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Online Scientific Argumentation Strategy on Improving Pre-Service Science Teachers' Scientific Reasoning through Experiment Activity: A Case Study in Indonesia

The problem and the aim of the study. Pre-service science teachers have to do some experiments to teach students to find scientific truth. As a result of COVID-19 and the distance learning situation, the unqualified experimental process is found in the ability of pre-service science teachers to discuss findings that lack the support of reliable data. This study aims to see the effectiveness of the online scientific argumentation strategy on the pre-service science teachers' scientific reasoning through a basic science experiment course during the COVID-19 pandemic.

Research methods. The research method used is a mix-methods research design. The data were collected using scientific reasoning tests and interviews and analyzed quantitively and qualitatively. Participants in this study were pre-service science teachers at Universitas Negeri Semarang in Indonesia, consisting of 32 pre-service science teachers in the experimental class and 32 pre-service science teachers in the control class.

Results. The essence of scientific argumentation is the delivery of ideas or statements accompanied by valid evidence by a group of people or individuals so that others can accept them. Considering the previous statement, the essence of the online scientific argumentation strategy is to deliver ideas or statements with valid and acceptable evidence through online media.

The mean score for the experimental class is 9.9 and 8.5 for the control class. The mean score of pre-service science teachers' scientific reasoning with online scientific argumentation strategy is better than those without online scientific argumentation strategy. However, the number of correct answers for difficult essay questions is more significant than easy multiple-choice questions in some items. Therefore, an interview with pre-service science teachers who answered correctly was conducted. The respondents from the experimental class have no difficulty, while respondents from the control class have difficulty applying Archimedes' law and understanding questions with more than two variables.

In conclusion, the implementation of the online scientific argumentation strategy effectively improves the pre-service science teachers' scientific reasoning through experiments at home during the COVID-19 outbreak. They learn to use the online scientific argumentation strategy in claims and evidence from the experiment results repeatedly to have proven new learning methods. For proper scientific reasoning, understanding is needed by integrating the data and facts so that the online scientific argumentation strategy becomes an alternative practical solution during a pandemic.

This study will provide new insight into the online scientific argumentation strategy to improve scientific reasoning for universities. The results of this study may serve as a tool for further studies to explore other learning strategies to improve scientific reasoning or determine other skills that can be improved using the online scientific argumentation strategy.

Keywords: online scientific argumentation strategy, pre-service science teachers, scientific reasoning

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Introduction

UNESCO state that education is one of the most affected fields by the coronavirus pandemic [69]. In the last week of March 2020, it is estimated that 1,3 billion children and youth, or around 80% student population, are affected by school closures in 138 countries [69]. This situation inspires researchers to make innovations in the teaching and learning process [63]. Many educational studies were conducted online to overcome the COVID-19 situation, such as Taufik et al. [55], who developed an instrument using Kahoot! to measure pre-service science teachers' cognitive aspect on COVID-19 pandemic. At the school level, Pratama and Mulyati [48] explored onsite and online learning.

The scientific reasoning skills of pre-service science teachers should be prepared based on mastery of theoretical concepts and the discovery of experimental results. If they have more experience doing experiments in science, they will have a deeper understanding [14]; [30]. One of the strategies in the learning process to improve scientific reasoning skills is a scientific argumentation strategy [2]. According to Sampson & Schleigh [50], scientific argumentation strategies consist of claims, evidence, and justification of evidence. Claims are used to answer questions of the problem, and evidence is an activity of interpreting the results of observing, measuring, or searching, while justification of evidence is valid evidence [50]. Data and scientific evidence are used to defend opinions, and the ability to do so supported by authentic evidence in science determines the acceptability of an argument Cavlazoglu & Stuessy [15]; Erduran et al. [23]; Erduran et al. [22]. Based on the scientific argumentation strategy stages from Sampson & Schleigh [50], these stages can be carried out in experiment activities.

Experiments are usually carried out in the laboratory. Pre-service science teachers are usually accompanied by laboratory assistants and utilize materials and tools in the laboratory. The COVID-19 outbreak has made experiments not be carried out in the laboratory, so they should do experiments at home. During experiments at home, laboratory assistants are not present, and materials and tools are unavailable. Moreover, there is no direct interaction between pre-service science teachers and lecturers or laboratory assistants because it is done online [49]. Science learning during the pandemic was carried out online from home, applying a distance learning model with various difficulties as Atmojo et al. [11] and Okur [44] found, including in the experiments [10; 51]. Based on the existing trends from various analyses of previous studies, many problems are found in online learning, so learning innovation is needed due to the COVID-19 pandemic [47].

