Available online at http://journal.um.ac.id/index.php/jps/
ISSN: 2338-9117/EISSN: 2442-3904

Jurnal Pendidikan Sains
Volume 6, Number 4, December 2018, pp. 128–134

Distributed Scaffolding on Inquiry Learning towards High Order Thinking Skills

Muji Sobirin[1)*], **Supriyono Koes H.** [2)], **Sentot Kusairi**[2)]
[1)]SMAN 1 Waru Pamekasan
[2)]Physics Education–Universitas Negeri Malang
Jl. Raya Waru Pamekasan, Indonesia 69353. E-mail: sobirinmuji79@gmail.com[*]

Abstract: The study aims to investigate the effect of distributed scaffolding in inquiry learning to higher order thinking skills (HOTS) of students, especially on optical geometry subject. This study used a quasi-experimental design with pretest and posttest control group design. The study used 10 multiple choices with open-ended questions. The data were analyzed using ANCOVA. The results showed that higher order thinking skills of students learned by inquiry learning with distributed scaffolding better than the control class. Every inquiry stage which integration with scaffolding train student to organize prior knowledge with new knowledge. Further research can deepen qualitatively about the thinking process of students in learning Physics with distributed scaffolding.

Key Words: higher order thinking skills (HOTS), distributed scaffolding, inquiry

Abstrak: Tujuan penelitian ini adalah mengkaji pengaruh *scaffolding* terdistribusi dalam pembelajaran inkuiri terhadap keterampilan berpikir tingkat tinggi (HOTS) siswa, pada pokok bahasan optik geometri. Jenis penelitian ini adalah kuasi eksperimen dengan rancangan *pretest and posttest control group design*. Instrumen penelitian untuk mengukur HOTS berbentuk pilihan ganda beralasan sebanyak 10 soal. Data penelitian dianalisis dengan menggunakan Ancova. Hasil penelitian menunjukkan keterampilan berpikir tingkat tinggi siswa yang belajar dengan pembelajaran inkuiri disertai *scaffolding terdistribusi* lebih baik dari pada kelas kontrol. Setiap tahapan inkuiri yang terintegarasi bersama *scaffolding* melatih siswa untuk berpikir pemecahan masalah yang komplek. Penelitian lanjutan dapat memperdalam secara kualitatif tentang proses berpikir siswa dalam pembelajaran Fisika dengan *scaffolding* terdistribusi.

Kata kunci: keterampilan berpikir tingkat tinggi , *scaffolding* terdistribusi, inkuiri

INTRODUCTION

The main purpose of learning Physics is to develop high order thinking skills of students (Zohar & Dori, 2003) that can be conceptualized as complex thinking skills to produce several alternative solutions, apply several criteria, and reflect (Resnick, 1987). The development of high order thinking skills of students in learning is an important aspect to build the ability to connect, manipulate, and transform the knowledge and experience that they already have to think broadly and deeply and to determine decisions in solving complex and new problems.

High order thinking skills are complex and involve several criteria. One of the criteria for high order thinking is Bloom's criteria which include the ability to analyze, evaluate and create (Anderson & Krathwohl, 2010). Analyzing is a thinking skill of students to decipher knowledge into small parts and think of those parts related to the overall structure as a whole. At this level, students have the ability to differentiate, organizing, and attributing. Evaluating is a thinking skill to make judgments based on certain criteria and standards. Creating is a thinking skill to generalize ideas, products, or new ways of seeing an event (Anderson & Krathwohl, 2010).

High order thinking skills can be achieved if the learning involves students by carrying out various activities that encourage students to analyze, evaluate and create. Inquiry learning contains high mental processes and is difficult to apply to students who are not accustomed, thus it need scaffolding in learning to assist. Scaffolding is able to assist difficulties with the knowl-

 Article received 12/03/2018; Approved 15/11/2018

edge and skills they want to achieve (Koes, 2013). Scaffolding also improves the clarity of thinking, organizing ideas, and analyzing and solving complex problems (Tan, et al., 2001; Kuhlthau, 2010; Hsu, et al., 2014). The use of scaffolding in inquiry learning cannot use only one type of scaffolding since the needs in learning are very complex (Hsu et al., 2014). Some scaffolding is needed to explore complex and important phenomena. Combining several types of scaffolding as a system in the form of learning is called distributed scaffolding (Reiser, 2004; Puntambekar & Hubscher, 2005).

