www.ijemst.net

Nurturing Argumentation Skills to Solve Complex Problems through Structured Scaffolding-Guided Inquiry (SSGI)

Muhammad Nasir
Institut Agama Islam Negeri Palangka Raya, Indonesia

Annur Indra Kusumadani
Universitas Muhammadiyah Surakarta, Indonesia

To cite this article:

Nasir, M. & Kusumadani, A.I. (2024). Nurturing argumentation skills to solve complex problems through structured scaffolding-guided inquiry (SSGI). *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 12*(5), 1197-1216. https://doi.org/10.46328/ijemst.4262

International Journal of Education in Mathematics, Science and Technology

2024, Vol. 12, No. 5, 1197-1216 https://doi.org/10.46328/ijemst.4262

Nurturing Argumentation Skills to Solve Complex Problems through Structured Scaffolding-Guided Inquiry (SSGI)

Muhammad Nasir, Annur Indra Kusumadani

Article Info

Article History

Received:
17 February 2024
Accepted:
13 July 2024

Keywords

Nurturing
Structured argumentation
Scaffolding
Guided inquiry
Complex problems

Abstract

This study aims to develop a structured scaffolding-guided inquiry (SSGI) learning model that is oriented toward nurturing argumentation skills to solve complex problems. Test the effectiveness of the SSGI model in improving students' argumentation skills to solve complex problems. This research is development research that refers to Dick and Carey. Test the effectiveness of the SSGI learning model in a quasi-experimental pre-test and post-test group design. Argumentation skills to solve complex problems data were collected using an essay test. The research sample used Physics Education students in the 4th semester (N = 30). The significance of the difference in pre-test and post-test scores was analyzed using the t-test. The impact of the SSGI is analyzed using effect size. The result of this study indicates that the SSGI enhances students' argumentation skills to solve complex problems. The increase in students' argumentation skills to solve complex problems was 7% in the high category, 57% in the medium category, and 36% in the low category. The effect size coefficient of the SSGI is 0.78 in the medium category. The SSGI syntax that contributes the most to growing argumentation skills to solve complex problems is the reasoning syntax. Then the next sequence is syntax exploration, closure, and orientation.

Introduction

Understanding science concepts and thinking skills is crucial in science learning to prepare students to master 21st-century skills related to creative thinking, critical thinking, problem-solving, communication, and collaboration. These 21st-century skills will be difficult to achieve if students' literacy in understanding basic science concepts and thinking skills is low. To address this, the Indonesian national curriculum framework has established competency standards that must be achieved by undergraduate students, namely understanding theoretical concepts in depth, being able to solve problems using science and technology, and being able to make appropriate decisions based on valid data or information. For this competence to be achieved, it requires technical innovation to foster an understanding of basic concepts towards more complex concepts as well as the ability to reason to solve problems based on cross-disciplinary techniques. Conceptual knowledge influences problem-solving thinking skills (Englund et al., 2017). Conceptual knowledge plays a significant role in influencing problem-solving thinking skills (Yessi et al., 2020; Masooma et al., 2019; Englund et al., 2017). Students need to have a deep understanding of concepts to effectively solve problems in various domains of mathematics and physics. Research studies have shown that students' conceptual understanding is positively correlated with their problem-solving skills (Restina et al., 2020; Calliste et al., 2020; Xian et al., 2015)

Argumentation skills are the ability to derive an explanation from a phenomenon and bolster it with pertinent data and arguments (McNeill et al., 2006). The degree to which students are able to express causal claims and determine whether the data they look at during their investigation supports those claims is known as their argumentation skills (De Sandoval, 2009). The ability to argue must follow the phenomenon's logical and cohesive causal history, which is linked to a number of underlying processes (Strevens, 2008). Understanding the causal story of natural phenomena through representation can make it easier to make conclusions about abstract entities and processes (Yeo & Gilbert, 2014). The implication of the research results of Wang (2015) is the need to improve the design of the scaffolds to facilitate the construction of argumentation skills.

Argumentation skills need to be empowered to train students to understand the nature of the scientific process. Science as a process provides an overview of how scientists work to make discoveries through the scientific method systematically to compile knowledge (Nersessian, 2010). Science as a process is an understanding of how scientific information in science is obtained, tested, and validated. Understanding science as a process is closely related to phenomena, conjectures, observations, measurements, investigations, and communication (Ludascher, et al., 2009). The process aspect in science has two aspects, namely gaining knowledge about the environment and creating a point of view that provides a framework for understanding the importance of information. These two activities are in no way separate from each other. Someone needs a point of view to gain new knowledge and vice versa someone needs the knowledge to create a point of view (John, 2016).

Information and data obtained from inquiry activities are very important to support claims and put forward scientific reasons. A structured argumentative scaffolding stimulus is needed in the inquiry learning model to produce an argumentation skill based on a systematic argumentation framework. Hsu et al (2015) research on structured argumentation scaffolding shows that there is a significant increase in argumentation skills. Inquiry-based learning is learning in which students follow methods similar to those used by professional scientists to build knowledge through developing questions and hypotheses, collecting data, analyzing data, and drawing and testing conclusions (NRC, 2008). Inquiry learning is defined as the process of finding a causal relationship where students formulate hypotheses and test them by making observations (Pedaste et al., 2012). Inquiry learning will promote the acquisition of scientific knowledge, skills, and attitudes through the investigation of questions and problems for which there is often no single answer (Bybee et al., 2008). Teaching using the inquiry model means involving students in investigative activities and teaching appropriate ways of thinking (Flick & Lederman, 2006).

The inquiry learning model has advantages and disadvantages. The advantages of the inquiry learning model include: (1) Emphasizing the balanced development of cognitive, affective, and psychomotor aspects; (2) Helping students transfer their concepts to new learning process situations; (3) Learners are more active in finding and processing information until they find answers to questions independently; (4) Students can understand basic concepts and ideas better; (5) Encouraging students to think and work on their initiative, to be objective, honest and open (Trianto & Ibnu, 2014; Jumaisa, 2020). The results of research by Wenno, et al (2016) and Azzahro (2018) show that the inquiry learning model can improve conceptual understanding. Weaknesses of the inquiry learning model include (1) If problem-solving questions are not formulated properly, students will not be directed; (2) The implementation takes a long time so that educators often find it difficult to adjust to the allotted time; and (3) In the classical system with a relatively large number of students, the use of the inquiry model is difficult to develop properly (Trianto & Ibnu, 2014; Buckwalter & Turri, 2016; Jumaisa, 2020). To overcome the shortcomings of the inquiry learning model, it is necessary to select the right type of inquiry to be used according to the student's condition. The type of inquiry learning model that is relevant to students who are not used to the inquiry is the guided inquiry model.

