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The effectiveness of multiple representation-based student worksheet of inheritance properties topic to improve students' critical thinking skill

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Abstract. This research aims to describe the effectiveness of multiple representation based-student worksheets in improving students' critical thinking skills. The research method used is a quasi-experiment by using pretest-posttest design. This research was conducted in one of the Lampung provincial junior high schools. The sample in this study amounted to 58 students consisting of two experimental classes obtained by using a purposive sampling technique. The data was gained by using questionnaire and test, and it analyzed by using paired sample t-test to investigate the effectiveness of the learning method in both groups of samples. The proposed methods show that there were differences of pretest and posttest score between the first and second experiment class as well as the size effect. Furthermore, students also give good responses to the learning process by using students' worksheet based on multiple representations. For all test cases, the experimental results imply that Multiple Representation-based Student Worksheet is one of the effective ways of improving students' critical thinking skills in the inheritance properties topic. This is evidenced by an average increase in all significant critical thinking indicators, especially indicators that advance clarification in the high category.

1. Introduction

The learning activity is a main point of education in schools, which means that the success of achieving learning goals depends largely on the learning process that occurs in class. However, it seems that the learning process still obtains many problems, and it is not as well as expected. Based on the *Program for International Student Assessment (PISA)* in 2006 about an average score of science literacy achievement, it reports that Indonesia's average score is 393 compared by the international average score is 500 [1]. Then, *Trends in International Mathematics and Science Study (TIMSS)* in 2011 shows that, generally, the average achievement of the natural science ability of junior high school students in Indonesia is at a low level. Therefore, the low achievement of students according to *PISA* and *TIMSS* shows that students' thinking skills are still low, and the learning process in school has not been successful yet.

Based on the results of research conducted by Nurisalfah et al. (2018) [2], it strengthens the reports taken from *PISA* and *TIMSS* that the learning activities are still centered on teachers and students tend to be passive. Students are only as listeners and are not actively involved in the learning process.



Butler et al. (2014) revealed that learning in the classroom without the activity makes students unfocused and can reduce or eliminate the effects of the intervention by the teacher [3]. Also, the students' thinking skills tend to be in a concrete form, and the students are not well-trained especially to operate abstract thinking skills so that students have difficulties in understanding the concepts of science and its relationship [4].

Lanani (2015) also explains that learning process conducted by teachers emphasizes more on aspects of knowledge and understanding, while aspects of the application, analysis, synthesis, and even evaluation are only a small part of the learning process conducted by teachers [5]. It causes students to become less trained to develop their reasoning power in solving problems and applying concepts that have been learned in real life. In other words, students are less trained to analyze, synthesize, and evaluate information, data, or arguments so that students' thinking skills are less well-developed, especially their critical thinking skills.

In addition, the result of observations gained from six state junior high schools in Lampung, showed that most of the science learning at school was taught using conventional methods namely lecturing, 77.7% of teachers explained that learning was still teacher-centered methods, 100% learning activity has been assisted by using students' worksheet, but its worksheet has not developed appropriately related to the students' representation skills, in other words, students' worksheet is presented in limited representation, especially on inheritance material and it has not trained well especially students' critical thinking skills. The complexity of the problems that occur above must be resolved properly, systematically, and precisely so that the learning process that occurs becomes more useful and meaningful. One of the learning tools that can be used by teachers to train students to think comprehensively in the learning process is the Students' Worksheet [6]. Mahardika et al. (2017) suggest that student worksheet is a student guide used to facilitate students to understand the material learned in class during the learning process [7]. Student worksheets are also used for investigation or problem-solving. Also, worksheets can be used by teachers to understand students' previous knowledge, the outcome of learning, and the process of learning; at the same time, they can be used to enable students to monitor the progress of their learning [8]. Furthermore, so that learning is more interesting and able to train students' reasoning that is still low, there needs to be an approach that is appropriate to the characteristics of the material to be taught.

In this case, the reasoning process can be developed using a multiple representation approach. The representation function can help a person to redefine a problem with his own words in that envisioning process maintains that one of the central characteristics of the concept of functions that makes it so central to the learning process is its nature of multiple representations [9-15]. Through studying functions, students can make connections between symbolic, graphical, verbal, and numerical representations of functions. Learning by using multiple representations is able not only to sharpen knowledge and understanding but also choose and process relevant information, then organize it into other forms [12-15]. Furthermore, Tsui et al. (2013) explain that effective conceptual representation help learners achieve successful knowledge acquisition. They can assist the student in such areas as making sense of complex phenomena, constructing representations in their minds, and correcting prior misunderstandings. They can also serve as a basis for students' discussions of the processes being learned. The use of appropriate and systematic approach and processes that involve students in finding information by themselves can train the students' high-level thinking skills, and one of them is critical thinking.