Some Scaffolding can be applied in inquiry learning. First, an advance organizer which is a step in the form of a flowchart investigation. Second, written prompt in the form of conceptual and metacognitive questions that guide students to make discoveries and problem solving (Raiser, 2004; Hsu, et al, 2014). Third, teacher facilitation by encouraging questions, or authentic contexts, provides immediate feedback to facilitate elaboration (Krajcik et al, 2009). Fourth, visualization tools assist students to design steps of work procedures in the form of Youtube videos to reduce the cognitive burden of students (Hannafin et al, 1999; Jo An, 2014). The four scaffolding works one unit at each step of the inquiry, to stimulate and train students' high order thinking skills.

Geometrical optics is one of the material in a high school Physics lesson. The results showed that students endured difficulty in Optics lesson, especially in analyzing the formation of shadows on mirrors and lenses which were subsequently overcome by experimental activities (Outtara & Boudaoné, 2012). To improve students' ability to understand and design optical devices, inquiry learning and the project in making refracting telescopes can be taken into account (Tural, 2015). When taught by guided inquiry learning strategy, students have lesser difficulty in understanding geometrical optics and obtain higher learning outcomes than conventional learning (Wijayati et al., 2010).

The results of the research on the use of scaffolding show that conceptual scaffolding encourages students to apply the basic principles of Physics that are appropriate in solving synthesis problems (Ding et al., 2012). There are differences in Physics learning achievement between students studying with learning and scaffolding with learning without scaffolding (Koes, 2013). Metacognitive scaffolding has a positive effect on designing students' problem-solving processes, although it is not significant to the results of problem-solving (Molenaar et al., 2011 & Joan, 2014).

The development of high order thinking skills requires initial knowledge. The results of the study show that initial knowledge will be carried by students in understanding the formation of reflection on the mirror and lens after learning, although it can be changed through the learning process (Galili, 1993). Students' initial knowledge causes differences in students making approaches to solving problems after learning (Liu et al, 2008).

This study aims to compare high order thinking skills between students who learn by means of inquiry learning with distributed scaffolding and students who learn by means of conventional learning.

METHOD

This study was a quasi-experimental study using the pretest and posttest control group design (Creswell, 2012). The experimental group was given inquiry learning treatment with distributed scaffolding and the control group was given conventional learning.

The study was conducted at SMAN 1 Waru Pamekasan in X Natural Science Class consisted of three classes, with a population of 117 students. Sampling was done using cluster random sampling technique. The random sampling obtained X-A as the experimental class and X-B as the control class. Students' high order thinking skills were measured using test instruments in the form of ten items of reasoned multiple choice questions. Pre-test of high-level thinking skills was also used for data on students' initial knowledge as covariates (Yilmaz & Eryilmaz, 2006). The impact of treatment on students' high-level thinking skills employed post-test scores. Data were analyzed using ANCOVA (Analysis of Covariance).

RESULTS

The results of data analysis show that the average value of the initial knowledge of the experimental class is higher than the control class, with a range of 0-100, the average value of the experimental class was 32.77 and the value of the control class was 27.26. There are differences in the average value of high order thinking skills of students, the experimental class was 65.64 and the control class was 59.00 from the range of 0–100.

High order thinking skills in the experimental class were higher than the high-thinking skills in the control class with an average difference of 5.88. This means that after being controlled by the covariable initial knowledge, higher order thinking skills of students who learn by means of inquiry learning with distributed scaffolding are better than students who learn by means of conventional learning. The data on students' high order thinking skills are shown in Tables 1 and 2.

Table 1. Students' High Order Thinking Skill Average

Dependent Variable: High Order Thinking Skill		
Learning Strategy	Avg	Std. Error
Inquiry with Scaffolding	65.262[a]	1,585
Conventional	59.379[a]	1,585

The probability of the initial knowledge F ratio value was 0.84 ($p > 0.05$) at the 95% confidence level indicating that there is no linear relationship between initial knowledge and students' high order thinking skills. The probability value of the F ratio of high order thinking skills was 0.011 ($p < 0.05$) indicating that by controlling the initial knowledge of high order thinking skills students who learn by means of inquiry learning with distributed scaffolding are better than students who use conventional learning.

