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Effectiveness of Scaffolding Worksheet on Students' Scientific Explanation Skills in Static Electricity and Application to Living Things

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Abstract: This study conducted a quasi experiment to investigate the effectiveness of scaffolding worksheet on students' scientific explanation. A total of 30 participants were randomly assigned into two groups. One class is the experimental class that received of scaffolding worksheet and one other class as the control class. The comparative analysis results revealed that scaffolding explanation worksheets are effective in improving students' science explanation skills. The average score of scientific explanation of students in experimental class and control class is 69.10 and 53.00. Regarding the SOLO taxonomic classification, in spite of the fact that the experimental class students on average exceeded the control class students, it can be seen that some students in the experimental class were still at the prestructural and unistructural levels. The incorrect timing to remove scaffolds and misusage of scaffolding worksheet were two possible reasons behind the failure of fading scaffolding practice.

Keywords: Fading scaffolding; Scaffolding worksheet; Science explanation skills

Introduction

Next Generation Science Standards (NGSS) argues that one of the main goals of science education is to prepare students to synthesize and evaluate scientific explanations (National Research Council, 2012). PISA Framework (Programe for International Student Assessment (OECD, 2013) explicitly states that the learning objectives are to develop students' ability to construct and interpret evidence-based explanations of the world of science and models, and to evaluate their own or others' explanations by assessing logical relationships between evidence and conclusions. (Wang, 2015). At school, students make explanations for various purposes, for example to gain understanding by explaining phenomena to themselves; for personal understanding of explanations obtained from textbooks, or teachers, or informal sources; and to produce answers to questions based on their understanding of a scientific phenomenon, posed by the teacher orally or in writing in exams (Yeo & Gilbert, 2014). Scientific explanation plays a central role in a person's quest to know and understand the world, and to study, understand, and communicate scientific phenomena (Zacharia, 2005). Skills in building reasonable scientific explanations can change the epistemic view of science and in scientific investigations give a person a good experience (McNeill, et al., 2006).

Functional linguists have identified four main genres in science (Halliday, 1993). These genres and their functions are: (a) experimental reports – to present experimental procedures and results, (b) information reports – to organize information about things or events in the world, mainly through classification, decomposition, description, or comparison, (c) argument – to state a claim or position and present supporting evidence to support the claim or position, and (d) explanation – to explain the underlying cause or process of a phenomenon. Although engaging in science explanation is an important learning goal for students,

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students often have difficulty articulating and retaining their knowledge (Sadler & Zeidler, 2009). Even in a classroom learning where science explanation is an explicit goal, there are still many students who have difficulty. Research that has been done regarding explanations built by students shows that students' explanations are often different from explanations built by the scientific community (McNeil, 2008). In the analysis of explanations built by students, it was found that the types of explanations constructed were different from causal explanations, which were produced by established science, generally students' explanations were driven by formulas or intuitive (Kapon et al., 2010). Even chemistry students with good mastery in writing chemical symbols are not able to develop explanations related to chemical reaction mechanisms successfully (Hand & Choi, 2010). The ability of children and adults to construct explanations does not appear naturally, it is evident that students have difficulty using appropriate evidence (Sandoval, 2003). Students also have difficulty providing sufficient evidence for their claims (Sandoval & Millwood, 2005) and the most frequent difficulty students experience is when students have to use the principles of science to justify the evidence that supports claims (McNeill et al., 2006)

Several strategies have been carried out to improve the ability of scientific explanation. On the use of computer simulation with the application of models Predict–Observe–Explain proven to have a positive impact on the nature and quality of science teacher explanations that explain physical phenomena. In addition, the teacher's explanation becomes more detailed, which reflects cause-and-effect reasoning and formal reasoning (Zacharia, 2005). With the mediation of a holistic learning model, the competence of high school students in synthesizing scientific explanations has increased. It is also proven that the learning practices carried out by teachers in introducing scientific explanations have been proven to affect students' ability to build scientific explanations in chemistry learning (McNeill, 2006). Motivating students to ask questions to be able to think deeply has been used to improve the quality of scientific explanation (Chin & Osborne, 2010). In research on the effect of scaffold as a cognitive guide through learning Cognitive Prompts and Metacognitive Evaluation Instruction Scaffolding Designs proven to be able to improve the construction of scientific explanations and content knowledge of seventh graders in inquiry-based biology learning (Wang, 2015). Through the implementation of the POGIL (Process Oriented Guided Inquiry Learning) inquiry model in the context of social-scientific issues (SSI), the complexity of students' scientific explanations in the experimental class can reach the extended abstract level (Mahanani, Rahayu & Fajaroh, 2019).