The success of the experiments is determined by the ability to explain the data used to solve problems rationally [4; 39]. Curiosity in science learning is channeled through experiments that prove concepts and allow learners to discover new concepts [36; 38]. The experiments carried out emphasize independence in preparing tools and materials. The preliminary study of this research found that pre-service science teachers had difficulty modifying practical tools and materials during experiments at home. The low ability to modify tools from existing resources at home makes experiments difficult during a pandemic. The data analysis and findings during the scientific process are used to solve problems. Pre-service science teachers cannot provide sufficient data to discuss experiment results [5; 43]. The main weakness of the experiment report analysis results is the weak evidence of the experiment results.

Analysis of the explanation in the discussion and conclusion of the experiment report describes the mastery of knowledge and practical skills of pre-service science teachers. When the ability to conclude does not provide strong evidence support, it means that the scientific reasoning of the pre-service science teachers does not develop. Inferences supported by empirical evidence during the experiment will determine the scientific reasoning when expressing opinions. Using an online scientific argumentation strategy can reflect scientific reasoning because valid evidence is used to express opinions. Scientific reasoning is a 21st-century skill pre-service science teachers need [31; 45]. Pre-service science teachers should have good scientific reasoning to facilitate science learning under the demands of the 21st century.

One strategy to foster pre-service teachers' scientific reasoning is the scientific argumentation strategy. To begin with, argumentation itself can be abstractly defined as the interaction of different arguments for or against some conclusion [67]. It uses language to justify or refute a standpoint to secure the agreement in views [68]. Argumentation, an interaction of different arguments to justify a standpoint, can also be applied in science to state scientific justification where the conclusion is justified and viewed from the scientific point of view. Scientific argumentation is a social practice in which community members make sense of the phenomena under study, proffering, evaluating, critiquing, challenging, and revising claims through discourse [64]. Scientific argumentation is an important activity for the development and refinement of scientific knowledge [65]. From the various previous research, we state online scientific argumentation as a social practice for community members' development and refinement of scientific knowledge under study proffering, evaluating, critiquing, challenging, and revising claims through online discourse.

The specificity of the online scientific argumentation strategy is the provision of statements with valid data support according to findings and evidence through online media. A statement has something to do with the evidence and consideration. This statement is supported by [66], who stated that the essence of scientific argumentation is the delivery of ideas or statements accompanied by valid evidence by a group of people or individuals so that others can accept them. Considering the previous statement, we may say that the essence of the online scientific argumentation strategy is to deliver ideas or statements with valid and acceptable evidence through online media. Correct arguments are built from the results of scientific investigation. Online scientific argumentation leads to the formation, modification of concepts and theories about science. Various weaknesses were found during the online experiment, especially in the scientific activities on concept discovery and application [19; 62]. Education for pre-service science teachers can not only be in theoretical studies. Unlike pre-service teachers from different subject matters, pre-service science teachers have to do some experiments to teach students to find scientific truth. As a result of COVID-19 and the distance learning situation, the unqualified experimental process is found in the ability of pre-service science teachers to discuss findings that lack the support of reliable data. The experiment that does not produce reliable data can be ascertained that the process has experienced errors or even failures. Pre-service science teachers make experiments errors due to depicting a low understanding of the procedures and problems. Errors in science can be found in conclusions in problem-solving that are not supported by strong scientific evidence [9].

Meta-analysis research found that the most effective scientific argumentation was conducted to improve scientific reasoning at the higher education level [52]. However, this meta-analysis does not specify the higher education level on pre-service science

teacher education. Argumentation-based Inquiry Courses can improve pre-service science teachers' scientific reasoning [2]. However, previous research was not carried out in online learning. Based on these findings, it is necessary to research the application of the scientific argumentation strategy during the pandemic through online learning and specifically for pre-service science teachers.

