Nurturing higher order thinking ability through visual scaffolding in group investigation

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Abstract. This study aims to determine whether prospective physics teachers who learn through visual scaffolding in group investigation have higher-order thinking ability better than that of learning by verificative methods. The research applied the mixed method with the explanatory design. Subjects were 69 physics education students of Jember University, 32 students as an experimental group and 37 students as a comparison group. The results showed that higher-order thinking ability of prospective physics teachers who learn through visual scaffolding in group investigation better than that of learning through the usual methods. Candidates for physics teachers who learn through visual scaffolding are superior in all aspects of higher-order thinking ability. They also revealed that visual scaffolding in group investigation is very helpful in understanding the concepts of geometry optics and guiding as well as directing them in problem exploration activities to find solutions for investigations.

1. Introduction
The higher-order thinking ability that students must possess in the face of 21st-century challenges [1] are new curriculum targets in many countries. In Hong Kong, maintaining the students’ higher-order thinking ability is the main goal of curriculum reform and is very important for community-based knowledge [2] [3] [4]. In Indonesia, developing higher-level thinking ability is one of the goals of the higher school physics curriculum. This higher-order thinking ability makes someone use critical and creative thinking and enable him to solve complex problems [4]. Researcher [5] added that this higher-order thinking ability is upper layers of Bloom's taxonomy, namely apply, analysis, and create.

Once the importance of higher-order thinking ability for students, many pieces of research has been done on this aspect. Researchers [2] sought to improve students’ higher-order thinking ability through flipped classroom models [6]. Researchers [7] create a learning environment through blended learning to develop the critical thinking skills of chemistry students. Researchers [8] combine inquiry learning with high- and low-level questions to determine their impact on students' higher-level thinking ability. Researchers [9] sought to develop higher-order thinking ability of chemical engineering students through inquiry-based learning.

In fact, the results of the study report that the students’ higher-order thinking ability tend to be low. Researchers [10] reported that higher-order thinking ability of Indonesian students are still low with a score of 361.4 and are ranked 40th out of 41 countries. The results of previous studies indicate that the thinking ability of higher-order students is still low, with each aspect: the ability to analyze 12.75%, the ability to evaluate 9.5%, and the ability to create 10.5% [11]. Researchers [12] also found that a higher-order thinking ability of students is still relatively low. Three factors at least cause this lowness
of higher-order thinking ability. First, students have a weak understanding of basic physics concepts [13]. Second, students are unable to apply what they know to new situations [13]. Third, there is a gap between students' prior knowledge and the complexity of the material being studied [11]. The lowness of critical thinking ability causes someone is unable to compete in a global world [1].

Some studies have focused on providing a positive influence on learning on one's higher-order thinking ability. One way to have a positive impact on higher-order thinking ability is to deliver active learning [3][14][15]. Researcher [14] shows that asking students to ask open questions can involve them in making comparisons, justifying or carrying out investigations based on their prior knowledge. This activity helps develop their higher-order thinking ability. Researchers [15] found that group discussions allow students to spend more time to higher-order learning. The research seeks to improve students' higher-order thinking ability, but it still rarely attempts to improve the students’ higher-order thinking ability through the distribution of assistance or scaffold.

Distribution of assistance can also be a positive impact on a person's higher-order thinking ability. One of the general assistances given in learning is scaffolding. The provision of scaffolding in learning is used to help students [16] [17]. Scaffolding is a learning strategy by assisting in overcoming learning difficulties and fostering problem-solving ability [18] [19]. As a result of the research by Researchers [19] shows that scaffolding can help students in solving problems of Introductory Physics. Besides that, Researchers [20] assist in the form of DEEPER scaffolding to improve problem-solving skills.

One of the general assistances given in learning is visual scaffolding. This visual can help the introduction of concepts related to the problems being faced in learning [21]. Besides, the provision of scaffolding visual can also help during the analysis and synthesis process student’s ideas for learning [22].