To help students be able to practice science explanation, Tang (2016) developed a learning strategy that aims to support students in building science explanations. The proposed learning strategy, Premise-Reasoning-Outcome (PRO), is conceptualized based on an understanding of the structure of scientific explanation, which consists of three main components: (a) premise, namely the received knowledge that provides the basis for explanation, (b) reasoning, which is a logical sequence that follows premise, and (c) outcome, which is a phenomenon. The PRO structure is very similar to the use of writing frames and it was used during intervention research whenever students wrote an explanation on any topic (Tang, 2016). A writing frame is a template that contains sentence beginners, key language information, connectives links, and sentence modifiers that collectively work together and provide a skeleton outline to scaffold writing and provide a view of the overall writing tasks (Wellington & Osborne, 2001).

To facilitate learner comprehension and reflection on complex tasks, researchers have been investigating the role of instructional scaffolds (Palincsar & Brown, 1984). The zone of proximal development (ZPD) is based for the construct of scaffolding (Vygotsky, 1978). In ZPD concept learners are assisted by a "more knowledgeable other" in solving problems and/or accomplishing tasks that they otherwise would not have been able to do. Scaffolding can generally be classified into two groups, namely hard and soft (Saye and Brush, 2002). Soft scaffolding refers to the teacher's actions in responding to the learner's efforts when the learner has specific needs. Hard scaffolding generally supports static which can be developed based on student difficulties before the assignment is given (Saye and Brush, 2002). Hard scaffolding can be in the form of computer or paper-based cognitive tools eg. worksheet. For the purposes of this research, scaffolding is defined as as worksheet features that support students in performing tasks that they would otherwise have been unable to accomplish and in learning from that experience.

There are three characteristics to be the center of scaffolding: a) Contingencies: teachers adjust their support to students; b) Fading: the gradual withdrawal of the scaffolding; c) Transfer of responsibility: the responsibility of transferring the teacher to students (Van de Pol et al., 2015). Fading a process of gradual reduction of support: scaffolding is not constant but can be removed or withdrawn. By fading the scaffolds provided by the teacher the student was able to obtain more ownership and responsibility over the task (McNeill, et a, 2006). Fading is another area that is largely ignored in the research of scaffolding (Puntambekar & Hubscher, 2005). In a few studies, fading was discussed, but it was never tested (Cho &

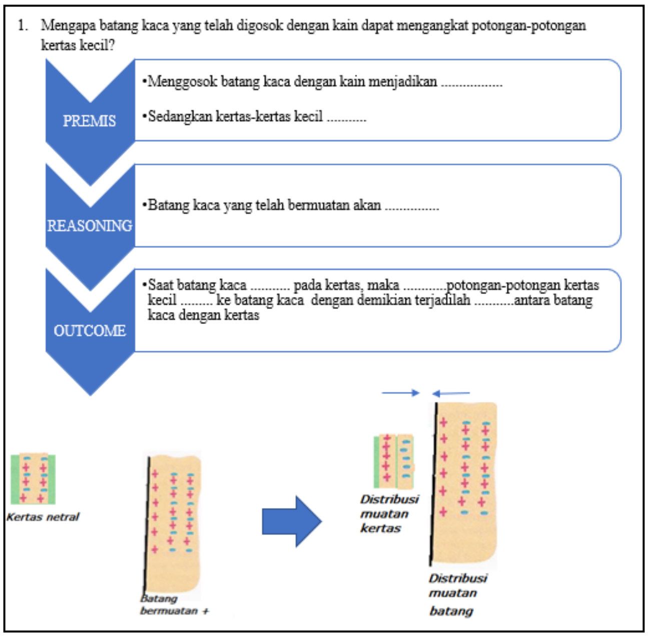
Jonassen, 2002). McNeil et al (2006) investigated the influence of scaffolding on students' scientific explanations. Students received one of two treatments: continuous, involving detailed scaffolds, or faded, involving less supportive scaffolds over time. On the posttest for the items without scaffolds, the faded group gave stronger explanations than the continuous group.