Based on the background, this study aims to see the effectiveness of the online scientific argumentation strategy on the pre-service science teachers' scientific reasoning through a basic science experiment course during the COVID-19 pandemic. This study will provide new insight into the online scientific argumentation strategy to improve scientific reasoning for universities. The results of this study may serve as a tool for further studies to explore other learning strategies to improve scientific reasoning or determine other skills that can be improved using the online scientific argumentation strategy.

The scientific reasoning will be measured by concluding experiment results supported by the valid data and facts through the presentation of the experiment results. This research only uses test data of scientific reasoning between experimental and control classes, need to use pretest data to investigate the difference of gain of scientific reasoning through online scientific argumentation strategy. Moreover, the observation method needs to investigate the learning process to get more findings on the scientific argumentation strategy towards pre-service science teachers' ways of improving their scientific reasoning.

Materials and methods

The design used in this study is mixed methods, according to Creswell and Clark [18]. The quantitative data was from the scientific reasoning test adopted from The Lawson Classroom Test of Scientific Reasoning (LCTSR) [35. The data from the test was analyzed and followed by interviews as qualitative data. The interviews were held with 19 pre-service science teachers (30%), and the interviews were conducted over the Google Meet application, with conversations lasting for about 30 to 45 minutes.

This study used a random sampling technique. There are 64 pre-service science teachers as the sample of this study at Universitas Negeri Semarang in Indonesia. The samples are divided into the experiment and control classes. The study used an instrument consisting of 24 multiple-choice questions to measure pre-service teachers' scientific reasoning. This instrument was adopted and translated to Indonesian from The Lawson Classroom Test of Scientific Reasoning (LCTSR) [35], first developed in 1978 and revised in 2000. Another instrument used interview guidelines validated by an expert teacher who had experience teaching science subjects for more than 20 years. An experiment at home with an online scientific argumentation strategy was used in the experimental class, and an experiment at home without an online scientific argumentation strategy was used in the control class. The experimental class is provided with skills and etiquette in argumentation about the experiment. After that, pre-service science teachers will know how to argue in spoken and written ways to arrange experiment reports.

Before hypothesis testing, the test data is tested for its normality and homogeneity.

Based on Table 1, the normality test results of the control class have a calculated sig value of 0.28 ≥ 0.06 sig table, so the data is normally distributed. The count sig value is 0.061 ≥ 0.06 sig table, so the experimental class data is normally distributed. The normality test indicates that the data is normally distributed, so it still uses parametric statistical analysis.

Table 1

Normality Test

Class	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Control	.133	32	.162	.960	32	.282
Experimental	.185	32	.007	.937	32	.061

The Levene homogeneity test is carried out with the results of sig 0.95> 0.05. It means that the data is homogeneously distributed and comes from a population with the same variance (homogeneous).

The data were analyzed from test and hypothesis testing. The hypothesis test used was the student's t-test because the data in this study were normally distributed [17]. The following are the hypotheses of this study.

H0: There is no difference between pre-service science teachers' scientific reasoning using online scientific argumentation strategy and without using online scientific argumentation strategy.

H1: There is a difference between pre-service science teachers' scientific reasoning using online scientific argumentation strategy and without using online scientific argumentation strategy.

The data interview collected needs to be interpreted and coded validly and reliably for analysis. The method seeks to classify the findings of discussions into an effective number of categories that represent similar meanings [41]. Thus, different respondents should code the exact text the same way, and the reliability of the analysis depends on this consistency [60].

The data was edited to reveal the interpretive truth in the text by searching for meaningful segments, cutting, pasting, and rearranging [40]. A semi-structured question interview approach was used to cover a broader scope of the data range. The expert judgment results declare that the instrument can be used for interviews and discover this study's actual information. The analysis of interview results is carried out in descriptive qualitative by looking through the dominant answers from respondents. The data analysis was obtained from the test results in Table 2 and Table 3.

Literature review

Ahied et al. [3] studied distance learning using augmented reality-based multimedia to improve students' scientific literacy. To find out teachers' and students' responses, Thongbunma et al. [56] surveyed and interviewed teachers and students at secondary school about online learning. Another study by Velazco et al. [58] determined the virtual andragogical competencies of education in Ecuadorian universities. Sukarno and El Widdah [54] measured the level of self-regulated and self-awareness in the science learning process and analyzed the students' self-regulated and self-awareness in science learning. A study using Technological Pedagogical Content and Knowledge (TPACK) by Atmojo et al. [11] investigated TPACK of biology teachers. While at the university level, Juanda et al. [32] investigated students' metacognition and digital literacy through virtual lecturers. Different from others, Al-Ansi et al. [6] investigated the advantages, opportunities, and challenges of using ICT-based learning at the school and university levels. Therefore, El Islami et al. [21]

suggested that research is necessary to answer the challenges of the COVID-19 outbreak in the learning context.