A bridge to grow basic concepts and argumentation skills toward solving complex problems can be done using structured scaffolding techniques in guided inquiry learning. The stages in learning scaffolding structured guided inquiry start from problem orientation, exploring basic concepts, and reasoning to develop concepts in the framework of solving problems in the context of science applications. Scaffolding structured guided inquiry is based on Ausubel's theory of expository advance organizers, namely providing new knowledge needed by students to understand future information. Advance organizers as a mechanism to help connect new learning material with related ideas (Ausubel, 1960). Scaffolding helps students proceed through tasks by providing structure (Reiser, 2018). The structured argumentation scaffold helped students significantly improve their skills in constructing argumentation skills, making more dialogue moves for explanation and query, and using more of all four argument components (Hsu et al., 2015).

Scaffolding structured guided inquiry is designed to be different from the scaffolding technique that is commonly used to help students learn to understand lessons. Scaffolding in this model emphasizes the assistance given to students to help them achieve independence. Students are given complex, difficult, and realistic problems, and then given sufficient assistance in solving these problems. The assistance provided by educators can be in the form of instructions, illustrations, and describing problems in the form of science applications that allow students to be independent in solving them with a multi-disciplinary approach, especially using STEM disciplines. STEM approaches can link scientific inquiry with formulating questions answered through inquiry before they are involved in the engineering design process to solve problems (Kennedy and Odell, 2014; Jackson & Mohr-Schroeder, 2018). Argumentation skills in a STEM context are expected to be taught in class as a provision for students to face the challenges of globalization. In this research, endoscopy technology as a STEM context to construct structured argumentation scaffolding. A significant portion of students perceived that they gained a deeper understanding of lecture contents when technology was used in class (Al-Labadi & Sant, 2021). Teaching strategies must have characteristics such as innovation, flexibility, criticism, perspective, and guiding level (Jiménez et al., 2023).

To achieve the research objectives, it is necessary to propose a problem formulation, namely what syntax profile of the SSGI model is compatible to foster argumentation skills in solving complex problems? Is the SSGI model syntax effective in improving argumentation skills in complex problem-solving? Students' argumentation skills can be nurtured through structured scaffolding-guided inquiry. This approach involves providing support and guidance to students as they engage in argumentation activities. The use of scaffolding techniques, such as providing prompts, examples, and feedback, can help students develop their argumentation skills. A structured scaffolding-guided inquiry model can provide the necessary support and guidance for students to develop their argumentation skills to solve complex problems.

Literature Review

The results of previous research show that the Argument-Driven Inquiry (ADI) learning model is effective in improving students' argumentation skills and conceptual understanding (Neni et al., 2022). The ADI model focuses on guiding students through the process of constructing arguments based on evidence and reasoning. It encourages students to critically analyze and evaluate information, and to communicate their ideas effectively (Agustina et al., 2023). Dialogic scaffolding, which involves facilitating meaningful discussions and encouraging student participation, has also been shown to enhance students' engagement in classroom argumentation (Sally, Baricaua, & Gutierez, 2023). By aligning teachers' levels of epistemic understanding with their intentions for dialogic scaffolding, students can be supported in developing their argumentation skills (Kathryn et al., 2022). Previous research shows that no one has developed an SSGI model syntax that is oriented toward developing argumentation skills to solve complex problems.

Theoretical Framework

Inquiry learning is learning where students follow methods similar to those used by professional scientists to build knowledge, namely through developing questions and hypotheses, collecting data, analyzing data, and drawing and testing conclusions (National Research Council, 2012). Inquiry learning is defined as the process of finding causal relationships where students formulate hypotheses and test them by making observations (Pedaste et al., 2012). Inquiry learning empowers scientific knowledge, skills, and attitudes through investigating questions and problems for which there is often no single answer. Teaching using the inquiry model means finding ways to involve students in investigative activities and also teaching appropriate ways of thinking.

This research uses guided inquiry for the reason of balancing the role of educators as facilitators and students' learning independence. By providing guided questions, the learning process is directed towards the targeted learning objectives. The type of guided inquiry learning model modified in this research is the Process-Oriented Guided Inquiry Activities (POGIA) model. POGIA is student-centered instruction, that is, they work in teams with activities that are prepared in a guided manner. The POGIA syntax consists of orientation, exploration, concept formation, and closure (Hale & Mullen, 2009).

The scaffolding learning method refers to Vygotsky's theory, namely learning that occurs when students work or learn to complete tasks that have not yet been studied but these tasks are in the zone of proximal development (ZPD) or development slightly above the student's current development. The essence of scaffolding is to provide a large amount of assistance to students during the early stages of learning, then little by little the assistance is reduced until the student can complete the tasks on his own. The assistance given to students can be in the form of instructions, warnings, encouragement, explaining problems, providing examples, or other things that enable students to learn independently.

The steps in learning using the scaffolding method according to Applebee and Langer in Zhao and Orey (1999), namely (1) Intentionality, namely classifying complex parts that will be mastered by students into several specific, clear and unified parts to achieve overall competence. intact. (2) Appropriateness, namely focusing on assisting students on aspects that have not been mastered optimally. (3) Structure, namely providing a model so that students can learn from the model displayed. Providing models can be through the process of thinking, words, actions, or performance, then students are asked to explain what they have learned from the model. (4) Collaboration, namely the teacher responds to the assignments carried out by students. The teacher's role is as a collaborator, not as an evaluator, so that the teacher collaborates with students. (5) Internalization, namely the teacher strengthens the knowledge that students have so that students master the material well. The key characteristics of scaffolding consist of (1) Recruitment, namely recording student interest and compliance with the requirements of the tasks given. (2) Reduction in degrees of freedom, namely simplifying the task so that feedback can be used for correction. (3) Direction maintenance, (providing verbal encouragement and correction) to keep students achieving certain goals. (4) Marking critical features, (confirming and checking) emphasizing something, and interpreting errors. (5) Frustration control, namely responding to emotions expressed by students. (6) Demonstration, namely modelling the solution to a task.

Argumentation skills are the ability to provide reasons to strengthen or reject an opinion (Toulmin, 2003). Toulmin Argument Patterns can be used as a structure to help students think about how to make arguments by describing the relationships between argument components (Gott & Duggan, 2007). Many other researchers have used Toulmin's argument patterns to design scaffolds to help students construct scientific arguments (Yeh & She, 2010).

Indicators of argumentation skills are generally derived from aspects of Toulmin argumentation. Toulmin's Argument Pattern Framework (2003) includes six aspects of argument, namely: (1) statement (claim), (2) evidence (evidence), (3) warrant, (4) support, (5) qualification, and (6) rebuttal. Assertions of points of view, beliefs about the state of affairs, and established values all lead to claims. The facts that back up a claim are known as evidence. A reason that links information to a claim is called a justification. Support is a fundamental presumption that underpins justification in a certain field. A situation where the claim is true is referred to as qualified. Rebuttals are statements that refute a claim as false or that lack evidence, logic, or support.

