experts, and data collection was conducted directly. Some research questions will require respondents to not be able to search for answers online as they are required to provide justification for their answers (Hildani & Safitri, 2021; Suprianto, 2019).

Results and Discussion

In the data analysis process, researchers can reveal two critical points based on characteristics related to teachers' epistemic beliefs on the implications for science learning: the first point is science as a research effort to produce research data to answer problems and draw conclusions. Point two is that scientific uncertainty is created due to scientists' perceptions, backgrounds, and biases.

Figure 2, shows the results of wordcloud analysis processed with Nvivo v.12 to determine the frequency of words that often appear in the interview results which are the main

data source. In the figure, it can be seen that there is a large redaction of words which shows that words that are widely discussed globally today are related to the understanding of epistemics. Epistemic understanding greatly affects the performance of teachers in delivering learning to students, so it is necessary to increase epistemic beliefs by every teacher in Indonesia in order to improve the quality of student graduates.

Figure 2. WordCloud

Sub Section 1: IPA As a research effort in order to produce analytical data to be able to answer problems and draw conclusions

The ensuing declaration was formulated to encompass an all-encompassing perspective of educators' views regarding the scientific goal, which is to understand science as a human pursuit that generates specific data in order to provide answers to queries and make informed conclusions (Setiawan, 2019). A declaration represented by the codes assigned to each question: This assertion offers some broad generalizations about the comprehension of epistemic beliefs by teachers in our data set. The following is a description of the sources of knowledge obtained:

Human effort

Using the term "human effort" means that the teachers' responses show that the majority view science as a human effort from habits carried out by humans influenced by various backgrounds, experiences, and the results of an effort. The results of the various ideas obtained from the teachers' responses to the researcher's questions are substantial evidence that needs to be considered. To answer the first question related to earthquakes and natural disasters that occur in the social environment, the teacher stated that knowing information related to mitigation can minimize disasters due to disasters (Arifuddin et al. et al., 2019). The process to avoid and prevent earthquake disasters is to avoid earthquake-prone areas for house construction and build houses with strong and sturdy foundations according to standards so that the house remains safe as the number 1 asset.

Using Data

Teachers who took part frequently discussed the idea of incorporating data into different questions. Numerous data-related codes, such as those for data collection, analysis, identification, and use in the creation of understanding and explanations, reflect this trend. The

following quotations highlight how important it is for teachers to use data in science lessons: "By collecting data from various experiments, then analyzing it and looking for patterns" and "I believe that data analytics can contribute to helping us find patterns in data and therefore phenomena".

Research Objectives

Teachers regard targeted research as the goal and result of scientific analysis. Data analysis revealed that there is still a feeling that science is based on inquiry. The inquiry process will apply to the Experimentation activity, which is the primary reference for scientists in creating new knowledge, as shown in the following statement. "Hypotheses in the realm of natural disasters that can be analyzed must go through various designs by applicable regulations."

Responses to Questions

Science being utilized as a source of various questions to respond scientifically and logically to natural events and various calamities and disasters is included in the ideas that will continue to be expressed by teachers emerging from the responses of prospective educators. Remarkably, a majority of the participants (n = 5) in the second question expressed their opinion that questions should be the first step in any scientific investigation to explore knowledge further because if a researcher or individual does not have questions, then there is nothing to investigate. Teachers' responses mainly focused on The notion that raises encourage inquiry, application or practice of science, trial and data analysis (Ratnasari et al., 2017).

The research process obtained teacher responses regarding the various problems presented, and the results showed that teachers had an exploration indicator between 31.25%-93.75% with an average exploration level of 67% so that it could be categorized as teachers who had curiosity about epistemic beliefs at a medium level (table 3). On the understanding indicator from the research results, teachers have a level of understanding in the range of 31.25%-75.5% with an average of 63% so that it can be categorized as teachers who have an understanding of epistemic beliefs at a medium level (table 3). On the analysis indicator from the research results, teachers have an analysis level in the range of 50%-75% with an average of 65.62% so that it can be categorized as teachers who have an analytical spirit about epistemic beliefs at a medium level (table 3). The three indicators that have been tested have values that have not met the existing epistemic belief threshold standards, where these standards can be adjusted to the cumulative value in Indonesia, so the epistemic beliefs possessed by a teacher need to be improved again in order to maximize teaching students about various epistemic beliefs in science learning (Suyitno et al., 2023). The efforts that can be applied to improve teachers' epistemic understanding include presenting programs for pre-service and in-service teachers, providing regular workshops, and offering internships or research experiences to science teachers.

Nodes Classification

Figure 3 mentions that this researcher analyzes keywords in the form of classification nodes to understand in more detail the keywords in the teacher's understanding of epistemic beliefs on the implications of SSI-based science learning. In the tree map, there are five types of keywords from the most mentioned, namely evaluation, explore, analyze, epistemic beliefs, and socio-emotional.

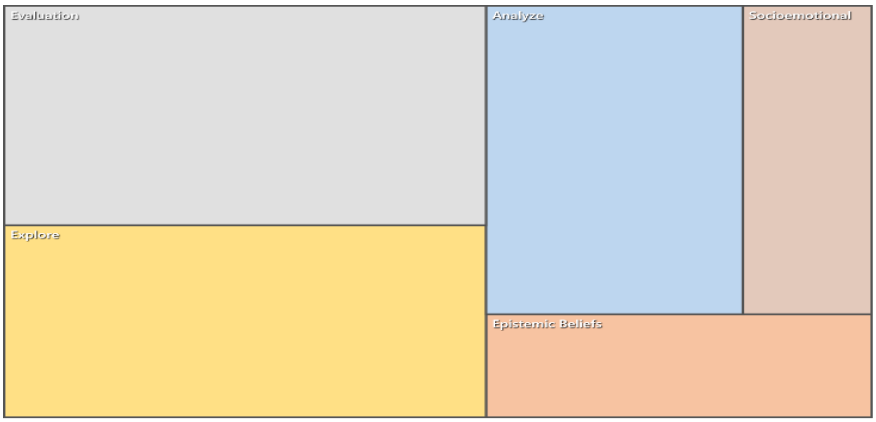

Figure 3. Tree Map of Nodes Classification using N-Vivo

Cross-Tab Analysis

Based on Figure 4, it is known that a teacher has a different level of epistemic beliefs. several factors that influence the level of teacher beliefs are the teacher's own desires such as the ability to regulate emotionally, understand, evaluate, explore, and analyze new knowledge, available facilities, and leaders in the educational institution.