The provision of visual scaffolding certainly has its drawbacks, one of them is its nature which can only be given to each. Of course, this is a new problem if the lecturer must give it to all students in one class simultaneously [23]. This deficiency can be overcome if cooperative learning is applied in the classroom. The application of scaffolding is more effective in group learning which can invite students to discuss and collaborate [23]. One of the supporting learning models is Group Investigation (GI) [24] because through GI students can exchange ideas with peers, unlike in individual learning [25] [24]. Also, assignments given in GI can improve students' cognitive abilities, especially higher-order thinking ability [26] [27]. Therefore, an effort to overcome this problem is carried out by integrating scaffolding into the GI model. Through the GI model, it is expected that a peer can perform scaffolding through a scaffolded worksheet. As a result of the research by Researchers [28] which states that experimental worksheets equipped with scaffolding are suitable to be used as learning resources.

GI model is learning by adopting the way scientists find physics concepts and emphasizes the learning process with peer groups. Learning with peer groups allows students to learn optimally [29]. Besides, the GI model can make learning more exciting and foster a right attitude in learning science [26] and improve attitudes toward science [30]. Furthermore, Researchers [31] show that cooperative learning such as GI can build concepts as well as students' social abilities.

Giving scaffolding in the GI model has a good influence on the mastery of students' concepts [32]. Also, the results of the study indicate that procedural scaffolding in group investigation can have a positive impact on student learning achievement [24]. While research on the effect of visual scaffolding in the GI model to higher-order thinking ability is still rare.

Higher-order thinking ability in physics that is owned by a person cannot be separated from the prior knowledge of the material. That is, the students’ higher-order thinking ability in geometry optics is also influenced by their prior knowledge in a geometrical optics. Results of previous studies show that prior knowledge greatly affect student’s achievement [33] and on a geometrical optics material consist of many difficult concepts [34] and one of them is the propagation of light [35]. Besides, other research also states that the reflection and refraction of light is also a concept that is difficult to be
comprehended [34] [35]. Shadow formation which is related to reflection and refraction events also becomes its difficulty in studying geometrical operations [34] [35].

Geometrical optics is one of the materials in physics that often raises misunderstanding, so appropriate learning strategies are needed in order to assist students in understanding the geometrical optical. One strategy is the laboratory learning activities that utilize visualization [35]. Through activities in the laboratory as in the GI model, students have the opportunity to be more productive, cooperative, and able to interact with peers [36]. In order that the strategy of GI on geometrical optics is more effective, the strategy needs scaffolding [21]. The learning activities not only provides guidance in the learning process but also support independent learning [22]. Based on the above description, this study aims to determine the effect of conceptual scaffolding in group investigation on the students’ higher-order thinking ability on geometrical optics.

2. Method

2.1. Research design
This study uses the mixed method, with an explanatory design [37]. This quantitative design applies a non-equivalent control group design, then a case study to explore the impact of the treatment. The treatment in the experimental group was visual scaffolding in group investigation, while the comparison group was a verification experiment, a commonly used learning model.

2.2. Research subject
The research subjects were physics students of Jember University who were taking geometrical optics courses. The experimental group consisted of 32 students, and the comparison group consisted of 37 students. The case study subjects were six students, selected based on the highest scores in higher-order thinking ability.

2.3. Research instrument
The instrument used in this study consisted of treatment and measurement instruments. The treatment instrument is a visual scaffolding worksheet in the form of a link map that is applied in GI learning. The measurement instrument consists of a prior knowledge test and a higher-order thinking ability test of geometrical optics. Besides, observation sheets, interview guidelines, and think-aloud protocols are used to obtain qualitative data. All instruments are validated by experts and field tested. The reliability of the prior knowledge test and higher-order thinking ability tests are 0.76 and 0.68 respectively.

2.4. Data analysis
Data analysis was carried out in two stages. The first stage, quantitative data were analyzed using ANCOVA analysis techniques. This analysis technique was carried out because the prior knowledge influences high-order thinking ability so that the prior knowledge needs to be controlled as covariables. Before being analyzed, the data were tested for normality, homogeneity, and linearity, as the requirements for analysis. The second stage, qualitative data were analyzed using domain analysis techniques. This technique was carried out through steps to encode, group, synthesize, and conclude.