Methodology

This research is development research that refers to Dick and Carey. Test the effectiveness of the SSGI learning model in a quasi-experimental pre-test and post-test group design. The experimental class used the 4th semester, which consisted of 30 students. Data on argumentation skills to solve complex problems were collected using a test consisting of 9 essay questions. The indicators measured in this study are listed in Table 1.

Table 1. Argumentation Skills Indicator

Indicator	Description
Claim	Ability to state a claim.
Evidence	Ability to show evidence in the form of facts/concepts/laws/principles/supporting claims.
Reasoning	Ability to provide logical reasoning relationships between claims and evidence.

Using the Aiken test, which involved eight experts, the content validity of the argumentation abilities to solve complex problem questions was evaluated. Nine questions are rated as good according to the validation results of the argumentation skills constructs for solving complex problems. Because the argumentation skills reliability test yielded a Cronbach's Alpha of 0.76, the argumentation skills instrument is deemed reliable.

The Shapiro-Wilk test results were used for the normalcy test, and the Levene test was used for homogeneity. With the aid of the SPSS software, the t-test analysis was used to test the effectiveness of the test. The normalized gain test was used to gauge how much students' ability to argue their way out of difficult situations had improved. The N-gain score is determined by the following formula:

$$N - gain = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score} \quad (1)$$

The results of the normalized gain calculation are interpreted using Table 2 (Hake, 2002).

Table 2. Interpretation of N-Gain Score

N-Gain Score	Criteria
$0.0 \leq \mathrm{N-Gain} < 0.3$	Low
$0.3 \leq \mathrm{N-Gain} < 0.7$	Medium
$\mathrm{N-Gain} > 0.7$	High

Using Cohen's formula, the extent to which the structured argumentation scaffolding enhanced the students' ability to use argumentation to solve complex problems was assessed. The following formula is used to determine Cohen's d value:

$$Cohen's\ d = \frac{(\bar{x}_1 - \bar{x}_2)}{s} \quad (2)$$

Table 3's effect size coefficient was interpreted based on the standards provided by Cohen (1988).

Table 3: Cohen's Interpretation of Effect Size

Effect Size (r)	Criteria
$0.0 \leq r < 0.2$	Low
$0.2 \leq r < 0.8$	Medium
$0.8 \leq r \leq 2.0$	High

The SSGI syntax correlation test to develop and improve argumentation skills to solve complex problems was analyzed using Partial Least Square (PLS) analysis.

Results

Results of Development of the SSGI Learning Model

The development of syntax for the SSGI learning model was developed from modifications to the POGIA syntax and the scaffolding method. Validation of the contents of the SSGI syntax development results has been carried out through Focus Group Discussion (FGD) activities. Suggestions for improvement from the Expert Team when validating of SSGI learning model are shown in Table 4.

Table 4. Suggestions and Follow-up to Improve the SSGI Learning Model

No	Aspect	Suggestion	Follow-up
1	The theoretical foundation of the model	The learning theory that supports the SSGI learning model must describe its implementation in the components of the SSGI learning model	Apply aspects of relevant learning theory for each SSGI syntax with the learning objectives to be achieved.
2	Model syntax	Find SSGI syntax distinctions that are compatible with STEM contexts.	Create a logical syntax to develop structured argumentation skills to solve complex problems.
3	Model supporting factors	It is necessary to study further the factors supporting the application of the SSGI learning model	Using the internet network to gather relevant information in solving complex problems.

SSGI syntax is reconstructed to facilitate the growth of argumentation skills in solving complex problems. The SSGI syntax that has been developed is shown in Table 5.

Table 5. SSGI Learning Model Syntax

Syntax	Description
Orientation	Preparing students to learn, namely: • Motivate activity and create interest. • Arouse curiosity and make connections to prior knowledge. • Identify the objectives and criteria for successful learning.
Exploration	Students have the opportunity to make observations, experiment, collect, examine, and analyze data or information, investigate relationships, and test hypotheses.
Reasoning	Reasoning using structured argumentation scaffolding to build and develop concepts: • Provide questions that force students to think critically and analytically. • Directing students to relevant information. • Lead students to appropriate connections and conclusions. • Help students build an understanding of the concepts being studied.
Closure	Learners validate the findings, reflect on what they have learned, and assess their performance.

Construct validity of the SSGI learning model based on the level of panelists' divergence on the indicators of developing the SSGI learning model. The results of the panelist divergence analysis can be seen in Table 6.

Table 6. Results of Panelist Divergence Analysis on the SSGI Learning Model

No	Model Development Indicators	Panelist						DS	IR	R	Decision		
		1	2	3	4	5	6				DS	IR	R
1	Clarity of model background	4	4	3	4	4	4	0.41	0	86%	Div	Div	Reliable
2	Clarity of model goals	4	4	4	4	4	4	0	0	100%	Div	Div	Reliable
3	Clarity of model benefits	3	4	4	4	4	4	0.41	0	86%	Div	Div	Reliable
4	Clarity of model ontology	4	4	4	4	4	3	0.41	0	86%	Div	Div	Reliable
5	Clarity of model epistemology	4	4	4	4	4	4	0	0	100%	Div	Div	Reliable
6	Clarity of model axiology	4	4	3	3	4	4	0.52	0.75	86%	Div	Div	Reliable
7	Clarity of model theoretical basis	3	4	4	4	4	3	0.52	0.75	86%	Div	Div	Reliable
8	Completeness of model components	4	4	4	4	4	4	0	0	100%	Div	Div	Reliable
9	Clarity of learning syntax	4	4	4	4	4	4	0	0	100%	Div	Div	Reliable
10	Clarity of social system	3	4	3	3	4	4	0.55	1	86%	Div	Div	Reliable
11	Clarity of reaction principle	4	4	3	4	4	4	0.41	0	86%	Div	Div	Reliable
12	Clarity of support system	3	4	4	3	4	3	0.55	1	86%	Div	Div	Reliable
13	Clarity of instructional and accompaniment impact	3	4	4	4	3	4	0.52	0.75	86%	Div	Div	Reliable

The result of the reliability test of the SSGI learning model obtained Cronbach's Alpha (α) = 0.82. Because the calculated value of Cronbach's Alpha (α) is more than 0.6, the SSGI learning model is Excellent Reliability.

Results of Testing Effectiveness of the SSGI Learning Model

Table 6 summarizes the results of the pre-test and post-test descriptive statistical analysis of argumentation skills to solve complex problems. The mean of the argumentation skills to solve complex problems in the post-test is higher than that of the pre-test. The standard deviation of the argumentation skills in the pre-test is higher than in the post-test.