DISCUSSION

The analysis results indicate that students' high order thinking skills is higher when they were taught by means of inquiry learning strategy with distributed scaffolding than when they were taught by means of conventional learning. This argument confirms that treatment given influences students' high order thinking skill.

Scaffolding given to the students in each step of inquiry learning assists them to be able to work independently and assists them to understand and comprehend the Geometrical Optics topic. The scaffoldings used are advance organizer, conceptual and metacognitive questions, and experimental procedure video. The scaffoldings were successfully motivating and encouraging students to plan and implement observation to discover a certain concept and its understanding. Synergy among varied scaffolding used during inquiry learning assist students to enhance their understanding and reasoning to achieve learning objective (Hsu et al., 2014; Smagorinsky et al., 2015). On the other hand, during conventional learning, students only required to follow stages that have been explained by the teacher and thus students' thinking processes were not enhanced optimally. This made students in the control class have limited chance to explore critical thinking in the observation processes in constructing their knowledge independently. Conventional class offered limited room for students to create their own learning and problem-solving strategies (Wallace, 1992). Inquiry learning with distributed scaffolding offers a wider opportunity to improve students' thinking skills.

Advance organizer scaffolding that contains schemes of the stages of investigation in general and questions related to the phenomena that occur are able to train students in finding problems with their own observations and experiences. By means of an advance organizer, the formulation of the problems made by students is more oriented towards learning goals. Advance organizers make students focus more on formulating investigations that must be done (Hsu et al., 2014). This stage provokes students to think systematically and critically to conduct investigations (Karlsson et al., 2012). Meanwhile, the initial phase of the control class learning centered on the teacher's explanation. Before explaining the formula, the teacher demonstrates the phenomenon in the experimental class. Teacher's explanation about the relationship of phenomena with the formulation of the problem, offers a prompt understanding of students about the topic to be studied compared to the experimental class, this occurs because they listen first to the explanation. Compared to the experimental class, students in the control class were less active in finding and discover problems to investigate. The teacher no longer needs to direct students to criticize problems such as in the experimental class, which in the experimental class students review problems from various perspectives

Table 2. Comparison of Students' High Order Thinking Skill Average Score

Dependent Variable: High Order Thinking Skill				
(I) pembelajaran	(J) pembelajaran	Average Score Comparison (I-J)	Std. Error	Sig.[b]
Inquiry with Scaffolding	Conventional	5.883*	2,262	0,011
Conventional	Inquiry with Scaffolding	-5.883*	2,262	0,01

thus the teacher needs to facilitate and discuss to direct learning according to the objectives.

In the experimental class, scaffolding in the form of conceptual questions stimulates students to focus more on facts and knowledge that must be explored to be concluded as hypotheses or temporary answers. Scaffolding is very effective in inquiry learning to stimulate students in scientific inquiry (Adorno & Pizzolato, 2015). In making a hypothesis, students answer conceptual questions. The answer was analyzed to answer the problem statement. The teacher does not need to give explanations to students, but students actively think and discuss in groups to form temporary answers. In the control class, so students can answer the hypothesis, the teacher gives questions and explains the concept of reflection or refraction through demonstrations. Classically, students are guided by the teacher to obtain answers from the problem statement. Learning in the control class tends to be teacher-centered, students only listen and carry out teacher instructions. Whereas in the experimental class, the stimulation given is a question aid and an advance organizer that makes the active students think independently to find hypotheses from the problem statement.

Scaffolding in the form of experimental videos and advance organizers offers access for students to assemble data collection tools and techniques. Students more easily understand the usefulness of the tool than the explanation of conventional learning. Video as an aid in the experimental procedure in each group allows students to design experiments about convex and refraction topics. Meanwhile, the video is no longer used on the topic of KIT tool functions because students already understand the function of an optical KIT tool and can design it themselves based on purpose and advance organizer. Visualization tools encourage students to carry out investigative steps at a high level (Linn et al., 2006). The visualization tool as scaffolding allows students to manipulate data from different perspectives. The integration of visualization tools with advance organizers helps students direct investigations to build their own knowledge (Hsu et al., 2014).