3. Results and Discussion

3.1. Description of Prior Knowledge and Higher Order Thinking Ability
The results of prior knowledge test on experimental and comparison groups showed a different tendency. The mean of prior knowledge of the experimental group was 49.5, and the comparison group was 57.2. The standard deviation of prior knowledge of the experimental group was 16.8, and the comparison group was 14.0. This result shows the tendency that the prior knowledge of the two groups is different. The prior knowledge of the comparison group is better than the experimental group.
The tendency of higher-order thinking ability differs from prior knowledge. The mean of higher-order thinking ability of the experimental group was 27.6, and the comparison group was 22.0. The standard deviation of the higher-order thinking ability of the experimental group was 8.2, and the comparison group was 10.2. This result shows the tendency that the higher-order thinking ability of the two groups is different. Higher-order thinking ability of the experimental group tends to be higher than the comparison group.

3.2. Normality, Homogeneity, and Linearity Test

Before the covariance analysis is carried out, the prerequisites of analysis of dependent variable were tested, that is the higher-order thinking ability. The prerequisite tests of ANCOVA include normality, homogeneity, and linearity test.

The normality test is carried out on the data of higher-order thinking ability for the experimental and control groups. The results of the normality test (Shapiro-Wilk’s test) showed that p of the experimental and comparison groups was 0.92 and 0.18, respectively (p > 0.05). Thus, data on higher-order thinking ability for both groups are normally distributed.

To find out whether the two groups have the same variance, the homogeneity test is carried out using the Levene’s test. The results of the test between the experimental and comparison groups showed p = 0.35 which was higher than 0.05. Thus, the data of both groups have a homogeneous variance.

The next prerequisite test is the linearity test, to find out whether the prior knowledge and higher-order thinking ability data in both groups have a linear relationship. The linearity test results p of deviation from linearity = 0.24. Because p > 0.05, this indicates that the prior knowledge and higher-order thinking ability data for both groups have a linear relationship.

Based on the results of the prerequisite test, it can be concluded that the research data meets the requirements for analysis of covariance (ANCOVA).

3.3. Hypothesis Testing

Analysis of Covariance produces F = 17.302, p = 0.00. Because p < 0.05, it can be concluded that the null hypothesis is rejected, meaning that there are differences in higher-order thinking ability between students who learn to use visual scaffolding in the GI and students who learn to use verification model. After being controlled with prior knowledge, the mean higher-order thinking ability of the experimental group was 28.9, while for the comparison group it was 20.7.

Analysis of observations shows that learning by using visual scaffolding in the GI gives students the opportunity to discuss. Forming groups with different prior knowledge can help peer interaction in groups. Students with high prior knowledge can help students with low prior knowledge using visual scaffolding. This interaction can facilitate students to build shared knowledge so that they can achieve higher-order thinking ability.

Interactions that occur in groups can help students improve higher-order thinking ability. Fatokun and Omenesa [38] stated that classroom interaction could increase students' interest and understanding so that they lead to high learning achievement. Also, teachers also need to connect students' prior knowledge in the learning process through visual scaffolding to help them understand scientific concepts.

The results of a more in-depth analysis of the components of higher-thinking ability show that the three components of higher-order thinking ability of students who learn to use visual scaffolding in the GI are higher than that of students who learn verification. Comparison of the three components of higher-order thinking ability between the two groups can be seen in Figure 1.
The ability to analyze (C4) in the experimental group was 23% and for the comparison group was 18%. The ability to evaluate (C5) in the experimental group was 34% and for the comparison group was 29%, while the ability to create (C6) in the experimental group was 58% and in the comparison group was 41%.

The results of the interviews and think aloud show that visual scaffolding in GI gives a positive impact on students’ learning of geometrical optics. Students revealed that the provision of visual scaffolding in the form of link maps in the GI could facilitate students when faced with higher-order problems. This result is shown by the score of higher-order thinking ability of students who learn to use visual scaffolding in GI better than that of students who learn with verificative learning. Besides that, learning in cooperative groups can facilitate students to discuss and exchange ideas, so that peers can help them when they experience difficulties during the learning process. The difference of analysis ability between the student who learns through visual scaffolding in GI and student who learns through verificative learning can be seen in Figure 2a.

Figure 1. Aspects of higher-order thinking ability

![Figure 1](image1.png)

Figure 2. (a) Work of a student who learns through the verificative method

![Figure 2](image2.png)
Figure 2 (b). Work a student who learns through visual scaffolding in GI.

