Integration conceptual scaffolding in the group investigation: its influence on students’ critical thinking skills

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Abstract. The enhancement of critical thinking skills (CTS) is one of the learning targets of universities. Although research on enhancing CTS has been achieved, the improvement of CTS through physics instruction is still becoming a problem. This study attempts to find out the integration of conceptual scaffolding to group investigation (GI) and its influence on students’ CTS. This mixed-method research used an explanatory design by involving 59 students in the Fundamental Physics III course in the Department of Physics, State University of Malang. The experimental group received treatment of conceptual scaffolding in GI, whereas the control group received conventional instruction. The instrument used was the prior knowledge test consisting of 17 multiple-choice items (Cronbach Alpha = 0.72) and the tests of CTS consisting of 11 essay items (Cronbach Alpha = 0.67), interview guidelines, and think-aloud protocol. The results of the study show that there are no differences in CTS between the experimental group and the control group. However, for the low prior-knowledge students, CTS of students who use conceptual scaffolding in GI higher than that of students who study with conventional instruction. Low prior-knowledge students who use scaffolding in the GI can use high-level strategies and exhibit more focused actions in solving problems.

1. Introduction
The enhancement of CTS is one of the learning targets of Indonesian universities. CTS is one of the crucial skills in this century that students need to have [1] [2]. Someone who can think critically can play an active role as a consumer of science that is critical in the enhancement of science and technology [3] also can follow the enhancement of science and technology well [4]. Quitadamo et al. stated that critical thinking abilities affect the professionalism and success of a person [5]. These abilities have a positive influence on one's success in learning [6].

The CTS is so essential that these skills get special attention in educational research. Some research has done to develop a learning environment that can enhance CTS [7]. Other research seeks to develop active learning [8][9] [10] as a medium for enhancing CTS. Some studies also develop student interaction in problem-solving through the web to develop problem-solving skills[11]. Research on the enhancement of a CTS test was conducted to meet the needs of measuring generic and specific critical thinking abilities [12].

In reality, the results of several studies show that students' CTS tend to be depleted [13] [9]. Research on the critical thinking abilities of postgraduate students is also low [14]. In Indonesia, students have an average score of the skills, only 37 [15]. In line with the study, other studies also obtained the average score of critical thinking abilities of physics teacher candidates is 30
The low ability causes a person to be undecided to compete in the global world [17]. The study also found that students' perceptions of their critical thinking abilities tended to be high [18].

Some studies are giving a positive effect on one's CTS. One method to have a positive influence on CTS is by presenting a physical phenomenon directly to be observed [19] [20]. Besides, the provision of assistance can also have a positive effect on one's critical thinking abilities [21] [22]. One of the usual assistance in studying is conceptual scaffolding. The conceptual scaffolding can help to introduce concepts regard to the problems [23]. Also, giving conceptual scaffolding can help when the process of delivering students' opinions in learning [24].

Giving scaffolding helps students if the scaffold is following their prior knowledge. The provision of different scaffold is useful for a student who has different prior knowledge [25]. Thus, one type of scaffold unfit to all students with different prior knowledge [26].

Giving the conceptual scaffolding, of course, has a disadvantage, it can only give to each learner. Of course, we will have a new difficult if the teacher has to provide it to entirely students in the same group at the same time [27]. Cooperative learning can overcome this deficiency, one of which is group investigation (GI). The integration of conceptual scaffolding in GI possesses an excellent effect on students' concept understanding [28]. Also, the study showed that implementation of a procedural scaffolding in GI could affect students' achievement positively [29], whereas research on conceptual scaffolding in GI concerning CTS is still infrequent.

The CTS possessed by a person is inseparable from the understanding of the contents he has, one of which is geometric optics. The results of previous studies showed that in geometric optics, there were many difficulties [30], and one of them was light propagation [31]. Also, other studies stated that reflection and refraction is also an elusive concept [31] [32]. The image formation associated with reflection and refraction also has a certain level of difficulty in studying geometric optics [33], [34], [32]. Based on this explanation, this research seeks to find out the influence of conceptual scaffolding in GI on students' CTS of geometric optics.

2. Method

2.1. Research design

The research is a type of mixed-methods research through an explanatory design [35]. The design applied quantitative research of nonequivalent control group design type [36] first, then proceed with qualitative research of a case study approach [37]. In this quantitative research, a group of students learns via conceptual scaffolding in GI, whereas another group of students learning through conventional instruction on the course of Fundamental Physics III.