Different from conventional learning, students work based on the example demonstrated by the teacher. The teacher explains how to use the tool until value the experimental data that must be investigated. Students only imitate the teacher in designing and carrying out experiments. In this method, the opportunity to think, analyze, evaluate, and design the experiment itself is not as much as in the experimental class. A detailed and classical explanation of the trial procedure is still carried out at each meeting, because students are not able to independently design the experiment just by looking at the experiment objectives in general. Students do not know systematically how to observe phenomena that must be investigated. While in the experimental class students are stimulated by an advance organizer to do the order of data retrieval. The advance organizer helps students identify and organize information important to understanding new knowledge (Ni et al, 2016). The teacher's role is very dominant in the control class because the teacher is the only facilitator for students. Less trained students think of solving technical problems during experiments. The dominant effect of teacher guidance is not training students to solve problems (Hsu et al, 2014).

Conceptual questions help students to analyze data. The use of scaffolding helps students in obtaining the initial idea to analyze, evaluate, and design mirrors and lenses according to their needs, conceptual and metacognitive questions. Also, guiding students to explore the concept of forming a reflection on mirrors and lenses. At this stage, students are more dominant because the scaffolding of conceptual questions helps students to organize ideas, improve misconceptions, generate plan and strategy in achieving learning and problem-solving goals (Ding et al, 2012). In the control class, the teacher gives the opportunity to discuss, analyze the experimental data by answering questions on the worksheet. When experiencing difficulties, the teacher immediately provides a solution therefore students immediately obtain answers without the thought process first. This offers a limited chance to solve simple and complex problems thus learning with scaffolding has a better effect on students' high order thinking skills. Learning that prioritizes student activities to think independently encourages students to practice high order thinking skills (Saido et al., 2015).

Teacher assistance directs students to recall findings during the experiment to draw the right conclusions. Scaffolding in the form of metacognitive questions trains students to re-organize findings in experiments with learning objectives. Metacognitive scaffolding encourages students to use several problem solutions based on investigations (Roll et al., 2012). Student activity in the control class is almost the same as the experimental class, students discuss the results of the experiment and analyze the data to draw conclusions. The difference is that students in the experimental class were assisted by questions to direct conclusions, while the control class only received guidance and explanation from the teacher. The process of drawing conclusions trains students to use the results of investigations to answer a problem (Hsu et al., 2014). The results of the investigation from the formulation of the problem to making conclusions were presented in front of the class in both the experimental and control classes. The aim is to share opinions and additions to the findings of other groups to be integrated into a conclusion.

Reflection questions from the teacher help students to understand the investigation method of conducting experiments, uncovering phenomena to answer a problem. Reflections in the form of questions from the teacher about the investigation, train students to monitor and reflect on investigations, improve and reinforce the findings of the investigation (Quintana et al., 2004; Sandoval & Reiser, 2004). In the control class there is no stage of reflection, so students are not accustomed to carrying out complex thinking processes such as remembering, selecting, determining, analyzing, then evaluating the method of investigation when trying to build knowledge. Reflection activities can develop students' scientific thinking skills that are very important in learning (Etkina et al., 2010).

Each stage of inquiry trains students' skills in building students' knowledge, by confirming students' initial knowledge and new knowledge gained from observing an event or fact. Organizing knowledge results requires some scaffolding, to provide a learning framework, which encourages students to develop initiative, motivation, and resources in training high order thinking skills.

Conventional learning tends to be dominant with the provision of information, as well as demonstrations directly and thoroughly. Learning in the control class does not stimulate students to think, develop problem-solving when collecting and analyzing data. Students imitate what the teacher exposes to express their knowledge. When facing new and complex problems, students in the control class have difficulty solving it. Therefore, the results of data analysis, and class averages, show the higher order thinking skills of students in the control class is lower than the experimental class learning with inquiry learning with distributed scaffolding. This is in line with other studies that show that inquiry learning or constructivist learning is better than conventional learning towards misconceptions, mastery of concepts and student achievement in geometrical optic material (Hussain et al., 2011; Tekos & Solomonidau 2009). In line with other studies, the achievement of high order thinking skills of students is better when learning by means of inquiry model with a pedagogical approach compared to conventional classes by means of laboratory lecturing (Madhuri et al, 2012).