Regarding the importance of research to overcome COVID-19 challenges, many kinds of educational research have been conducted, especially at the university level, including in the teacher education program towards students' achievement. There is research in the teacher education program on improving students' critical thinking skills, such as Ernawati and Sujatmika [24], who developed a worksheet based on a scientific approach, and Azzahra and Simatupang [12], who implemented a talking stick method. Other research showed students' achievements developed in the teacher education program. Mukhtar et al. [42] used dynamic mathematics software GeoGebra on problem-solving and self-efficacy, and Aberilla et al. [1] surveyed university students' acceptance of the evolution concept to address the misconceptions about evolution. WF et al. [61] also addressed students' memory using Mneumonic learning at the school level. Even though some previous studies still address the students' learning achievement [34; 37] and students' motivation [8], these previous studies show us that the achievements of students both at the university and school levels has become one of the important goals on the educational researches.

Research results

Based on the test results, the mean score for the experimental class is 9.9 and 8.5 for the control class. The mean score of pre-service science teachers' scientific reasoning with online scientific argumentation strategy is better than those without online scientific argumentation strategy. The results can be seen in Table 2.

Table 2

Inferential Statistical Test: Independent Sample T-test

Class	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Conclusion
Control vs Experimental	-4.412	62	.000	-10.281	2.330	H0 is rejected

Based on Table 2, the hypothesis test obtained the independent t-test with equal variance assumed. Sig <0.05 means that H0 is rejected, indicating a difference between the mean learning outcomes of the experimental and control classes. The follow-up test is the one-tailed t-test. Because t is negative, the experimental class' average learning outcome is higher than the control class with sig < 0.025.

Before interviewing pre-service science teachers, researchers analyzed the distribution of correct answers from 24 items of scientific reasoning in the experimental and control classes, as shown in Figure 1.

Odd number questions are questions with multiple-choice answers, while even number questions ask the reason. Odd number questions have a lower difficulty level than even number questions. With a lower difficulty level, the number of correct answers for odd number questions should be higher than even number questions. However, in some questions, even numbers got more correct answers than odd numbers. The correct answers in even numbers are in two items: numbers 3, 4, 5, and 6. The four questions are about the application of Archimedes' law in the experiment activities. Unusual findings were further explored by conducting interviews with respondents who correctly answered the questions

that asked the reason but answered incorrectly on the multiple-choice questions. The results of the interview to explore the findings on the four items are in Table 3.