Table 6. Descriptive Statistical of Argumentation Skills to Solve Complex Problems

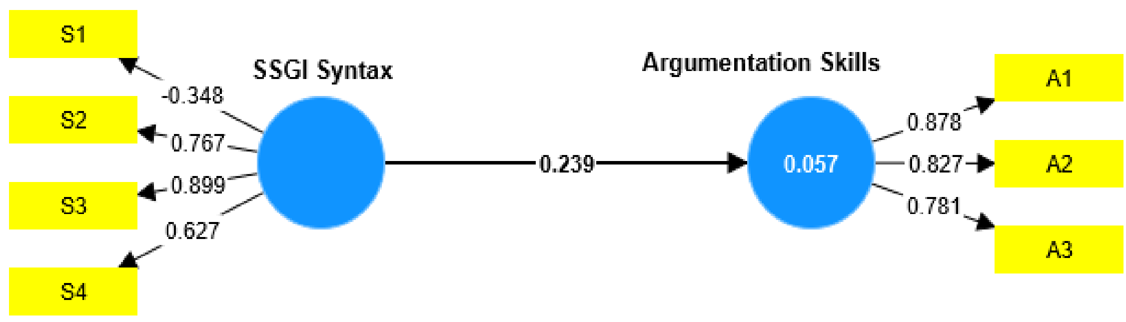
Data	Mean	N	Variance	Std. Deviation	Minimum	Maximum
Post-Test	74.57	30	117.03	10.81	52.00	96.00
Pre-test	39.00	30	181.20	13.46	11.00	70.00

The analysis prerequisite test results in Table 7 show that the data is normally distributed and homogeneous. The normality test of the data is indicated by the significance value of the Shapiro-Wilk test, both post-test and pre-test data more than 0.05, then the data is normally distributed. The homogeneity test of the data is indicated by the F-test value showing the post-test data and pre-test data are homogeneous.

Table 7. Data Analysis Results in Argumentation Skills to Solve Complex Problems

Test	Test type	Sig.	Decision
Normality	Shapiro-Wilk	Post-test: 0.420	Normal
		Pre-test: 0.354	Normal
Homogeneity	Uji-F	$F_{calculation}\ (1{,}31) < F_{Table}(2{,}40)$	Homogeneous
Difference	Uji-t	0.000	There is a difference
Effectiveness	*Effect size*	0.78	Medium

Table 7 shows that the significance of the t-test is less than 0.05, so H_0 is rejected. In other words, there is a significant difference in the mean of argumentation skills to solve complex problems before and after the application of SSGI. This is reinforced by the results of the descriptive statistical test in Table 6 which shows that the difference between the post-test and pre-test means is 35.5. The effect size coefficient value in table 7 is 0.78, indicating that SSGI effectively improves students' argumentation skills abilities. The increase in students' argumentation skills to solve complex problems was 7% in the high category, 57% in the medium category, and 36% in the low category.The results of the SSGI model syntactic relations test using PLS on the argumentation skills to solve complex problems indicator are shown in Figure 1.



[Note: S1 = Orientation, S1 = Exploration, S3 = Reasoning, S4 = Closure, A1 = Claim, A2 = Evidence, and A3 = Reasoning.]

Figure 1. The Relationship between the Syntax of the SSGI Model and the Indicator of Argumentation Skills to Solve Complex Problems

Figure 1 shows that the SSGI syntax that has the greatest contribution to growing argumentation skills to solve complex problems is the reasoning syntax with a correlation coefficient of 0.899. Exploratory syntax has a contribution of 0.767 with a high category as well, closure syntax gives a moderate contribution of 0.627, and syntax that contributes the least is orientation syntax of -0.348. All indicators of argumentation skills to solve complex problems have a very high increase because their factor loading value is above 0.7.

Discussion

The orientation syntax is carried out to stimulate students' interest and curiosity related to the problem at hand. In this phase, learning topics are introduced by educators or defined by students (Scanlon et al., 2011). In this phase, educators prepare students to solve problems by providing problem-solving instructions, identifying the main variables, and directing students to prepare relevant basic concepts for solving problems. The result of this phase is the emergence of problem questions and hypotheses.

The questions asked can lead students to make an observation or investigation. Questions about natural phenomena, the application of concepts learned in science and technology, and social conditions need to be developed in the orientation process to generate curiosity and motivate students. Orientation questions should be started with brainstorming to map the concept from the basic concept to the application of the concept in solving a problem. Being challenged by students with the concepts being studied is very useful for creating appropriate technology or problem-solving in everyday life, making students more enthusiastic about learning the material being studied.

The exploration syntax is carried out by guiding students to collect information from relevant sources and carry out investigations to find relationships between the variables involved. In this phase, students can conduct experiments, collect data, and investigate relationships between variables. The goal of the exploration syntax is to strengthen students' foundational conceptual understanding.

Data in the exploration process can be obtained in the form of real data and virtual data. Real data is obtained by directly observing the object in an experimental design or in the field. Real data can be observed when we study concepts that can be observed concretely. For microscopic data and abstract concepts, it is not possible to observe directly with the five senses in nature, so modeling or simulation is needed. Modeling, for example, observing modeling drawings of atomic theory while simulations, for example observing the movement of electrons using PhET.

Exploration activities in addition to obtaining data can also be carried out to obtain information from a reading. To get information in reading effectively and efficiently, students need to be trained to do skimming and scanning in reading literature. Initial information about something that is being studied is very important for students as a provision for brainstorming in designing solutions to a problem assigned to learning activities. This initial information serves as a schema for adapting information or data to be studied later.

Reasoning syntax is the phase where the synthesis of new knowledge from research has been done (de Jong, 2006). The reasonings to make meaning from the data collected. In this phase, students discuss questions or research hypotheses and consider whether the problem formulation is answered with sufficient and appropriate evidence (Scanlon et al., 2011). The results of this phase are concept building and concept development by directing students to use relevant information and guiding students to make appropriate conceptual connections and conclusions. The reasoning syntax orientation is to develop basic concepts that have been built on exploratory syntax in the STEM context, in this case, the context of endoscopy. Students are trained to argue to solve complex problems which are the application of the basic science concepts they have learned.

The ability to process information/data through reasoning and rational thinking is an important competency that must be possessed by students. Data or information obtained from exploration activities must be processed to find the linkage of one piece of information with other information, find patterns of interrelationships from the information, and draw conclusions from the patterns found.

Processing information requires the ability of logic or reasoning. Reasoning is a special mental activity in making inferences. The inference is drawing conclusions based on opinions (premises), data, facts, or information. Processing of information based on the scientific method through empirical reasoning based on inductive and deductive logic. Inductive reasoning uses specific evidence such as facts, data, information, and opinions from experts as a reference for making a conclusion. Inductive reasoning can use generalizations, analogies, causal relationships, and reasoning based on characteristics or signs. Deductive reasoning is reasoning that uses advanced logic based on general observations (major premise) to specific observations (minor premise) that lead to specific conclusions.

Efforts to train students to reason can be done by asking them to analyze the data they have obtained so that they find relationships between variables, explain data based on existing theories, test hypotheses that have been proposed, and make conclusions, develop concepts that have been learned in new contexts, relating to the application of the concept being studied.