Research on scaffolding in inquiry learning currently integrates computer simulation technology in achieving Physics learning goals. The results showed that the use of computer-based scaffolding improves student learning outcomes in science, technology, engineering and mathematics (STEM) (Belland et al, 2015). Other research shows that there is an increase in student motivation and achievement of learning goals by students in inquiry learning which is accompanied by scaffolding in the form of computer simulations in learning physics (Rutten et al., 2015).

CONCLUSION

The results show that controlling students' initial knowledge and high order thinking skills by means of Inquiry Learning with distributed scaffolding offer higher outcomes rather than by means of conventional learning in Geometrical Optics topic.

According to the results obtained, some points of suggestion are made as follows: Teachers are advised to apply distributed scaffolding in Inquiry learning because students are directly involved in active learning and stimulate students' high-order thinking skills. Expanded research should be conducted in a qualitative manner about how students think in high order thinking skills thus it obtained qualitative findings that are useful for learning. It is also suggested to conduct other forms of distributed scaffolding research in complex learning and stimulate the achievement of high order thinking skills of students in other Physics topics.

REFERENCES

Anderson, L.W. & Krathwohl, D.R. (2011). *Kerangka landasan untuk pembelajaran, pengajaran, dan asesmen.* Terjemahan Agung Prihantoro. 2010. Yogyakarta: Pustaka Belajar.

Adorno, D. P. & Pizzolato, N. (2015). An inquiry-based approach to the Franck-Hertz experiment. *Il Nuovo Cimento,* (38 C), *109*, 1–9.

Belland, B.R., Walker, A.E., Olsen, M. W., & Leary, H. 2015. A Pilot Meta-Analysis of Computer-Based Scaffolding in STEAM Education. *Educational Technology & Society,18*(1), 183–197.

Creswell, J.W. (2012). *Educational research: Planning conducting and evaluating quantitative and qualitative research fourth edition*. Boston: Pearson Education, Inc.

Ding, L., Reay, N., Lee, A., & Bao, L. (2011). Exploring the role of conceptual scaffolding in solving synthesis problems. *Physical Review Special Topics-Physics Education Research*, *7*(2), 020109.

Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., & Hmelo-Silver, C. E. (2010). Design and reflection help students develop scientific abilities: Learning in introductory physics laboratories. *The Journal of the Learning Sciences*, *19*(1), 54–98.

Galili, I. (1993). The effects of prior knowledge and instruction on understanding image formation. *Journal Of Research In Science Teaching, 30*(3), 271–301.

Galili,I. (1996). Students' conceptual change in geometrical optics. *International Journal of Science Education, 18*(7), 847–868.

Hannafin, M.J, Land, S., & Oliver, K. (1999). Open learning environments: Foundation, method, and model. In C. Reigeluth (Ed), *Intructional-design theories and models* Volume II. Hillsdale, NJ: Lawrence Erlbaum.

Hsu, Y.S., Lai, T.L., & Hsu, W.H. (2014). A design model of distributed *scaffolding*for inquiry-based learning. *Springer ScienceBusiness Media Dordrecht.*

Hussain, A., Azeem, M., & Shakoor, A. (2011). Physics teaching methods: Scientific vs traditional lecture. *International Journal of Humanities and Social Science, 1*(19), 269–276.

Jo An, Y. (2014). Examining the effects of metacognitive *scaffolding* on students' design problem solving and metacognitive skills in an online environment. *MERLOT Journal of Online Learning and Teaching, 10*(04), 552–568.

Karlsson, G., Ivarsson, J., &Lindstrom, B. (2013). Agreed discoveries: Students' negotiations in a virtual laboratory experiment. *Instructional Science, 41*(3), 455–480.

Krajcik, J., McNeill, K. L., & Reiser, B. J. (2009). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*(1), 1–32.

Kuhlthau, C.C. (2010). Guided inquiry: School libraries in the 21st century. *School Libraries Worldwide,16*(1), 1–12.