Furthermore, Paul and Elder (2013) argues that critical thinking helps to integrate three dimensions of thought, which are must be idealistic thinking (able to imagine a better world), realistic thinking (seeing things as they really are), and pragmatic thinking (adopting effective steps to move towards ideals) [16]. The critical thinking process requires active argumentation, initiative, reasoning, imagining, analyzing complex alternatives, and making contingencies related to value assessments. Therefore, based on the explanation above, the writer of this article aims to describe the effectiveness of worksheets based on plural representations of inheritance material to develop students' critical thinking skills.

2. Methods

This research was conducted in one of the Lampung provincial junior high schools. The sample in this study amounted to 58 students consisting of two experimental classes obtained by using a purposive sampling technique. The research method used is a quasi-experimental with pretest-posttest design [17] as presented in Table 1.

Table 1. Pretest-Posttest design

Class	Pre-test	Treatments	Post-test
Experiment 1	O ₁	X	O ₂
Experiment 2	O ₁	X	O ₂

Notes:

O₁ is a pre-test, X is learning activities by using worksheets based on multiple representations of the development results, and O₂ is post-test

3. Results and Discussion

3.1. Normality test, T-Test, n-Gain, and effect size

The mean score of pretest and posttest on students' critical thinking skills in first and second experimental classes are presented in Figure 1.

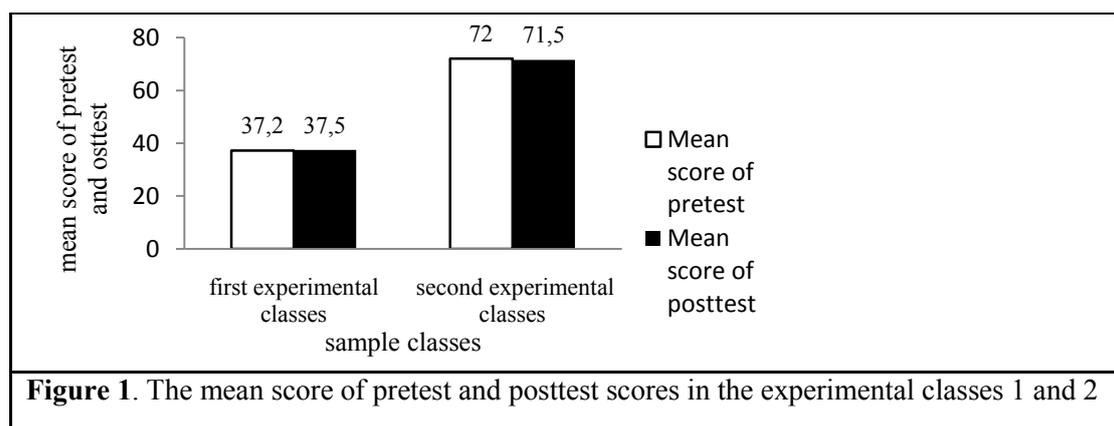


Figure 1. The mean score of pretest and posttest scores in the experimental classes 1 and 2

Based on Figure 1, it is known that the mean score of students before and after being taught by using multiple representation-based worksheets is different, in which the average posttest score is greater than the average pretest score. Then, here are the following results of the normality test for the average pretest and posttest scores in the first and second experimental classes that are stated in Table 2.

Table 2. The normality test for the average pre-test and post-test scores In the first and second experimental classes

	Class	Statistic	Df	Sig.
Pretest	1	0,955	29	0,252
	2	0,968	29	0,499
posttest	1	0,950	29	0,187
	2	0,958	29	0,285