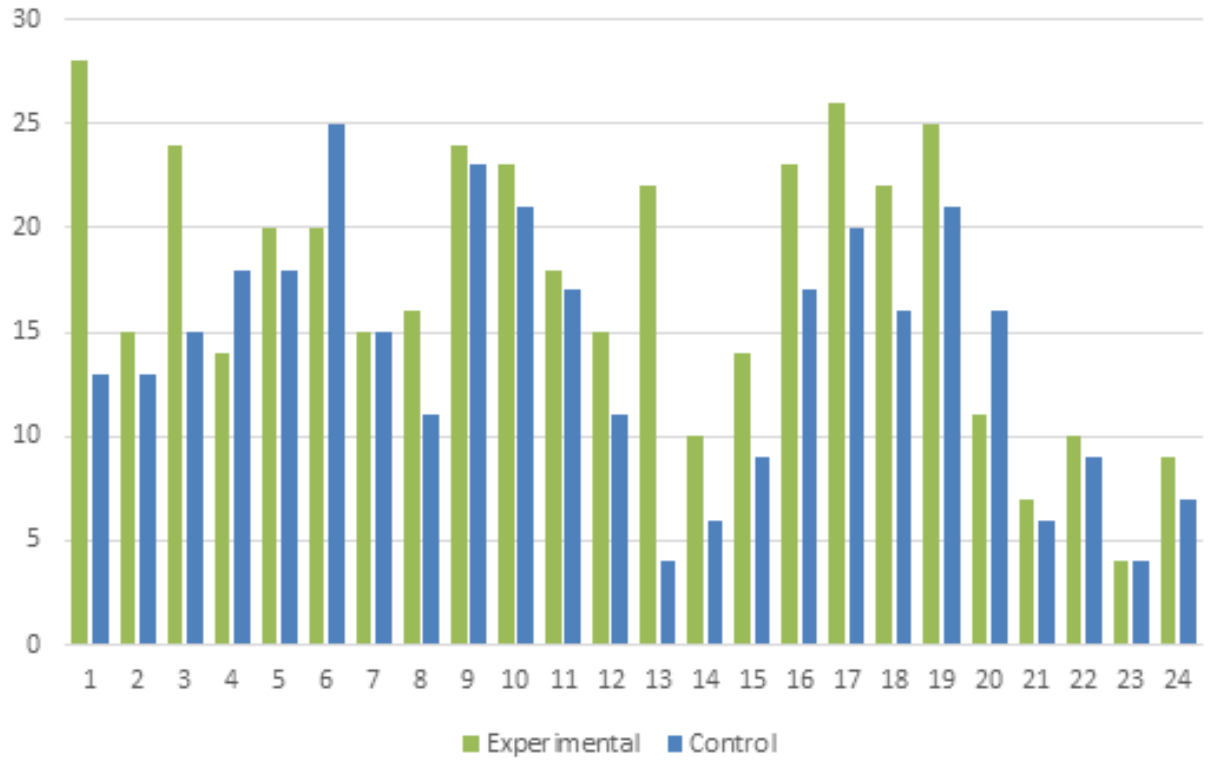

Figure 1 Correct answer distribution in the experimental and control classes

Table 3

Interview Results

Questions	Respondents' Answers	
	Control Class	Experimental Class
Do you have difficulty applying Archimedes' law in the experiment activities?	Yes, because the concept is often mistaken when memorized but easier to understand in practice because of visible symptoms.	No, because it is easier to understand from the experiment results of theoretical studies.
Do you have difficulty understanding questions that connect more than two variables?	Yes, especially in the form of relationships between variables.	No, because we have been trained to understand the form of the relationship between variables
Do you have difficulty with questions with an experimental image stimulus?	No, because the pictures presented in the questions make it easier to understand scientific phenomena.	No, because we are accustomed to analyzing pictures/graphics in practice.

Table 3 consists of pre-service science teachers' responses from the interview after the implementation of the online scientific argumentation strategy through experiments during the COVID-19 outbreak. The questions in the interview guide are gone through expert judgment before use and declared valid and reliable. The questions are about whether the pre-service science teachers have difficulty in learning. The respondents from the experimental class have no difficulty. On the other hand, respondents from the control class have difficulty applying Archimedes' law and understanding questions with more than two variables. Based on the results, the implementation of an online scientific argumentation strategy in experimental class effectively helps pre-service science students learn.

Discussion

Based on the results of hypothesis testing in Table 2, it can be concluded that the online Scientific Argumentation strategy effectively improves the pre-service science teachers' scientific reasoning through experiments at home. An in-depth interview was conducted to determine why pre-service science teachers correctly explained but answered the questions incorrectly (Table 3). The interview results found that the causative factor was not understanding the concept but connecting questions and the answers.

In the experimental class, pre-service science teachers with the given treatment are more accustomed to analyzing questions with different variables and are trained to analyze stimuli from practical results. The experiments in the experimental class differ from the control class in the strategy of critically analyzing learning studies. The learning outcomes analyzed are the experiment results according to the experiment topics collected by the lecturer and used as material for online discussions before the experiment is carried out. The experiment results analyzed are in the experiment reports and video presentations obtained from various YouTube channels. Pre-service science teachers are more ready to experiment even though they are done remotely from home after training in critically analyzing learning resources. Analyzing the experiment results before experimenting is carried out repeatedly every time they experiment. Iterative strategies provide experiences for learners to sharpen their analytical power [20]. A repetition strategy in learning science that is carried out sustainably impacts reasoning acuity [57]. Giving the online scientific argumentation strategy to the experimental class positively impacts the pre-service science teachers' scientific reasoning compared to the control class.