The closure syntax is the process of presenting problem-solving products to others to get feedback from them. Feedback is used as material for reflection to assess what they have produced. Through reflection activities, the success of the learning process can be increased (Moon, 2013; Chang, 2019). To optimize the achievement of instructional impact and the impact of accompaniment learning, learning activities in the SSGI learning model are designed by taking into account Vygotsky’s theory (1997) concerning the zone of proximal development of students through the application of structured argumentation scaffolding techniques. Associating learned concepts with the context of more complex problems in the SSGI learning model refers to meaningful learning theory, which is a process of associating new information with relevant concepts contained in a person's cognitive structure. Information and ideas previously obtained can be incorporated into cognitive structures and generate meaning (Ausubel, 1965). The independence of students in constructing concepts and solving complex problems in the SSGI learning model refers to the andragogical learning theory initiated by Knowles (1977) which states that learning should help students increase independence in learning.

There is a significant difference in the mean of argumentation skills to solve complex problems before and after the application of SSGI. The average argumentation skills to solve complex problems after the application of SSGI (post-test scores) were higher than the pre-test scores. This shows that SSGI is effective in improving students' argumentation skills to solve complex problems. The size of the impact of SSGI in improving argumentation skills to solve complex problems in the medium category because the effect size value is 0.78. The results of this study are in line with the results of research by Podolefsky & Finkelstein (2007) which shows that the model of analogical scaffolding posted substantially greater gains than students taught using a more traditional-based tutorial.

The pre-service teachers' argumentation skills improved after learning with e-scaffolding in blended learning (Amelia, 2020). The students' argumentation skills ability significantly increased after they experienced blended physics learning with e-scaffolding (Oktavianti et al., 2018). The scaffolding will help ensure that the children have the knowledge and skills to be able to write their texts with confidence (Gibbons, 2002). Scaffolding can support students' efforts to address learning needs and refine their understanding as well as strengthen faulty assumptions or incomplete understanding (Sharma & Hannafin, 2007). The scaffolding set helped students explain the biochemistry aspects and context of Socio Scientific Issues (Erman, et al., 2022).

The scaffolding on SSGI learning model refers to Vygotsky's theory, namely learning that occurs when students work or learn to complete tasks that have not yet been studied but these tasks are in the zone of proximal development (ZPD) or development slightly above the student's current development. The essence of scaffolding is to provide a large amount of assistance to students during the early stages of learning, then little by little the assistance is reduced until the student can complete the tasks on his own. The assistance given to students can be in the form of instructions, warnings, encouragement, explaining problems, providing examples, or other things that enable students to learn independently.

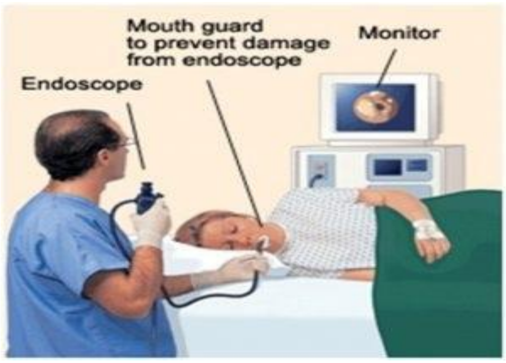
The key characteristics of scaffolding consist of (1) Recruitment, namely recording student interest and compliance with the requirements of the tasks given. (2) Reduction in degrees of freedom, namely simplifying the task so that feedback can be used for correction. (3) Direction maintenance, (providing verbal encouragement and correction) to keep students achieving certain goals. (4) Marking critical features, (confirming and checking) emphasizing something and interpreting errors. (5) Frustration control, namely responding to emotions expressed by students. (6) Demonstration, namely modelling the solution to a task.

The SSGI guides students to elaborate on the concept of total internal reflection and the context of endoscopic technology as shown in Figure 2. Structured argumentation scaffolding in this case relates to the analysis of the concept of total internal reflection in the context of endoscopic technology. The ability of students to answer claims in the case is 79% of students who submit claims very accurately and 21% who submit claims incorrectly. The ability of students to present evidence to support the claim in the case is 64% very accurately, 15% with accuracy, and 21% with less accuracy. The ability of students to propose reasons to connect between claims and evidence in case number 2 is 50% very accurately and 50% in a very precise way.

Instruction case number 2a aims to train the ability of students to submit their claims to the concept of signal transmission in endoscopic technology. After understanding the concept of total internal reflection, students can make claims that the concept used to transmit signals in endoscopic technology is the concept of total internal reflection. An example of an answer to a claim against the concept of total internal reflection in endoscopic technology is "the concept of total internal reflection."

Instruction case number 2b aims to train the student to show evidence of justification for the claims submitted in question number 2a. The construction of endoscopic technology has a core refractive index value greater than the cladding refractive index, allowing total internal reflection to occur in endoscopic technology. An example of an answer to submit evidence to support the claim of the concept of total internal reflection in endoscopic technology is "the endoscope contains a camera and a small light source as well as a porous fiber placed in a flexible bundle."

Endoscopic technology is the application of fiber optics in medical science. The doctor can see the inside of the patient's arteries through the camera. The results of the diagnosis are shown in the figure.



Source: https://rsbedahsiaga.co.id

Light entered from the outer end of an optical fiber undergoes total internal reflection within the optical fiber. When light reaches the inner end of the optical fiber, the interior of the artery is illuminated. Some of the light reflected from the interior then returns out through a second optical fiber whose outer end is equipped with a small camera. The signal captured by the second optical fiber is converted into an image on the monitor screen.

a. What concepts are used as the basis for the working principle of the endoscope?
b. Show evidence in the form of facts/concepts/laws/principles to support your claim!
c. Explain the logical reasons that can link between the claims and the evidence you put forward!

Figure 2. Endoscopic Technology Context

Instruction case number 2c aims to train students' ability to make logical reasoning of the relationship between the claim and the evidence that has been submitted. By the occurrence of total internal reflection along the optical fiber in endoscopy technology so that no light is refracted. Examples of students' reasons for linking claims and evidence on the concept of total internal reflection and endoscopic technology are

> *"Doctors can see the inside of a patient's artery by running two fiber-optic beams through the chest wall and into the artery. Light entered at the outer end of one beam undergoes repeated total internal reflection within the fiber so that most of the light eventually exits from the other end and illuminates the interior of the artery. Some of the light reflected from the interior then returns to the second bundle, where it is detected and converted into an image on the monitor screen."*

The social system of the guided inquiry learning model is centered on students, where educators act as guides, facilitators, motivators, and mediators. The role of the educator is an activity that describes how educators treat and respond to students (Effendi & Fatimah, 2019). Using the scaffolding and working within the student's Zone of Proximal can develop a structured adult intervention that increases the effectiveness of learning (Coltman et al., 2002). Vygotsky is of the view that there is a need for other learning resources to make it easier for students to learn according to the capacity of students which is given the term Zone of Proximal Development (ZPD) or the closest development zone (Santrock, 2018. Assistance provided by educators can be in the form of instructions, warnings, encouragement, and outlining problems in other forms that allow students to be independent in learning. Yang and Wang's (2014) research showed that students in the teaching model for scaffolding better than students in the comparison group. Learning using scaffolding has advantages, namely: (1) Scaffolding strategies to facilitate ongoing articulation of ideas, findings, and interpretations; (2) Scaffolding strategies to support explanation building and development of working hypotheses; and (3) Scaffolding strategies to facilitate monitoring, reflection, and revision (Land & Zembal-Saul, 2003).