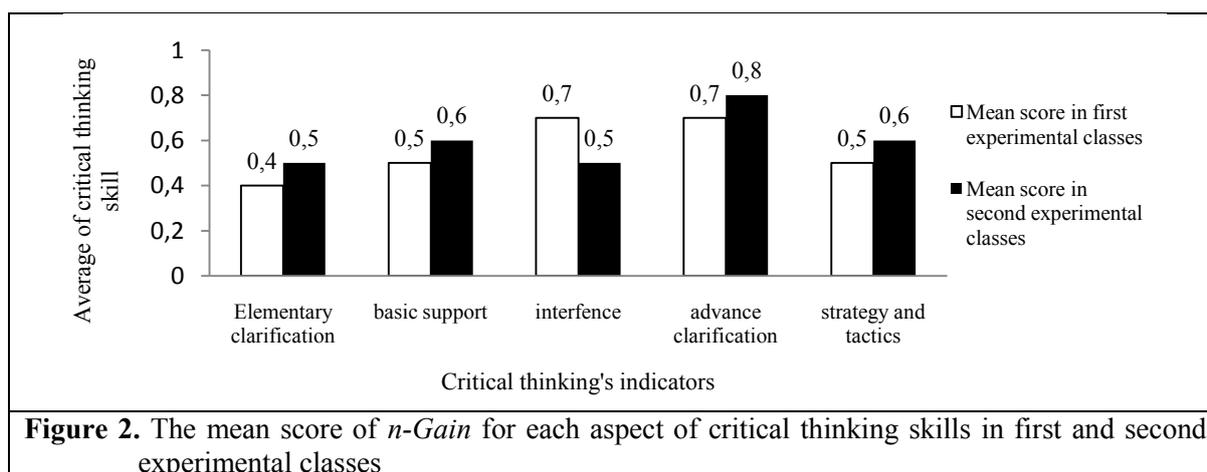
Based on Table 2, it is known that the pretest and posttest data of the first and second experimental classes obtain a *shimp Sig value* is greater than α 5% (0.05), it shows that H₀ is accepted and the gained data from a population that is normally distributed. Next, the researcher conducted an *effect size test* by using prerequisites test, namely the calculation of the two mean difference tests (t-test). In other words, to calculate an *effect size test*, firstly, it is necessary to calculate the *t-obtained* from the two mean difference tests. The test results are presented out as Table 3.

Table 3. The two average difference tests of the first and second experimental classes

	Class	Std. Deviation	T	Df	Sig. (2-tailed)
Exp 1	pretest1 - posttest1	9.3293	-20,030	28	0.000
Exp 2	pretest2 - posttest2	7.4201	-24,688	28	0.000

After calculating *t-obtained*, then the *effect size test* is calculated. The purpose of the *effect size test* is to determine the size of the effect of using multiple representation-based worksheets to develop students' critical thinking skills. The calculation of the *Effect size test* is carried out by using the Abu (2014) further; it will be categorized according to Cohen's effect size (1998) [18]. Based on the results of the data calculation, the *effect size* value for the first experiment class is 0.96 or 96.68%, and the second experimental class is 0.97 or 97.77%. Therefore, as if its result is categorized based on [19], so the effect sizes of both classes are stated as a **high category**. It means that multiple representation-based worksheets have a great influence in improving students' critical thinking skills.

Furthermore, to find out how much increasing critical thinking skills in the experimental class, it is necessary to calculate *n-Gain*. Based on the results of the calculation of *n-Gain* critical thinking skills in the first and second experimental classes, the average *n-Gain* is 0.58 (medium category). Then the mean score of *n-Gain* for each aspect of critical thinking skills in first and second experimental classes is shown in Figure 2.

**Figure 2.** The mean score of *n-Gain* for each aspect of critical thinking skills in first and second experimental classes

Based on Figure 2, it is known that there is an increase of the *n-Gain* mean scores in all critical thinking indicators in the first and second experimental classes. Therefore, it occurred because of the multiple representations based-students' worksheet, in which students are given a lot of practices about various aspects that are suitable with its indicators, especially the indicator about advance clarification which has the highest increase.

Here is the following example of students' answers on indicators, especially about advance clarification presented in Figure 3. Furthermore, based on figure 3, students are trained to identify the crossing charts carefully so that they can give symbols orderly, and then write down the definitions given to each symbol by considering carefully in order avoiding errors definition. Based on the crossing charts, students will be asked to identify more about Figure 3. Here is the example of students' answers on its indicator, referring to providing further explanation about the nature that will be inherited on to their child. Thus, students can explain further this issue based on their analysis understanding and can be accounted for.