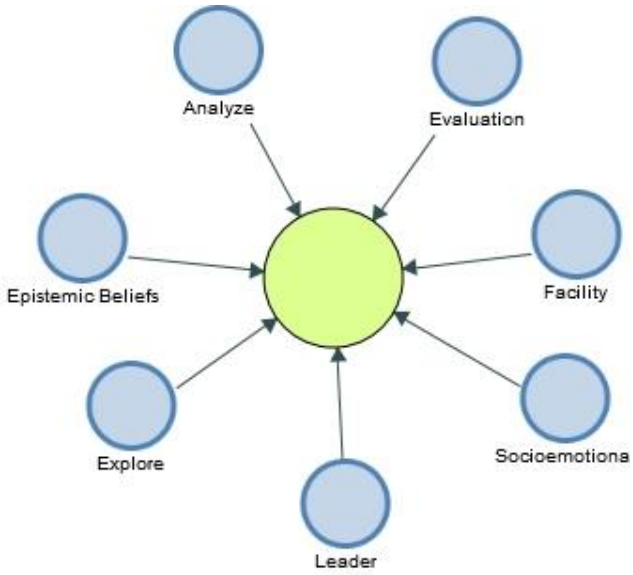

Figure 4. Cross-Tab using N-Vivo "Factors that Influence Teachers' Epistemic Beliefs"

Sub Section 2: Scientific Uncertainty Created by Perception, Background, and Bias.

Mastering science is a human endeavor that risks introducing bias into the research procedure when instructors answer some questions, mainly questions 1 to a few on slide three. In answering the research questions, a maximum of teachers (75%) stated that scientists come to extraordinary conclusions despite asking similar questions and accumulating records. Scientific uncertainty occurs due to chance factors, nonpublic reports, bias, outlook, and human error are often used to justify variations between scientists' conclusions and research results, thus impacting everyone's epistemic beliefs. Teachers experience that "absolutely everyone thinks differently approximately expertise," and different things affect the translation of

records, such as "personal enjoy previous knowledge and personal beliefs." Those results offer full-size evidence that technology teachers' recognition of the impact of human cognition and bias will affect the development of technology understanding and epistemic ideals of each man or woman (Sudirman et al., 2022; Setiawan et al., 2021).

In addition, instructors frequently regarded the function of scientific and computational questioning as techniques for constructing analogical thinking. Several character responses (n=2) recognized computational wondering as a rational process to reduce human bias. Therefore, using scientific questions to investigate data is an excellent and impartial method of doing so without human bias. It gives the researcher a view of the consequences received with the aid of the records to hand, without filtering out experimental consequences or perceptions of previous check outcomes(Winarni & Koto, 2020). Typical instructors expressed their perspectives on human bias and reveled in clinical research endeavors in half of the study questions. A few instructors must understand the methods wherein scientists mitigate and decrease the capacity dangers that human cognition poses to scientific research that bring about a person's epistemic beliefs (Risma et al., 2019).

Research Limitations

The results of this study provide much renewable knowledge about the epistemic beliefs of science teachers. Researchers also realize that the results of research that are applied directly cause various limitations, such as the lack of respondents obtained because the distance between schools in Ponorogo is quite far (Alatas & Fauziah, 2020; Kumar et al., 2023). In contrast to data collection carried out online, respondents' enthusiasm in responding to the results of the data obtained from all teacher populations can be perfectly and accurately represented (Hapidin et al., 2022).

Conclusion

It was concluded that most of the current technology knowledge teachers lack substantial experience in technology knowledge and are not well versed in its implications. This is the main cause of teachers' limited understanding of epistemic beliefs and the implication process in science learning. The sources of knowledge that can be obtained by teachers to support understanding and implications of epistemic beliefs are science sourced from humans or experts and science sourced from data or events. In the data analysis process carried out on the teacher's response to social science problems, the results showed that the teacher had an exploration indicator with an average of 67%, the understanding indicator obtained an average of 63%, and the analyzing indicator obtained an average of 65.62%. The three indicators that have been tested have values that have not met the threshold standards of epistemic beliefs, so that the epistemic beliefs possessed by a teacher need to be improved again in order to maximize teacher teaching to students about various epistemic beliefs in science learning. In addition to these three indicators, teachers also have other factors that are closely related to the level of epistemic beliefs, namely the ability to regulate emotions, understand, evaluate, explore, and analyze new knowledge, available facilities, and leaders in educational institutions. The efforts that can be applied to improve teachers' epistemic understanding include presenting programs for pre-service and in-service teachers, providing regular workshops, and offering internships or research experiences to science teachers.

Credit Authorship Contribution Statement

Eka Safitri: Conceptualization, Methodology, Software, Visualization, Formal analysis, Writing-original draft, Writing-review & editing. **Wirawan Fadly**: Conceptualization, Methodology, Formal analysis, Resources, Writing-review & editing, Supervision, Project administration.

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