It is imperative that students acquire the ability to construct argumentation skills that encompass the elements of cause and effect, evidence-based reasoning, and logical reasoning (NRC, 2008). Certain traits distinguish science argumentation skills: (1) they are typically deeper, more methodical, and more accurate than explanations based on common sense; and (2) they seek to comprehend phenomena by taking into account additional scientific facts or developing novel theories to explain the behavior of newly discovered phenomena (Osborne & Patterson, 2011). Students need scaffolding, while teachers need scaffolding set to aid their students in science teaching and learning to scientifically explain (Erman, et al., 2022). To empower students' ability to explain scientifically, educators must strive to empower critical thinking skills to explain science through the habituation of science questions (Sidiq, et al., 2021). Educators need to improve professionalism in guiding students in improving argumentation skills by mastering Pedagogical Content Knowledge (Anif and Zain, 2015; Agustina, 2015). In addition, the success of increasing argumentation skills is also determined by the seriousness and motivation of students in carrying out scaffolding instructions given by educators. Students who are highly motivated get better learning outcomes than students whose learning motivation is in the low category (Nurcahyanto, 2022).

Students' ability to solve complex problems through argumentation can be enhanced by the reasoning syntax of SSGI. Students come to conclusions about conceptual or causal relationships through the process of self-explanation (Bisra et al., 2018). Self-explanation aids in the organization of ideas into comprehensive knowledge, makes it easier for students to comprehend ideas in their entirety, and teaches them how to retrieve knowledge that has been committed to long-term memory (Tekeng, 2015). The ability to solve physics problems well will depend on one's ability to argue persuasively (Badeau, et al., 2017). The results of research by Weng, Lin, & She (2017) show that both the online learning process and scientific argumentation assessment results indicated that the continuous scaffolding group performed significantly better in terms of the quality and quantity of argumentation than the withdraw scaffolding group about the hypothetical biology concepts. The web-based reflective scaffolding supported students in providing valid evidence in support of their explanations (Kyza, Constantinou, & Spanoudis, 2011).

Understanding concepts and logical reasoning abilities using argumentation skills will affect the ability to solve more complex physics problems. Problem-solving abilities involve complex cognitive activities to obtain information and organize it in the form of knowledge structures. Before students obtain and organize information, they can be started by exploring the sources of knowledge of students. Learning models for understanding and applying concepts in solving physics problems need to empower finding sources of information, practice categorizing questions, be self-explanatory, and compare analogies using work examples (Sujarwanto, 2019). The syntax of SSGI also improves self-awareness and empathy skills in solving complex problem processes. The impact of accompanying learning includes communication, self-awareness, empathy skills, and feedback proficiency (Le et al., 2024).

Conclusion

The study's conclusions show that the SSGI develops and strengthens students' ability to argue their way through challenging situations. The reasoning syntax in SSGI is the one that most helps with developing argumentation abilities to tackle challenging problems. Syntax exploration, closure, and orientation follow next. Students' ability to solve complex problems through argumentation increased by 7% in the high category, 57% in the medium category, and 36% in the low category. The effect size coefficient of the SSGI is 0.78 in the medium category. SSGI can foster argumentation skills to solve complex problems because the SSGI syntax is constructed based on a learning theory base linking what concepts have been learned with the STEM context, helping students to learn to be more independent in solving complex problems.

References

Agustina, Dua, Kuki., Rudiana, Agustini., Utiya, Azizah. (2023). Analysis of Effectiveness of Argument-Driven Inquiry to Improve Students’ Argumentation Skill and Conceptual Understanding. IJORER. http://dx.doi.org/10.46245/ijorer.v4i3.316

Agustina, P. (2015). Pengembangan PCK (Pedagogical Content Knowledge) Mahasiswa Calon Guru Biologi FKIP Universitas Muhammadiyah Surakarta Melalui Simulasi Pembelajaran. Jurnal penelitian dan pembelajaran IPA, 1(1), 1-15.

Al-Labadi, L., & Sant, S. (2021). Enhance learning experience using technology in class. *JOTSE: Journal of Technology and Science Education*, *11*(1), 44-52.

Amelia, R., Rofiki, I., Tortop, H. S., & Abah, J. A. (2020). Pre-service teachers’ scientific explanation with e-scaffolding in blended learning. *Jurnal Ilmiah Pendidikan Fisika Al Biruni* [*Scientific Journal of Physics Education Al Biruni*,], *9*(1), 33-40. *https://doi.org/10.24042/jipfalbiruni.v9i1.5091*

Anif, S., & Zain, A. (2015). Efektivitas model peningkatan kompetensi profesional guru biologi berbasis Continuous Professional Development (CPD) di Karesidenan Surakarta [The effectiveness of the model for increasing the professional competence of biology teachers based on Continuous Professional Development (CPD) in the Surakarta Residency]. *Jurnal Varidika* [*Varidika Journal*], *27*(2), 162-173. https://doi.org/10.23917/varidika.v27i2.1877

Ausubel, D. P. (1965). Perception versus cognition in meaningful verbal learning. *The Journal of General*

Psychology, *73*(2), 185-187.

Azzahro, R. (2018). *Analisis penguasaan konsep dan kesulitan siswa* yang *belajar dengan model inkuiri terbimbing disertai dengan formative feedback pada materi hukum Newton* [Analysis of concept mastery and difficulties of students who learn with the guided inquiry model accompanied by formative feedback on Newton's law material] (Doctoral dissertation, Universitas Negeri Malang). Universitas Negeri Malang Repository. ttp://repository.um.ac.id/id/eprint/18874

Badeau, R., White, D. R., Ibrahim, B., Ding, L., & Heckler, A. F. (2017). What works with worked examples: Extending self-explanation and analogical comparison to synthesis problems. *Physical Review Physics Education Research*, *13*(2), 020112. https://doi.org/10.1103/PhysRevPhysEducRes.13.020112

Bisra, K., Liu, Q., Nesbit, J. C., Salimi, F., & Winne, P. H. (2018). Inducing self-explanation: A meta-analysis. *Educational Psychology Review*, *30*(3), 703-725. https://doi.org/10.1007/s10648-018-9434-x

Buckwalter, W., & Turri, J. (2016). Perceived weaknesses of philosophical inquiry: A comparison to psychology. *Philosophia*, *44*(1), 33-52. https://doi.org/10.1007/s11406-015-9680-9

Bybee, R. W., Carlson-Powell, J., & Trowbridge, L. W. (2008). *Teaching* secondary *school science: Strategies for developing scientific literacy*. Columbus: Pearson/Merrill/Prentice Hall.

