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Scientific Argumentation Measurement Pattern of Pre-Service Elementary School Teachers: A Literature Review

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Abstrak. Scientific argumentation is a means to encourage students' critical thinking skills toward natural phenomena. By having scientific argumentation, a higher conceptual understanding of students could be ensured. This research aims to review and explore the related scientific argumentation findings for describing the importance of scientific argumentation measurement and finding out the patterns of scientific argumentation measurement. The literature review analyses showed that scientific argumentation-based learning could improve critical thinking, creative thinking, and problem-solving skills. Besides that, the scientific argumentation measurement pattern could be found out by using Toulmin Argumentation Pattern (TPA), Scientific Argumentation and Reasoning (SRA), and Claim, Evidence, and Reasoning (CER). Scientific argumentation could be used to improve students' understanding of scientific concepts related to science phenomena. Thus, creating conclusions and understanding learning concepts by using claims and rebuts logically, analytically, and scientifically could occur. The empowerment strategy by using scientific argumentation measurement pattern is important to apply. Using an appropriate learning model is also important to create better students' outcomes with 21st-century skills.

Key words: scientific arguments, measurement pattern, literature review

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INTRODUCTION

Improving the students' soft skills became the challenges of Educational Personnel Educational Institution. By education process, *soft skills* could be trained. Any system or sophisticated technology cannot replace this reality. In this 4.0 industrial revolution era, people must have thinking skills, technology masteries, and other skills. Students of the Preliminary Education Department are pre-service teachers. They are prepared to have abilities and skills based on the 21st century. Thus, Indonesia's future generation will have the skills as long as the teachers have reliable skills.

The required skills are critical thinking, creative thinking, and problem-solving skills. Problem-solving skill is important to improve the human resource quality, especially the pre-service teachers of elementary schools. The expected learning achievements could prepare students to practice innovative learning by applying reliable soft skills. The teacher candidates need appropriate learning support. This challenge becomes the principle to develop scientific argumentation and problem-solving skills. Argumentation skill is an important skill to master by students. The skill is a process that supports a claim by emphasizing idea-notion sharing skills about science in daily life based on the evidence and existing theories. Obsorne (2010) also argues that argumentation has an important role in science learning activity because it provides students a chance to discuss in a group and share opinions that show conceptual understandings, skills, or scientific reasoning skills. Scientific argumentation skill is supported by relevant, empirical, and verified information and evidence. An excellent argumentation skill could establish new explanations so students could obtain new knowledge. They could also develop their problem-solving skills with scientific literacy thinking patterns.

Students should always be involved in the discussion, so their abilities and skills to make decisions concerning scientific problems in daily life. Science is strongly bound with a cognitive perspective of reasoning and thinking (Billig, 1987). Thus, students should be involved in scientific discussions. Even they should be the decision-makers of related scientific problems (Wardani et al., 2018). By involving them to argue, students will learn to respect the correlation between evidence and claim. They

also learn the importance of revision in scientific arguments. From these various perspectives, the argumentation quality has been developed in theoretical and methodological frameworks for the conception and scientific argumentation analysis (Jiménez-Aleixandre, Rodríguez, dan Duschl 2000; Zohar and Nemet, 2002; Erduran et al., 2004)). One of the scientific argumentation measurement patterns is based on *Toulmin's Argumentation Pattern* (TAP). In this model, the scientific argumentation components are data, claim, warrant, backing, and rebuttal. Data deals with the applied phenomena as evidence to support a claim. A claim is the result of applied values, opinion about the existing values, or an emphasis on a perspective. A warrant is regulation and principle that explains the correlation between data and claims. Support or *backing* is the basic assumption underlying a certain warrant. The rebuttal is a specific case in which a claim cannot be verified or different arguments (Simon *et al.,* 2006). On the other hand, Yan & Enduran (2008) believe that argumentation is an important component in scientific literacy. Thus, by properly arguing, students could at least mater scientific concepts.

Scientific argumentation has an important role in scientific learning. Scientific argumentation is an appropriate approach to inquiry-based learning (Wang & Buck, 2016). Teaching scientific argumentation could explain several complex phenomena clearly (Nichols, 2015). Moreover, it could deepen or develop students' conceptual understanding (Wang & Buck, 2016; Nichols, 2015). However, based on the obtained data from several previous findings, the students' scientific argumentation skills were still low. The scientific argumentation results showed only two students provided argumentation with data, evidence, and rationale, while about a percentage of 30% of students only argued without supportive data or evidence (Sulaiman et al., 2019). Treagust (1988) and Leksono (2017) also revealed that most students were not skillful in writing scientific arguments. They did not understand and could not connect the information with the explanation about phenomena or conceptions. Supeno (2014) explains the importance of appropriate measures to determine students' scientific argumentation skills because it will become the basis for students to think and understand the already owned concept.