In this research, integrating PRO structure in fading of hard scaffolding, which hereinafter we call scaffolding explanation worksheet, will be examined if scaffolding would influence students' skills in scientific explanation. The topic that will be used in this research is the topic of static electricity. This is based on the majority of students' answers in the questionnaire on Basic Physics topics that they feel have a high level of difficulty (Şahin & Yağbasan, 2012). Furthermore, this study will test two aspects, 1) whether scaffolding explanation worksheet implemented in the POGIL inquiry learning effective in improving students' scientific explanation skills on static electricity and its application to living things, 2) How does fading scaffolding affected on improving students' scientific explanation

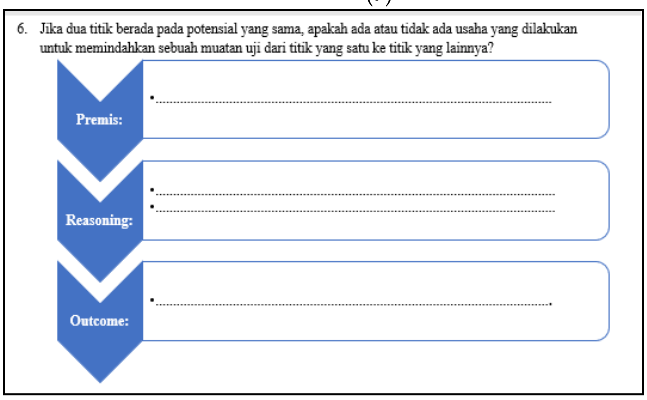
Method

This study is a quasi-experimental study using a pre and posttest only design (Creswell, 2012). The research sample was 30 second year students (2 classes) from one State University in Bandung and selected by convenience sampling technique. One class is the experimental class which applies the POGIL inquiry model (n=15). POGIL consists of five learning steps: 1) orientation, 2) exploration, 3) concept formation, 4) application and 5) closure (Hanson, 2005). In step application (step 4) students received scaffolding explanation worksheet. The scaffolding on the worksheet given to each concept is gradually reduced so that in the end it is hoped that students can construct scientific explanation without scaffolding. One other class as the control class applied the verification learning model (n=15). In control class verification learning model knowledge transfer carried out by teachers to students through lecture activities: 1) explaining concepts, 2) providing analogies, and 3) providing problem solving steps to students.

The research instrument used consisted of treatment instruments and measurement instruments. The treatment instruments were scaffolding explanation worksheet. Figure 1 shows an example of scaffolding worksheet.



(a)



(b)

Figure 1. Example of Worksheet: (a) Full Supportive Scaffold, (b) Less Supportive Scaffold

Measurement instruments were used for data collection is scientific explanation test. The scientific explanation test instrument is in the form of five open-ended questions developed by the researcher and validated by two experts in biology and physics expert. Each student received all five items without scaffolds. Three items were used to test explanation skills where during learning students get a scaffolding explanation worksheet while the other 2 items were used to test where during learning scaffolding explanation worksheet is faded or involving less supportive scaffolds. Five test items were tested to measure students' science explanation skills according to the university level curriculum, sequentially from number 1 to number 5 are: 1) electric charge, 2) electric force, 3) electric field, 4) electric potential and 5) application static electricity in living things.

To measure how well students written scientific explanation was assessed using a 1–5 rubric scoring system that refer to SOLO Taxonomy (Table 1) with a score of 1 indicating that students' scientific explanation was pre-structural level, a score of 2 indicating this characteristic was unistructural level, a score of 3 indicating this characteristic was multi-structural level, score of 4 indicating this characteristic was relational level and a score of 5 indicating this characteristic was extended abstract level. The SOLO taxonomy, was developed by Biggs and Collis (1982) was used for analyze the structure of the students' scientific explanation with consideration PRO structure is conceptualized based on an understanding of the structure of scientific explanation. The indicators for each level in the SOLO taxonomy are presented in Table 1.

Table 1. SOLO Taxonomy Level

Level	Indicator(s)
Prestructural (P)	Students use incorrect data so the conclusions obtained are not relevant.
Unistructural (U)	Students only use at least one information and one concept.
Multistructural (M)	Students use some data/information but the data are not interconnected so they can't draw relevant conclusions.
Relational (R)	Students use some data/information, apply the concept and then give temporary results. Students connect the data so that they can draw relevant conclusions.
Extended Abstract (EA)	Students use some data / information then apply the concepts and link between data so that they can draw relevant conclusions. Students think conceptually and can generalize it to another domain of knowledge and experience.