2.2. Research subject

Subjects of the research were students of the State University of Malang who were attending Fundamental Physics III as many as 59 students. The research subjects consisted of four classes, namely two experimental classes as many as 30 students and two control classes as many as 29 students. The qualitative research subjects consisted of nine students with a significant improvement of CTS, namely six students (NPL, KN, AT, LW, DSF, and SYF) in the experimental group and three students (IM, AEO, and RA) in the control group.

2.3. Research instrument

The instruments of this study included two instruments, namely, quantitative and qualitative research instruments. Quantitative research instruments consisted of two test instruments; namely, the prior knowledge test consisted of 17 multiple-choice items (Cronbach Alpha = 0.72), and the CTS test consisted of 11 essay items (Cronbach Alpha = 0.67). Qualitative research instruments are guidelines for semi-structured interviews and think-aloud protocol.
2.4. Data analysis
Data analysis included two parts, namely the quantitative and qualitative analysis. Quantitative data analysis started from the assumption test for parametric analysis, namely the normality test, homogeneity test, and linearity test. After data fulfill assumption tests, analysis of covariance was carried out and continued with the t-test in the group of low prior knowledge to find out the difference of critical thinking abilities. Qualitative analysis was accomplished employing the flow model [38] which broadly outlined: 1) classifying qualitative data into two parts, namely student behavior during the intervention process and student thinking pattern during semi-interviews and think-aloud session, and 2) synthesizing student's behavior and thinking patterns to get an overview of CTS on two research groups.

3. Result and Discussion

3.1. Prior Knowledge and Critical Thinking Skills
The prior knowledge of the experimental and control group tended to be slightly different. Table 1 shows prior knowledge of each group.

| Group     | N  | Lowest score | Highest score | Average score | Standard Deviation |
|-----------|----|--------------|---------------|---------------|--------------------|
| Experiment| 30 | 11.76        | 82.35         | 42.35         | 15.78              |
| Control   | 29 | 17.65        | 76.47         | 45.03         | 16.73              |

In the experimental group, the average score of prior knowledge is 42.35 (S_D = 15.78), with the highest score is 82.35, and the lowest score is 11.76. In a control group, the average score of prior knowledge is 45.03 (S_D =16.73), between the highest score of 76.47 and the lowest score of 17.65. Based on Table 1, the average score of preceding knowledge of the two clusters was not very dissimilar. The prior knowledge of the treatment group is slightly lower than that of the comparison group.

When treatment, we measured the skills of critical thinking of the two groups. Table 2 presents the results of measuring CTS.

| Group     | N  | Lowest score | Highest score | Average score | Standard Deviation |
|-----------|----|--------------|---------------|---------------|--------------------|
| Experiment| 30 | 2.63         | 48.68         | 29.12         | 9.56               |
| Control   | 29 | 9.21         | 51.32         | 27.77         | 11.69              |

In the treatment group, the average CTS was 29.12 (S_D = 9.56), with the highest is 48.68, and the lowest is 2.63. Whereas in the comparison group, the average of the students’ skills is 27.77 (S_D = 11.69) between the highest is 51.32, and the lowest is 9.21. Based on Table 2, the average of the students’ skills in both groups was not too much different. The average students' skills of the treatment group were slightly higher than that of the comparison group.

3.2. Normality, Homogeneity, and Linearity Test
Tests of assumption for covariance analysis that is normality, homogeneity of variance, and linearity are carried out through standard residual examinations for scores of prior knowledge and CTS. For prior knowledge, the Kolmogorov-Smirnov test (p > .05) and boxplot suggested that prior knowledge scores of the two groups distributed normally. Homogeneity of variance using Levene's F test, obtained F (1,57) = 0.292, p = 0.591. For the score of CTS, the normality test using the Kolmogorov-Smirnov (p > .05), and boxplot examination showed that CTS for the treatment group and the comparison group also distributed normally.

Furthermore, the test of variance homogeneity based on Levene's F test yields (F (1, 57) = 1.907, p = 0.173). The linearity test between prior knowledge and CTS shows that the two variables are linearly
correlated, with linearity (F(1, 27) = 9.993, p = .004). This test shows that the preceding knowledge scores and CTS scores in two groups have a linear relationship.

3.3. Hypothesis Testing

The test of difference in CTS was carried out using ANCOVA, with prior knowledge as a covariate. Table 3 shows the summary of the ANCOVA.

| Source               | Type III Sum of Squares | df | Mean Square | F      | Sig. |
|----------------------|-------------------------|----|-------------|--------|------|
| Corrected Model      | 1136,348^a              | 2  | 568,174     | 5,929  | 0.005|
| Intercept            | 1915,891                | 1  | 1915,891    | 19,993 | 0.000|
| Prior knowledge      | 1109,219                | 1  | 1109,219    | 11,575 | 0.001|
| Intervention         | 63,533                  | 1  | 63,533      | 0.663  | 0.419|
| Error                | 5366,461                | 56 | 95,830      |        |      |
| Total                | 54285,442               | 59 |             |        |      |

Summary of analysis of covariance on CTS due to different treatments produce F = 0.663, p = 0.419. The result shows that there is no difference in the CTS between the treatment and comparison groups.