National and international researchers had done various studies about scientific argumentation. The argumentation measurement patterns could be made by written test, multiple-choice, or essay in an online manner. Then, the results can be verified to find out the argumentation profile with TAP (*Toulmin Argumentation Pattern*), SRA (*Scientific Reasoning Argumentation*), and CER (*Claim, Evidence, and Reasoning*). With various scientific argumentation measurement patterns, further review is needed in terms of the conformity with the students' characteristics in Indonesia. Thus, the measurement patterns will be appropriate and accurate. This research aims to review and explore the research findings dealing with scientific argumentation to describe the importance of scientific argumentation measurement and to find out the pre-service elementary school teachers' scientific argumentation measurement.

METHODS

This research is literature review research with several databases (Scopus, ERIC, and Google Scholar) based on article searchers about scientific argumentation measurement in scientific learning. The first stage of this research was defining the terms of scientific argumentation. The second stage was then measuring the applied scientific argumentation to measure the scientific argument from the obtained articles. Third, the obtained reasons were analyzed by using the measurement pattern. The data conformity with the scientific argumentation was analyzed by scientific argumentation measurement until the conclusion about the appropriate measurement pattern was reached.

RESULTS AND DISCUSSION

Scientific argumentation is an important skill for students to understand the scientific concept. Park (2016) and Siswanto (2014) also revealed that argumentation skills could help students understand the scientific concept. By emphasizing scientific argumentation, students could develop and understand their understanding during the learning process (Nichols, 2013; Khishfe, 2014; Suhandi, 2012; Siswanto, 2014); train their reasoning skills (Suhandi, 2012; Topalsan, 2020; Wang, 2020),; support cognitive and meta-cognitive thinking process (Topalsan, 2020) train scientific competence (Tsai, 2015); improve scientific literacy (Topalsan, 2002); and facilitate students to make a decision and improve problem-solving

skills (Ibrahim & Robello, 2012).

Wang & Buck (2016) revealed that scientific argumentation could deepen and develop students' conceptual understanding. Nichols (2015) also found that scientific argumentation learning development could explain several complex scientific phenomena. With a scientific argument, students could connect several complex materials to arrange claims until logical and scientific rebuttals. It means a scientific argument allows an individual to create, support, challenge, or improve a claim to produce credible validation and conclusion (Songsil, 2019). Iodanou & Constantinou (2015) revealed that scientific argumentation could be seen as a proportional scientific decision in the science educational context. It also involves critical thinking to create fact-based statements (Lee et al., 2014; Topalsan, 2020).

Scientific argumentation involves scientific reasoning to conclude the available information and critical thinking skills to create statements based on facts (Lee et al., 2014; Topalsan, 2020). According to Heng, Surif, and Seng (2014), the scientific argument has an important role in instilling scientific concepts for students. These concepts are the core of reasoning skills and academic achievement. Scientific argumentation could be used to improve students' understanding of scientific concepts related to science phenomena. Thus, creating conclusions and understanding learning concepts by using claims and rebuts logically, analytically, and scientifically could occur.

Learning implementation by emphasizing scientific argument is still considered low. Songsil (2019) showed that students still had difficulties determining the claims from the argumentation process revealed in socioscientific issue-based learning. Viyanti (2015) also found that the documented argumentation quality was low due to a lack of awareness of the importance of developing new skills rather than to use the already mastered skills. Scientific argumentation skills could be developed by implementing several models, such as 1) physical investigation, 2) questioning, and 3) scientific (Lewis, 2019), 4) Argument-Driven Inquiry (Cetin and Eymur, 2017; Hasnunidah, 2013, Erenler and Cetin, 2019), 5) revised Argument-Driven Inquiry (Songsil, 2019), SSIs-Online-Argumentation Pattern-based learning (SOAP)(Tsai, 2017).

Educators have roles in encouraging scientific argumentation skills. Ortega et al. (2018) revealed that scientific argumentation skills required correlations from three aspects: conceptual, didactic, and structural aspects. Students of the Preliminary Education Department are pre-service teachers. They are prepared to have abilities and skills based on the 21st century. Thus, Indonesia's future generation will have the skills as long as the teachers have reliable skills. Thus, to prepare reliable and eligible teacher candidates and apply scientific argumentation learning, three main skills should be developed. They are 1) identifying the main elements in the argumentation process during science class, 2) interpreting the elements, and 3) creating a decision based on training for a better argumentation process in science class (Ortega et al., 2018).