Figure 2 (a) shows the work of the student who learns to use verificative learning and Figure 2 (b) is the work of a student who learns to use visual scaffolding in GI. The difference in analyzing ability is evident between them. The first student was unable to give a detailed reason in solving the problem. While the second student who learns to use visual scaffolding in GI was able to provide theoretical explanations and analyze mathematically about the Snellius law of light refraction.

3.4. Discussion
The results of this research can be explained through the creation of a learning community. Learning community in the form of group work (group investigation) with visual scaffolding can increase the intensity and quality of learning. Through visual scaffolding in GI, construction of meaning is related to cognitive development that occurs in the zone of proximal development [39]. Construction of meaning through visual scaffolding in GI resonate with students’ needs to create a coherent learning society in order to achieve a solution.

Through group work and the process of peers scaffolding, dialogue interaction facilitates students to build shared knowledge. The construction of meaning does not occur spontaneously and requires specific structures to facilitate and maximize the potential of these processes. Therefore, dialogue interaction is placed in a cooperative framework (group investigation) with visual scaffolding to facilitate the occurrence of peer scaffolding. The context of dialogue through peer scaffolding is one of the determining factors in the success of peer learning. Learning is based on the process of mutual assistance between friends that provides transfer of control among students in the classroom [40].

Interaction and involvement are important aspects of peer learning. Many studies have shown that the cognitive processes needed for students to develop deeper learning occur in dialogue [41]. Thus, GI learning with visual scaffolding creates a moderate social learning space that is important for these dialogues to occur. For example, students using the forum of group investigation to explore ideas, ask peers, and criticize the ideas of others. These encouraging findings in using an inquiry forum can have a beneficial effect compared to just transferring teaching materials. Some of the factors that contribute to enhanced interaction are instructional strategies, which make students actively participate in the exploration and exchange of ideas. Other factors are the presence of lecturer her visual scaffolding and empower students to solve problems. Lecturers work diligently to support student learning asking them to give ideas about their understanding of specific concepts and write follow-up questions for students’ ideas about various investigative issues.
These students are also more willing to bring concepts learned from visual scaffolding to group dialogue for improvement of further ideas. These elements represent some element of social constructivist theory, which emphasizes the students’ interaction in the process of constructing new knowledge. The main implication here is that using active discussion forums can produce important learning effects. This idea leads to GI with visual scaffolding also having a positive impact on students' higher-order thinking ability. Because this strategy provides an excellent vehicle for students to be fully involved in dialogues to solve problems with high success rates. This kind of involvement is very supportive of improving students' higher-order thinking ability.

The students involved in the search for new ideas through visual scaffolding in GI create learning communities among their members. Researchers [43] stated that cooperation in completing this kind of task gives students the opportunity to reach new levels of knowledge that they did not achieve when working alone. The results of this study are supported by the research [44] which revealed the application of scaffolding in group learning, had a positive impact on students' cognitive outcomes.

Social learning emphasizes collaboration among students and is a fundamental process for constructing and improving knowledge. Findings from this study reveal that students in verificative learning environments have little chance of conducting exploratory investigations. The educational and cultural context does not give them a diversity of fluent knowledge. However, social and cognitive dynamics in the learning environment of visual scaffolding in GI is a place for students to explore investigative problems and achieving various conceptual progression. Moreover, additional learning opportunities offered by visual scaffolding in GI motivate students to move to a higher level of knowledge through integrating explorative ideas. They also go beyond learning outside the subject to deal with real life. Such progression in knowledge illustrates the students’ way achieve certain mastery in cognitive processes.

4. Conclusion

The visual scaffolding in group investigation fosters students' higher-order thinking ability. The ability growth occurs in all three aspects. This growth is the impact of the interaction of dialogue and student involvement in exploring problems. Dialogue interaction through visual scaffolding in group learning, have a positive impact on students' cognitive outcomes. Visual scaffolding helps students when they are experiencing difficulties during the process of exploring problems in geometrical optics. If the lecturer wishes to improve higher-order cognitive outcomes, they need to apply peer scaffolding in group learning.

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