The learning strategy in the experimental class emphasizes three learning experiences that are given repeatedly every time they do experiments. The three iterative strategies are to claim, prove, and justify the evidence. Students have opportunities to seek alternative perspectives and reasoning to reinterpret data to evidence and evaluate their knowledge claims [16]. In the experimental class, pre-service science teachers can answer questions better because they can make claims based on facts. Pre-service science teachers' reasoning is formed from the experiment facts obtained so that they are helped to answer questions correctly. They are trained to verify the results of observing and measuring during practicum. The questions to measure scientific reasoning in this study are given a stimulus: experiment results in pictures, tables, charts, and narratives of practical results. They are better at finding the correct answers because they are used to analyzing practical findings due to the experiments. The ability to prove facts becomes material to communicate findings confidently in science learning [59]. In the experimental class, pre-service science teachers used data and scientific evidence to defend their arguments orally through presentations and written experiment reports.

The online scientific argumentation strategy can be the reason for the achievement of pre-service science teachers' science experiments at home due to COVID-19. Even though lecturers and laboratory assistants do not directly accompany the experiment as in the laboratory, the experiment in the experimental class goes well. From the interview, they were serious about each stage of the experiment because they felt it was impossible to give correct arguments without understanding everything done. As Grooms et al. [28] stated, argumentation helps students during practicum. This expression is not a fear but rather an

awareness of each pre-service science teacher to provide arguments following the process and findings of the experiment. Awareness of the importance of mastering learning content in science creates an internal impulse that impacts the urge to analyze learning resources critically [7; 29].

In the experimental class, pre-service science teachers who got the experiment lecture process with the online scientific argumentation strategy have an advantage over the control class. Their advantages are based on data analysis and in-depth interviews. Evagorou and Osborne [25] and Kuhn [33] stated that collaborative argumentation to establish a consensus might more productively result in students' argument skills, reasoning abilities, and significant knowledge development. Most of them can connect variables in the questions and answers to be sharp in analyzing questions and choosing the right reasons [26]. Connecting variables is a fundamental skill in understanding a scientific phenomenon [53]. Skills to connect the relationship between variables are essential in providing arguments. Experimental barriers in the COVID-19 pandemic can be overcome with an online scientific argumentation strategy because, after repeated activities, pre-service science teachers are accustomed to using data and fact findings as a basis for solving problems critically.

The correctness of scientific reasoning in this study is determined from the level of validity of experiment data. The experiment method chosen for the experimental class is assessed according to the learning needs of pre-service science teachers in the university. From preparing worksheets to experiment reporting, scientific independence has provided a new way to solve the obstacles to experiment during the pandemic. More content from experiment results needs to be made that applies scientific argumentation through social media, which can be used as a reference to remote the experiment. Implementing the experiment method in the experimental class can be applied more broadly to prepare pre-service science teachers to experiment during the COVID-19 pandemic. Scientific argumentation to strengthen scientific reasoning is carried out repeatedly from one experiment to the next. This study found a pattern of repetition of up to twelve times for experimenting for one semester or six months. Repetition is carried out to familiarize pre-service science teachers with making claims, presenting evidence, and justifying evidence.

Conclusion

Implementation of the online scientific argumentation effectively improves pre-service science teachers' scientific reasoning through experiments at home during the COVID-19 outbreak. They are correct in giving reasons but wrong in answering questions because they do not understand the concept but connect variables. They learn to use the online scientific argumentation strategy in claims and evidence from the experiment results repeatedly to have proven new learning methods. In the experimental class, they can do it during science experiments at home. For proper scientific reasoning, understanding is needed by integrating the data and facts so that the online scientific argumentation strategy becomes an alternative practical solution during a pandemic.

It is necessary to further research on what is the difference between pre-service science teachers' scientific reasoning obtained through online and offline learning using scientific argumentation strategy are needed to obtain a more effective scientific argumentation strategy. Moreover, it needs to implement a new approach such as STEM Education to address scientific reasoning as Bao et al. [13] state that The Lawson Classroom Test of

Scientific Reasoning (LCTSR) [35] is viral in the STEM Education community. Additionally, STEM Education is a new approach that popular in Indonesia since 2019, as Parmin et al. [46] stated and Farwati [27] researched. Moreover, it is also crucial for practitioners to use scientific argumentation strategy using experiments at home to address the pre-service science teachers' scientific reasoning through online professional development programs.

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