Koes H, S. (2013). Pengaruh strategi *scaffolding*-kooperatif dan pengetahuan awal terhadap prestasi belajar dan sikap pada matakuliah fisika dasar. *Jurnal Pendidikan Humaniora, 1*(1), 70–80.

Linn, M. C., Lee, H. S., Tinker, R., Husic, F., & Chiu, J. L. (2006). Teaching and assessing knowledge integration in science. *Science, 313*(5790), 1049–1050.

Liu, H. C., Andre, T., & Greenbowe, T. (2008). The impact of learner's prior knowledge on their use of chemistry computer simulations: A case study. *Journal of Science Education and Technology, 17*(5), 466–482.

Madhuri, G. V., Kantamreddi, V. S. S. N., & Goteti, L. N. S. P. (2012). Promoting higher order thinking skills using inquiry-based learning. *European Journal of Engineering Education, 37*(2), 177–123.

Molenaar, I., van Boxtel, C.A., & Sleegers, P.J. (2011). Metacognitive scaffolding in an innovative learning arrangement. *Instructional Science, 39*(6), 785–803.

Outtara, F. & Boudaone, B. (2012). Teaching and learning in geometrical optics in burkina faso third form classes: Presentation and analysis of class observations data and students' performance. *British Journal of Science, 5*(1), 83–103.

Puntambekar, S., & Hubscher, R. (2005). Tools for *scaffolding* students in a complex learning environment: What have we gained and what have we missed. *Educational Psychologist, 40*(1), 1–12.

Quintana, C., Reiser, B. J.,Davis, E.A.,Krajcik, J., Fretz, E. B., Duncan, R. G., et al. (2004). A scaffolding design framework for software to support science inquiry. *Journal of The Learning Sciences, 13*(3), 337–386.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences, 13*(3), 273–304.

Resnick, L. (1987). *Education and learning to think.* Washington DC: National Academy Press.

Roll, I., Holmes, N. G., Day, J., & Bonn, D. (2012). Evaluating metacognitive scaffolding in guided invention activities. *Instructional science, 40*(4), 691–710.

Rutten, N., van der Veen, J. T., & van Joolingen, W. R. (2015). Inquiry-based whole-class teaching with computer simulations in physics. *International journal of science education, 37*(8), 1225–1245.

Sandoval, W. A., & Reiser, B. J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science Education, 88*(3), 345–372.

Saido, G. A. M., Siraj, S., Nordin, A. B. (2015). Teaching strategies for promoting higher order thinking skills: A case of secondary science teachers. *Malaysian Online Journal of Educational Management (Mojem), 3*(4), 16–30.

Smagorinsky, P., Clayton, C. M., & Johnson, L. L. (2015). Distributed scaffolding in a service-learning course. *Theory Into Practice, 54*(1), 71–78.

Tan, S. C., Turgeon, A. J., & Jonassen, D. H. (2001). Develop critical thinking in group problem solving through computer-supported collaborative argumentation: A case study. *Journal of Natural Resources and Life Sciences Education, 30*(97–103).

Tekos, G., & Solomonidou, C. (2009). Constructivist learning and teaching of optics concepts using ICT tools in Greek primary school: A pilot study. *Journal of Science Education and Technology, 18*(5), 415–428.

Tural, G. (2015, June). Active learning environment with lenses in geometric optics. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 16, No. 1, pp. 1–18). The Education University of Hong Kong, Department of Science and Environmental Studies.

Wallace, P. R. (1992). A proposed reconciliation of conservative and liberal approaches to instructional design. *Australian Journal of Educational Technology*, *8*(1), 13–26.

Wijayanti, P. I., & Hindarto, N. (2010). Eksplorasi kesulitan belajar siswa pada pokok bahasan cahaya dan upaya peningkatan hasil belajar melalui pembelajaran inkuiri terbimbing. *Jurnal Pendidikan Fisika Indonesia*, *6*(1), 1–5.

Yilmaz, S., Eryilmaz, A., & Geban, O. (2006). Assessing the impact of bridging analogies in mechanics. *School Science and Mathematics*, *106*(6), 220–230.

Zohar, A., & Dori, Y. J. (2003). Higher order thinking skills and low-achieving students: Are they mutually exclusive? *The journal of the learning sciences*, *12*(2), 145–181.