Calliste, Scheibling-Seve., Elena, Pasquinelli., Emmanuel, Sander. (2020). Assessing conceptual knowledge through solving arithmetic word problems. Educational Studies in Mathematics. https://doi.org/10.1007/S10649-020-09938-3

Chang, B. (2019). Reflection in learning. *Online Learning*, *23*(1), 95-110. https://doi.org/10.24059/olj.v23i1.1447

Coltman, P., Petyaeva, D., & Anghileri, J. (2002). Scaffolding learning through meaningful tasks and adult interaction. *Early Years: An International Journal of Research and Development*, *22*(1), 39-49. https://doi.org/10.1080/09575140120111508

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (*2nd *ed.)*. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

De Jong, T. (2006). Technological advances in inquiry learning. *Science*, *312*(5773), 532-533. https://www.science.org/doi/full/10.1126/science.1127750

De Sandoval, W. A. (2009). Conceptual and epistemic aspects of students' scientific explanations. *The journal of the learning sciences*, *12*(1), 5-51. https://doi.org/10.1207/S15327809JLS1201_2

Englund, C., Olofsson, A. D., & Price, L. (2017). Teaching with technology in higher education: understanding conceptual change and development in practice. *Higher Education Research & Development*, *36*(1), 73-87.

Effendi, A. & Fatimah, A.T. (2019). Implementasi model pembelajaran creative problem solving untuk siswa kelas awal sekolah menengah kejuruan [Implementation of creative problem-solving learning models for early grades of vocational high schools]. *Teorema: Teori dan Riset Matematika* [*Theorems: Mathematical Theory and Research*], 4(2), 89-98. http://dx.doi.org/10.25157/teorema.v4i2.2535

Erman, E., Pare, B., Susiyawati, E., Martini, M., & Subekti, H. (2022). Using scaffolding set to help students addressing socio-scientific issues in biochemistry classes. *International Journal of Instruction*, *15*(4). https://doi.org/10.29333/iji.2022.15447a

Flick, L. B., & Lederman, N. G. (2004). *Scientific Inquiry and Nature of Science*. Kluwer Academic Publishers. https://doi.org/10.1007/978-1-4020-5814-1

Gibbons, P. (2002). *Scaffolding language, scaffolding learning*. Portsmouth, NH: Heinemann

Gott, R., & Duggan, S. (2007). A framework for practical work in science and scientific literacy through argumentation. International Journal of Phytoremediation, 25(3), 271–291. https://doi.org/10.1080/02635140701535000

Hale, D., & Mullen, L. G. (2009). Designing process-oriented guided-inquiry activities: A new innovation for marketing classes. *Marketing Education Review*, *19*(1), 73-80. https://doi.org/10.1080/10528008.2009.11489063

Hake, R. R. (1998). Interactive engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74. https://doi.org/10.1119/1.18809

Hsu, C. C., Chiu, C. H., Lin, C. H., & Wang, T. I. (2015). Enhancing skill in constructing scientific explanations using a structured argumentation scaffold in scientific inquiry. *Computers & Education*, *91*, 46-59. https://doi.org/10.1016/j.compedu.2015.09.009

Jackson, C. D., & Mohr-Schroeder, M. J. (2018). Increasing STEM literacy via an informal learning environment. *Journal of STEM Teacher Education*, 53(1), 4.

Jiménez, M. M. B., Ríos, I. D. M., Bonilla, A. M. S., & Gámez, M. R. (2023). Teaching Strategies Against Artificial Intelligence in the Learning of 21st Century Students. Journal of Law and Sustainable Development, 11(9), e1635-e1635.

Johns, G., & Mentzer, N. (2016). STEM integration through design and inquiry. *Technology and engineering teacher*, 76(3), 13.

Jumaisa, J. (2020). Model pilihan pembelajaran, inquiry atau expository? [Learning choice model, inquiry or expository?] *Jurnal Ilmiah Mandala Education* [*Mandala Education Scientific Journal*] , *6*(2), 339-348. http://dx.doi.org/10.58258/jime.v6i2.1441

Kathryn, Rupp., Karyn, Higgs., M., Anne, Britt., Steven, McGee., Randi, Mcgee-Tekula., Kathleen, M., Easley. (2022). Scaffolding Scientific Argumentation in a Science Inquiry Unit. http://dx.doi.org/10.51420/conf.2022.2

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International*, 25(3), 246-258.

Knowles, M. (1977). Adult learning processes: Pedagogy and andragogy. *Religious Education*, *72*(2), 202-211.

Kyza, E. A., Constantinou, C. P., & Spanoudis, G. (2011). Sixth graders' co-construction of explanations of a disturbance in an ecosystem: Exploring relationships between grouping, reflective scaffolding, and evidence-based explanations. *International Journal of Science Education*, *33*(18), 2489-2525. https://doi.org/10.1080/09500693.2010.550951

Land, S. M., & Zembal-Saul, C. (2003). Scaffolding reflection and articulation of scientific explanations in a data-rich, project-based learning environment: An investigation of progress portfolio. *Educational Technology Research and Development*, *51*(4), 65-84. https://doi.org/10.1007/BF02504544

Le, S. Q., Le, D. T., Bui, D. T. T., & Tran, B. X. (2024). A Ability to advise and support students in educational activities of primary school teachers. *Journal of Law and Sustainable Development*, *12*(1), e2258-e2258.

Ludascher, P., Greffrath, W., Schmahl, C., Kleindienst, N., Kraus, A., Baumgartner, U., ... & Bohus, M. (2009). A cross-sectional investigation of discontinuation of self-injury and normalizing pain perception in patients with a borderline personality disorder. *Acta Psychiatrica Scandinavica*, *120*(1), 62-70. https://doi.org/10.1111/j.1600-0447.2008.01335.x

Masooma, Ali, Al-Mutawah., Ruby, Thomas., Abdulla, Eid., Enaz, Yousef, Mahmoud., Moosa, Jaafar, Fateel. (2019). Conceptual Understanding, Procedural Knowledge and Problem-Solving Skills in Mathematics: High School Graduates Work Analysis and Standpoints. International Journal of Education. https://doi.org/10.18488/JOURNAL.61.2019.73.258.273

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences*, 15(2), 153-191. https://doi.org/10.1207/s15327809jls1502_1

Moon, J. A. (2013). *Reflection in learning and professional development: Theory and practice*. London: Kogan Page Limited.

National Research Council. (2008). *Inquiry and The National Science* Education *Standards: A guide for teaching and learning*. National Academies Press.