The data analysis technique used is a quantitative and descriptive analysis technique. Quantitative analysis was used to test the research hypotheses. The null hypothesis tested in this study is that there is a difference in scientific explanation of students who apply the POGIL model with scaffolding explanation worksheet, and the verification learning model. Hypothesis testing was carried out by parametric statistical tests the paired samples t-test is obtained with the help of the SPSS 20.0 for Windows program.

The effectiveness analysis was carried out in two stages, by testing the research hypothesis through independent t test and by calculating the effect size to prove that the scaffolding explanation worksheet has better effectiveness compared to verification learning. Effectiveness is determined by comparing the impact measures of Cohen's d (Thalheimer and Cook, 2002). The size of this impact is calculated based on the difference in the average post-test of the experimental and control class.

Result and Discussion

To understand the effectiveness of the scaffolding explanation worksheet on students' scientific explanation skills, we used a writing test to assess changes in students' scientific explanation. Students' scientific explanations were transcribed first by the researcher, and then scored by researchers, based on the rubric refer to SOLO Taxonomy. The average score of scientific explanation of students in experimental class and control class in pre and post-test is shown in Table 2.

Table 2. Average Score of Students' Scientific Explanation in Experimental Class and Control Class

Class	Average Pre-Test scores	Average Post-Test scores
Experiment	43.73	69.10
Control	48.53	53.00

The average score of scientific explanation of students in experimental class and control class is 69.10 and 53.00. This value showed that students who applied the scaffolding explanation worksheet had higher class averages. In order to find out the significance of the difference in improving science explanation skills between the experimental group and the control group, an inferential statistical test was carried out. Independent t test was used using the Mann-Whitney test. Analysis of the Mann-Whitney test showed that there was a significant difference in the average score of increasing science explanation skills between the experimental class that received scaffolding explanation worksheets compared to the control class with a value of Sig (α) = 0.045, which is less than 0.05. These results indicate that the hypothesis Ha is accepted, meaning that scaffolding explanation worksheets significantly improves science explanation skills. The meaning is students in the experimental group performed significantly better than students in the control group.

To find out the effectiveness of scaffolding implemented in learning science explanation skills besides determining the Mann-Whitney test, an effect size test was also carried out. The results of the effect size test show that the effect size is d = 1.12. This proves that the scaffolding explanation worksheet has a high effect size in improving students' science explanation skills. Based on the Mann-Whitney test and the influence size test, it can be concluded that scaffolding explanation worksheets are effective in improving students' science explanation skills.

To classify and describe the various skills produced by students in trying certain academic activities such as writing essays or answering open-ended questions, it is carried out with reference to the Taxonomy Structure of Observed Learning Outcomes (SOLO), which was developed by Biggs and Collis (1982). The SOLO model describes five levels, Pre-structural (P), Unistructural (U), Multi-structural (M), Relational (R), dan Extended Abstract (EA). Pre-structural response shows no understanding. Unistructural responses are characterized by using only one information, fact, or idea, which is obtained directly from the problem. Multi-structural Responses make use of more than one piece of information, fact, or idea. Relational responses integrate at least two separate pieces of information, facts, or ideas, that work together to answer the question. Extended Abstract responses go beyond the information, knowledge, or ideas provided, and infer more general rules or evidence that apply to other scenarios. The results of classifying students' scientific explanation answers based on the SOLO taxonomy are presented in Table 3.

Table 3. Classifying Students' Scientific Explanation

SOLO Level	Sum of Students' Anwers (%)									
	Item 1		Item 2		Item 3		Item 4		Item 5	
	E	C	E	C	E	C	E	C	E	C
P	13	69	0	13.3	0	0	13	40	0	13
U	6.5	20	20	27	20	27	40	26	33	40
M	27	7	27	13,3	13	20	27	7	27	20
R	6.5	4	20	33	27	20	0	20	13	20
EA	47	0	33	13.3	40	33	20	7	27	7

Notes:
E: Experiment Class
C: Control Class

SOLO taxonomy classification of experimental class before and after being given treatment by providing scaffolding worksheets, is presented in Figure 2. Referring to Table 2 and the results of the effectiveness test, both of which are reviewed from the point of view of applying the scaffolding explanation worksheet, it appears that in the final scientific explanation test, students who were given the scaffolding explanation worksheet treatment (experimental class) were higher than the control class. In addition to providing scaffolding explanation worksheets, at the beginning of student learning in the experimental class received other scaffolds such as introduce the components and structure of explanations and depicted what counts as good explanations by specifying the relations among premis, reasoning and outcome, they also modeled how to construct an explanation and supplemented the instruction with Tang et al. (2016) written scaffold. The role of scaffolding given by the teacher during the learning process is one of the factors that increases the effectiveness of learning in developing students' scientific explanations. This condition is in line with the research conducted by Wang (2015), the written explanation scaffold was designed to help students understand the general structure and components of a scientific explanation and can later be used during explanation construction to remind them of the key features of an explanation. McNeill et al (2006) in their research shows that students with scaffolding gained greater learning experience and learning outcome.