The argumentation measurement patterns should be considered so that the profile of students' scientific argumentation skills could be found. It is for the educators' inputs to determine what action should be applied in a learning process. The scientific argumentation measurement patterns could be made by using TAP *(Toulmin Argumentasi Pattern*) (Toulmin, 1958; Larraina et al., 2018; Viyanti, 2015; Hasnunidah, 2013; Giri & Paily, 2020; Muhlen et al., 2018; Accusto and Saggion, 2020; Faize et al., 2020; Dawson and Carson, 2017), SRA (Scientific Argumentation and Reasoning) (Dorfner et al., 2018), CAI (Cognitive Appraisal Interview) (Sampson and Blanchard, 2012), dan CER (Claim, Evidence, and Reasoning) (McNeill & Krajcik, 2011; Evagorou et al.; 2020). Generally, the differences and similarities could be seen in Table 1.

Table 1. Differences and similarities of scientific argumentation measurement patterns

Argumentation Components	TAP	SRA	CAI	CER
Data	✓		✓	
Claim	✓	✓	✓	✓
Warrant	✓			
Backing	✓	✓	✓	
Rebuttal	✓	✓		
Evidence	✓	✓		✓
Reasoning				✓

The measurement patterns of TAP (*Toulmin Argumentation Pattern*) used the proposed theory by Toulmin (1958). It says that the scientific argumentation components are data, claim, warrant, backing, and rebuttal. The argumentation structures consist of theory-

evidence coordination in a claim-data guarantee supports and uncertainty dealing with the argument strength in rebuttal qualification condition (Zhu et al., 2014). Mao et al. (2018) found that formative assessment consisted of eight item sets of argumentations. Each set consisted of four items measuring the scientific arguments in four structural elements. They were: 1) creating scientific claim (measured with the multiple-choice claims); 2) explaining the scientific claims based on evidence in theory (based on the established response explanations), 3) revealing the uncertainty level of the claim explanation (measured with uncertainty rate on five-point Liker scale), and 4) describing the sources of uncertainty (measured by the established uncertainty response reasons).

The measurement patterns with SRA stages were proposed by Dorfiner et al. (2018) with eight integrated epistemic activities in a learning process.

They were problem identification, the result of the scientific process, and concrete problems. The given problems might be more practical, for example, the real-world problems. Thus, at the beginning of SRA, it dealt with the missing explanation of a certain phenomenon.

Questioning - a question is proposed based on problems or based on a question that could be answered or formulated.

Hypothesizing - as a future process that deals with a question based on the proposed problems.

Constructing and redesigning artifacts. Physical artifact is established based on the theoretical concept.

Creating evidence: the evidence is produced in different manners. Fischer et al. (2014) described the deductive-hypothetic manner or inductive manner as possibilities to create evidence.

Evaluating the evidence It is an assessment of evidence with a claim or a theory. Therefore, a critical judgment on the evidence is needed.

Concluding: This activity deals with drawing conclusions based on the previous reasoning process.

Communicating and researching: The reasoning process and the results should be shared and considered again critically.

The measurement patterns with CAI stages (Cognitive Appraisal Interview) were made in the learning process by 1) determining how teachers evaluated the alternative explanation of a natural phenomenon. Teachers should be prepared with natural phenomena, focus questions, three-alternative explanations, and data collections about the phenomena. Teachers were then asked to determine which explanation was the most valid or the most acceptable. Then, they provided their reasons. 2) determining how teachers arrange the scientific argument, identifying what things teachers should instill in the scientific argument. Teachers were asked to select the most familiar topic and to create a written argument as their first preference explanation during the first stage. They were then asked to reflect on their arguments and the scientists' arguments. They also had to explain what made their argument persuasive scientifically. 3) identifying the teacher's perspective about integrated argumentation in science teaching and learning. The teachers were asked to explain their perception about argumentation for classroom purposes and the hindrances. They had to describe their perspectives about argumentation's potential values (Sampson and Blanchard, 2012).

The measurement patterns with CER stages were proposed by Evagorou et al. (2020). They argued that claims were statements of the answered questions or problems. Evidence is scientific data that supports the claim. Evidence is from students' investigation directly or indirectly from online and book studies that provide data. Finally, reasoning justifies why or how such evidence supports the claim. Rebuttals describe alternative claims and compare why alternative claims are not matched (McNeill & Martin, 2011; Evagorou et al., 2020).

Based on the previous findings' literature analysis, the scientific argumentation of students was important to do with accurate measurement patterns. By doing so, educators could determine the appropriate teaching method to improve students' scientific argumentation. Besides that, to develop scientific argumentation skills, appropriate learning models could be applied.

CONCLUSION

Based on this exploratory study, scientific argumentation learning development could explain several complex scientific phenomena. With a scientific argument, students could connect several complex materials to arrange claims until logical and scientific rebuttals with several stages. They were creating, supporting, opposing, or revising a scientific claim to produce credible validation and conclusion. The scientific argumentation measurement pattern could be found out by using *Toulmin*

Argumentation Pattern (TPA), *Scientific Argumentation and Reasoning* (SRA), and *Claim, Evidence, and Reasoning* (CER).

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