If we only observed students who have low prior knowledge, the CTS of the treatment and comparison groups tend to be different. Table 4 shows a description of the CTS for low prior-knowledge students. In the treatment group, the average of CTS for low prior-knowledge students is 31.07 (SD = 4.71). In the comparison group, the average of CTS for low prior-knowledge students is 27.35 (SD = 4.71). Thus, the average of the CTS of the treatment group was slightly higher than that of the comparison group.

| Group   | N  | Mean   | Std. Dev | Std. Mn Error |
|---------|----|--------|----------|---------------|
| CTS     |    |        |          |               |
| Experiment | 15 | 31.0787| 4.70983  | 1.21607       |
| Control | 14 | 27.3507| 4.70989  | 1.25877       |

Note: CTS = Critical Thinking Skills

Table 5 presents a summary of the t-test on CTS for low prior-knowledge students. The t-test results show that t = 2.13, p = 0.042. Thus, there are differences in the CTS for low prior-knowledge students between the treatment and control groups.

| Levene's Test | t-test for Equality of Means | Levene's Test | t-test for Equality of Means |
|---------------|------------------------------|---------------|------------------------------|
| Equal variances assumed | .004 | .952 | 2.130 | 27 | .042 |
| Equal variances not assumed | 2.130 | 26,862 | .042 |

These results indicate that conceptual scaffolding in the GI affects only low prior-knowledge students. The effect of conceptual scaffolding in GI does not obey the "one-size-fits-all" tenet but relies on the traits of particular learners, a kind of prior knowledge [26].
3.4. Discussion

There are indications that effective types of assistance for studying differ between students with dissimilar stages of prior knowledge [25]. The results have shown that low prior-knowledge students who are given conceptual scaffolding in GI apply more sophisticated strategies and demonstrate behavior that is more directed in solving problems than students who are not receiving assistance. This result shows that low prior-knowledge students promote from high stages of assistance [39]. Instead, high prior knowledge students require less help since they already have sufficient comprehension to hold up the construction of mental representations [26]. For such students, conceptual scaffolding can be surplus and even harm studying; this is known as "expertise reversal effect" [40]. That is why conceptual scaffolding in GI does not affect the whole students in the treatment group positively.

Throughout the learning process, there were four of the six students in the treatment group who were seen actively participating in learning, namely NPL, LW, DSF, and SYF. They did not only see other students in conducting experiments, but they were also actively involved in experimenting. Besides, they use conceptual scaffolding to implement the proper strategy in solving problems. Although AT and KN are not as active as the four students mentioned earlier, they were using conceptual scaffolding to chose the appropriate strategy in solving the problem. They discuss with group members to analysis data. Through utilizing conceptual scaffolding, students can connect the observed phenomena to the theory of geometric optics so that they can find a solution. This behavior causes students can criticize natural phenomena based on existing knowledge. This result supports the study [26] that low prior knowledge students who are not assisted need fewer trials to reach conclusions [42] [26].

Instead, three students in the control group are unable to criticize natural phenomena. We were not assisting them in solving problems. They are less able to give a logical explanation of natural phenomena and connect them to existing knowledge. Even though AEO seemed to be quite active in solving problems, AEO was not trained to connect the experiment to the physics concepts. AEO is less able to criticize existing natural phenomena. When asked to explain, AEO answered: "just like that." Besides, IM and RA are also less able to criticize how solar stoves work by using the principle of geometric optics. Students with low prior knowledge who are not assisted tend to show undirected behavior [41] [26].

Students from the experimental group show different behavior. They can well explain how the solar stove works. Even AT can provide a sophisticated explanation of the solar stove shortly after being shown the picture of the solar stove. This result is in line with this study that low prior knowledge students who are assisted needed fewer trials to reach conclusions [42] [26].

4. Conclusion

CTS entire students who use conceptual scaffolding in the GI did not differ significantly than that of students learn through conventional instruction. However, for low prior-knowledge students, the CTS of students who use conceptual scaffolding in GI was higher than that of students learn via conventional instruction.

With conceptual scaffolding in the GI, low prior-knowledge learners promote from more complex problem-solving strategies and more directed behavior towards conclusions while high prior-knowledge students do not promote from the scaffolding since they already have sufficient comprehension to hold up the construction of mental representations.

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