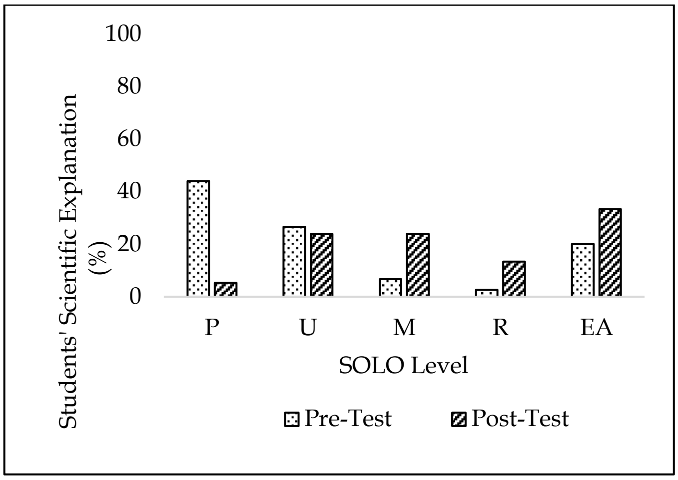


Figure 2. Comparison of Science Explanation Skills Test in Experimental Class

The next discussion is a discussion of the level of complexity of students' answers in experimental class, based on the SOLO taxonomy presented in Table 3 and Figure 2. Related to the SOLO taxonomy classification (Figure 2), although the experimental class students were involved in learning science explanation skills and the science explanation skills of the experimental class students on average exceeded the control class students, it was seen that some students in the experimental class were still at the pre-structural and unistructural levels.

Based on Table 3, it can be concluded that the percentage of students in the experimental class was the majority able to reach the extended abstract level on item questions 1, 2 and 3 respectively 47%, 33% and 40%. While items 4 and 5 the majority of students reach the unistructural level. Items 4 and 5 are related to questions on the topic of electric potential and the application of static electricity to living things. In fact, this condition is still better when compared to the control class. Student in control class is at the pre-structural and unistructural level on items 4 and 5 in their scientific explanation. Learning on these two topics, the researchers began to apply the fading scaffolding strategy, resulting in the majority of students' scientific explanations being at the unistructural level.

The occurrence of these conditions is likely due to two factors. The first factor is Fading scaffolding which was started to be applied during the learning process. The findings in our study contradict the findings in a study conducted by McNeil, et al (2006) where the faded group gave stronger explanations than the continuous group for certain content area. In fact our research inline with the research related to the effectiveness of three types of scaffolding practices (i.e., full scaffolding, fading scaffolding, and none scaffolding), fading scaffolding seemed to produce decreasing gradually approximate 45% decrease and the effectiveness of fading scaffolding was inferior to that of full scaffolding (Han et al. 2021).

The second factor is the cause of items 4 and 5 where the majority of students reach the unistructural level, is related to the topic of material content which is relatively difficult to understand compared to the previous three contents. McNeil (2009) state that if students do not understand the content, they are unable to construct valid scientific explanations. This means that their understanding of the content is not strong enough to demonstrate their ability to construct scientific explanations. The results of this study show that the fading scaffolding applied has not been able to have an effect on students' scientific explanation up to the extended abstract level. The findings in this study illustrate that it seems that fading should be given when students no longer need scaffolding, fading is not given at a fixed time. Fading should be applied as students become more capable of completing assignments, teachers provide less support and ultimately the teacher's role is that of a supportive audience and students have taken over the responsibility of the expert.

Conclusion

The results of this study show that scaffolding explanation worksheets that was applied in POGIL are effective in improving students' science explanation skills. The incorrect timing to remove scaffolds and misusage of scaffolding worksheet were two possible reasons behind the failure of fading scaffolding practice caused the fading scaffolding applied has not been able to have an effect on students' scientific explanation reach to the extended abstract level.

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Author Contributions
Handayani, W, carried out the experiment. Handayani, W & Agustina, T.W contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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