Neni, Hasnunidah., Herawati, Susilo., Mimien, Henie, Irawati., Hadi, Suwono. (2022). Student conceptual and epistemic quality improvement argumenation with scaffolding on argument-driven inquiry. Jurnal Kependidikan. http://dx.doi.org/10.21831/jk.v6i2.48183

Nersessian, N. J. (2010). *Creating Scientific Concepts*. Cambridge: MIT Press.

Nurcahyanto, G. (2022). Eksperimentasi model pembelajaran blended learning menggunakan open learning dan classrom lesson ditinjau dari motivasi belajar terhadap hasil belajar mahasiswa [Experimentation of blended learning learning models using open learning and classrom lessons in terms of learning motivation on student learning outcomes]. *Jurnal Penelitian Sains Teknologi* [*Journal of Technology Science Research*], *13*(2), 1-12. https://doi.org/10.23917/saintek.v13i2.1081

Oktavianti, E., Handayanto, S. K., Wartono, W., & Saniso, E. (2018). Students’ scientific explanation in blended physics learning with e-scaffolding. *Jurnal Pendidikan IPA Indonesia* [*Journal of Indonesian Science Education*], *7*(2), 181-186. https://doi.org/10.15294/jpii.v7i2.14232

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), 994-1020. https://doi.org/10.1002/tea.20035

Osborne, J. F., & Patterson, A. (2011). Scientific argument and explanation: A necessary distinction? *Science Education*, *95*(4), 627-638. https://doi.org/10.1002/sce.20438

Pedaste, M., Mäeots, M., Leijen, Ä., & Sarapuu, T. (2012). Improving students’ inquiry skills through reflection and self-regulation scaffolds. *Technology, Instruction, Cognition, and Learning*, *9*(1-2), 81-95.

Podolefsky, N. S., & Finkelstein, N. D. (2007). Analogical scaffolding and learning abstract ideas in physics: An example from electromagnetic waves. *Physical Review Special Topics-Physics Education Research*, *3*(1), 010109. https://doi.org/10.1103/PhysRevSTPER.3.010109

Reiser, B. J. (2018). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. In *The Journal of the Learning Sciences* (pp. 273-304). Psychology Press.

Restina, Muji, Mulyati., Sunyoto, Eko, Nugroho., Sulhadi, Sulhadi. (2020). Conceptual Problem Solving and Student's Empirical Inductive Reasoning in Elasticity Subject. https://doi.org/10.15294/PHYSCOMM.V4I1.26408

Sally, Baricaua, Gutierez. (2023). Alignment of Teachers’ Epistemic Understanding and Intended Dialogic

Scaffolding of Classroom argumentation: Implications on Face-to-Face, Open and Distance Learning Environments. International journal on open and distance e-learning. http://dx.doi.org/10.58887/ijodel.v8i2.97

Santrock, J. W. (2018). *Educational Psychology Sixth Edition*. McGraw-Hill Education.

Scanlon, E., Anastopoulou, S., Kerawalla, L., & Mulholland, P. (2011). How technology resources can be used to represent personal inquiry and support students' understanding of it across contexts. *Journal of Computer Assisted Learning*, *27*(6), 516-529. https://doi.org/10.1111/j.1365-2729.2011.00414.x

Sharma, P., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive learning environments*, *15*(1), 27-46. https://doi.org/10.1080/10494820600996972

Sidiq, Y., Ishartono, N., Desstya, A., Prayitno, H. J., Anif, S., & Hidayat, M. L. (2021). Improving elementary school students' critical thinking skill in science through HOTS-based science questions: A quasi-experimental study. *Jurnal Pendidikan IPA Indonesia* [*Journal of Indonesian Science Education*], *10*(3), 378-386. https://doi.org/10.15294/jpii.v10i3.30891

Strevens, M. (2008). *Depth: An Account of Scientific Explanation*. Harvard University Press.

Sujarwanto, E. (2019). Pemahaman konsep dan kemampuan penyelesaian masalah dalam pembelajaran fisika [Understanding of concepts and ability to solve problems in learning physics]. *Diffraction*, *1(1)*, 22-33. https://doi.org/10.37058/diffraction.v1i1.806

Tekeng, S. N. Y. (2015). Using a self-explanation strategy to improve students' understanding of the to-be-learned material. *Auladuna*, 2(2): 173-184.

Toulmin, S. E. (2003). The uses of argument. Cambridge: Cambridge University Press.

Trianto, I. B., & Ibnu, B. (2014). *Mendesain Model Pembelajaran Inovatif, Progresif, dan Kontekstual* [Designing Innovative, Progressive and Contextual Learning Models]. Jakarta: Prenadamedia Group.

Vygotsky, L.S. (1997). *Educational Psychology*. Boca Raton, Florida: St. Lucie Press.

Wang, C. Y. (2015). Scaffolding middle school students' construction of scientific explanations: comparing a cognitive versus a metacognitive evaluation approach. International Journal of Science Education, 37(2), 237-271. https://doi.org/10.1080/09500693.2014.979378

Weng, W. Y., Lin, Y. R., & She, H. C. (2017). Scaffolding for argumentation in hypothetical and theoretical biology concepts. *International Journal of Science Education*, *39*(7), 877-897. https://doi.org/10.1080/09500693.2017.1310409

Xian, Wu., Tianlong, Zu., Elise, Agra., N., Sanjay, Rebello. (2015). Effect of Problem Solutions on Students' Reasoning Patterns on Conceptual Physics Problems. https://doi.org/10.1119/PERC.2014.PR.066

Yang, H. T., & Wang, K. H. (2014). A Teaching model for scaffolding 4th-grade students' scientific explanation writing. *Research in Science Education*, *44*(4), 531-548.

https://doi.org/10.1007/s11165-013-9392-8

Yeh, K.H., & She, H.C. (2010). Online synchronous scientific argumentation learning: nurturing students' argumentation ability and conceptual change in a science context. *Computers & Education*, 55(2), 586-602. https://doi.org/10.1016/j.compedu.2010.02.020

Yeo, J., & Gilbert, J. K. (2014). Constructing a scientific explanation: A narrative account. *International Journal of Science Education*, *36*(11), 1902-1935. https://doi.org/10.1080/09500693.2014.880527

Yessi, Affriyenni., Arif, Hidayat., Galandaru, Swalaganata. (2020). Conceptual understanding and problem-solving skills: the impact of hybrid learning on mechanics. https://doi.org/10.29100/EDUPROXIMA.V2I2.1626

Zhao, R, & Orey, M. (1999). *The Scaffolding Process: Concepts, Features, and Empirical Studies*. University of Georgia.

Author Information

Muhammad Nasir	**Annur Indra Kusumadani**
http://orcid.org/0000-0003-0245-4033	https://orcid.org/0009-0004-5815-2119
Physics Education	Biology Education
Institut Agama Islam Negeri Palangka Raya	Universitas Muhammadiyah Surakarta
Indonesia	Indonesia
Contact e-mail: *nasir@iain-palangkaraya.ac.id*	