It is also in line with Abdurrahman (2016) research that students will be more effective in the learning process when they process the information in various ways, so the multimodal approach to learning and teaching becomes the very potential point to produce an effective learning process [20].

a. Simbol-simbol

P₁⁽¹⁾ (Parental) E₁⁽²⁾ (fenotip): Sapi Lampung jantan ♂⁽³⁾
 E₂⁽⁵⁾ (genotip): SS

P₂⁽⁴⁾ (Parental) E₂⁽²⁾ (fenotip): Sapi Bali Betina ♀⁽⁴⁾
 E₂⁽⁵⁾ (genotip): ss

Gamet : S₁⁽⁶⁾ (Sperma) S₂⁽⁷⁾ (Ovum)

F₁⁽⁸⁾ (Filial): Ss⁽⁹⁾
 Fenotip: _____⁽¹⁰⁾

b. pengertian simbol

- 1) Parental adalah organisme yg menjadi induk atau orang tua.
- 2) Fenotip adalah suatu karakteristik yg dapat diamati dari suatu organisme.
- 3) ♂ : lambang sapi jantan
- 4) ♀ : lambang sapi betina
- 5) Genotip adalah komposisi pewarisan individu dengan tanda ekspresi.
- 6) Spermia adalah gamet jantan (sel) yg berfungsi dalam reproduksi.
- 7) Ovum adalah sel telur yg digunakan dalam proses reproduksi.
- 8) filial adalah individu yg dihasilkan oleh pertkawinan parental.
- 9) genotip hasil persilangan
- 10)

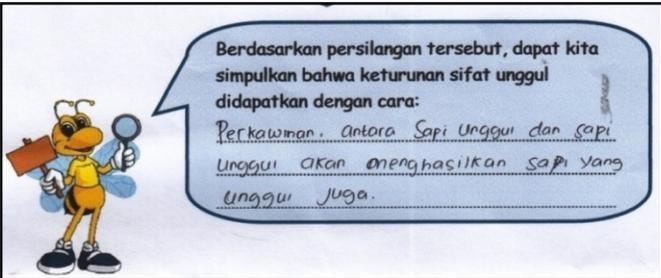
b. Sifat induk yang dapat dimiliki anak:

sapi kak pendek, sapi kaki sedang dan sapi dgn kaki tinggi.

Figure 3. The example of students' answers on indicators especially about advance clarification

Moreover, the results of Halpern (2014) show that learners are likely to benefit when information is presented in more than one representation [21]. This is because specific information can best be conveyed in a particular representation, several representations can be more useful in displaying a variety of information, and problem-solving expertise depend on the problem solver's repertoire of multiple representations of the same domain.

Also, a significant increase occurred in the critical thinking indicator, especially about interference aspects. Here is the example of students' answers to the interference aspects that are presented in Figure 4.



Berdasarkan persilangan tersebut, dapat kita simpulkan bahwa keturunan sifat unggul didapatkan dengan cara:
 Perkawinan antara sapi Unggul dan sapi Unggul akan menghasilkan sapi yang unggul juga.

Figure 4. The students' answer on indicators of critical thinking skills about interference aspects

Figure 4, which is the students' answers, especially about interference aspects above, shows that firstly students must conduct an investigation or identification on how to produce superior traits so that students can write answers correctly. In these worksheets, it is presented animal crossings chart in great details, and then students are asked to work on the crossing process in detail. Thus, students can make and determine the results of consideration based on the application of facts to draw up a conclusion. Halpern (2014) suggests that critical thinking is used to describe thinking that is purposeful, reasoned, and goal directed-the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions when the thinker is using skills that are thoughtful and effective for the particular context and type of thinking task [21].

3.2 Student Response to Learning Using Worksheet Based on multiple representations

The percentage of students' responses after conducting the learning process by using multiple representation-based worksheets shows that most of the students agree that the used worksheets are very helpful in the learning process, in which the existence of plural representation worksheets is able to facilitate students to learn especially for inheritance material, learning process is more fun and systematic, in other words, it is also able to increase students' motivation in learning and facilitate students to do calculations and crosses. This is proved by the average students' responses who agreed is 95.38% with the very high category.

4. Conclusion

Based on the results of data analysis, it can be concluded that multiple representation-based worksheets can effectively improve students' critical thinking skills. This can be seen from the difference in the average score of pretest and posttest in the first and second experimental classes and the *effect size test* and high *N-gain values*. Besides that its effectiveness can also be seen from the improvement of all critical thinking indicators with the medium category. Moreover, students give also good responses in the learning process by using multiple representation worksheets.

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