The effectiveness of Inquiry-based learning to train students' thinking skill based on SOLO taxonomy

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Abstract. The aimed of the research was analyzed the effectiveness of IBL (inquiry-based learning) device for training thinking skills of students based on SOLO taxonomy. The research was a part of research and development with the application of used one group pretest-posttest design. Research participant included 88 grade X student taken from senior high school in Manokwari. Collected of data used an achievement test to measure thinking skills was used a rubric SOLO taxonomy with five levels. Wilcoxon test was used for data analysis. It is revealed that sig. $0.000 < 0.05$, 64 students experienced an increased level of thinking, 24 students were ties, and no students decrease in the level of thinking. Based on findings data, inquiry-based learning applications to train the thinking skills of learners is effective.

1. Introduction

School is one of the places aside from home which is substantial for the formal development of children [1]. The young people's interest in natural science has been declined in the last decade [2]. Hence, future study should focus on using an active method to encourage students to become creative, to properly understand knowledge, and to bring them closer to the real-life experience. The design of the learning environment for science education is heavily influenced by two types of study, inquiry-based science learning, and constructivism [3]. The effectiveness of teaching, science-concept mastery and the improvement of student skills is influenced by types and number of inquiry-based learning applied during in the class by the teacher [4]. when students engage in direct observation and group discussion in the class based on inquiry learning, it is making them motivated and interested in learning [5]. The students have potentials to develop a conceptual understanding from inquiry-based activities [6]. Review of 72 studies carried out by Lazonder & Harmsen [7] consistently point out that IBL is more effective than other learning as long as students received appropriate supports. The thinking skills can be accommodated through constructivism-based learning [8]. The inquiry learning is constructivism-based learning and is useful in harnessing students' thinking skills [9].

   Within the constructivism approach, the strategy to obtain something is more important than the amount of knowledge obtained or remembered by students. Learning should encourage the students to think critically toward the problem in learning. The teacher should be able to observe and measure their students' critical thinking ability. Learning should be able to enhance learner critical thinking skills [10]. Thinking skill is one crucial skill that needs to be improving in the 21st century. In Indonesia, the measurement of students' thinking skill has extensively been done in the area of high-level reasoning,

creative thinking, logical thinking, and critical thinking. Most of the reasoning/thinking ability measured are still using instruments, which refer to the Bloom Taxonomy level of questions from C1-C6. There is also one skill that often measured by researchers in Indonesia namely, thinking skill based on SOLO taxonomy level.

Thinking skill has been extensively studied in Indonesia, especially in mathematics learning [11,12]. The SOLO taxonomy is developed to be used in all level of subjects, not only in mathematics but also in other areas of science and computer science [13]. This SOLO taxonomy can also be used to measure students' cognitive achievement in various subjects, school levels, and types of tasks, in the subject of computer science, mathematics, chemistry, biology, sociology, dental education, and language study [14–18]. The SOLO taxonomy is specifically used to measure the thinking ability and evaluation of learners [19]. SOLO taxonomy can be implemented within the class in different subjects, either those oriented toward process or those who are conceptually oriented. The teacher uses SOLO taxonomy to design, recognize, describe and learning assessment in various level of cognitive difficulties in fulfilling high expectancy and coherence for the purpose of developing curriculum and attainment standard [20]. The SOLO taxonomy is considerably effective to be used within the learning program and during the teaching and learning process [21].

The above studies reveal that inquiry-based learning correlates with students' thinking skill. Thus, the utilization of IBL in the biology subject is effective to train the level of thinking of the students. To create IBL in biology, a valid and effective teaching device based on inquiry learning model needs to be created to improve students' thinking skill. Development of learning by providing an inquiry-based approach is important as it can help students to think and discover [22,23]. Damopolii et al [24] in their study suggest the utilization of IBL to train students' thinking skill [24]. The problem that would be addressed in this study is how the development of an effective teaching device to improve the thinking skill of the students in biology learning? The focus of this study is to analyze the effectiveness of the teaching device, which oriented on inquiry learning to train the students' thinking skill based on the level of SOLO taxonomy.

2. Methods

This is a research and development (R&D) model using a 4-D model adopted from Thiagarajan [25]. This model consists of four stage, that is define, design, develop, and disseminate stages. This study has been carried out for two consecutive years, and in this article, the result from the initial year study is presented to analyze the effectiveness of inquiry-based learning teaching device on the development stage. In this development stage, the stage in the learning device has been revised based on input from experts and following the result of the trials. The trial uses a group pre-test and post-test design to see the improvement of students' thinking skill.

This research conducted using three classes of science of a public high school in Manokwari. The total subject in this study involved 88 students. They were grouped into three groups (Group 1 = 34 students; group 2 = 27 students; and group 3 = 27 students). All of the students in these classes were taught using the teaching device with inquiry-based learning.

The instruments used are a lesson plan, student worksheets, achievement test, and student book. Achievement test consists of 9-essay item test. Prior to the implementation step, three experts were validating the instrument. These instruments can be used if the following criteria are fulfilled [26]:

Table 1. Validity Criteria

Range of percentage	Validity Criteria	Note
85.00 < % ≥ 100.00	Strongly Valid	The instruments are used without revision
70.00 < % ≤ 85.00	Valid	The instruments are used with minor revision
50.00 < % ≤ 70.00	Less Valid	The instruments are used with major revision
% ≤ 50.00	Not Valid	The instruments are unusable

A rubric from SOLO taxonomy level as presented in Table 2 below is used to measure the thinking skill of the students. This rubric is used to analyze students' answer and will be coded 1-5 based on the level of students' answer.

Table 2. Rubric of SOLO taxonomy level

SOLO Taxonomy Level	Characteristics	Code
P = Pre-structural	A learner does not understand the material; learner does not understand the task/question. Thus, they cannot appropriately answer the task; they are even unable to answer the question.	1
U = Uni-structural	A learner can describe a relevant concept/fact. A learner only uses one information; hence, the task/question is simply accomplished without any further explanation.	2
M = Multi-structural	A learner can describe in detail more than one fact/concept, the learner can work on the task/question by utilizing two or more information, and can determine more than one ways to accomplish/answer the task/question correctly.	3
R = Relational	A learner can describe more than one facts/concept, describe the correlation among various facts/concepts, a learner can accomplish task/question by making a correlation of several ways to accomplish the task.	4
EA = Extended abstract	A learner can describe various possible answers, provide several new solutions outside the concept that has been taught, a learner can construct a new concept outside the given concept.	5

(Adopted from Biggs & Collis and Mahmood et. al[14,20])

Data analysis are in the percentage of achievement in each SOLO taxonomy level. Wilcoxon test is used to see the increase of students' thinking skill in SOLO taxonomy level. The increased of thinking skills of learner see from their pretest and posttest. The criteria indicate that if $p < 0.05$, the students' thinking skill is increased. On the other hand, if $p > 0.05$, there is no significant increase in student thinking skill. The IBM SPSS version 22 for windows is used in data analysis.

3. Results and Discussion

Research instrument validation is presented before the IBL effectiveness in increasing students' thinking skill is analyzed. Experts validate the developed instrument. In addition, focus group discussion (FGD) is also held to have a similar perception with the validator. The table 3 is presented validation result.

Table 3. The result validation by expert

Teaching device	Result	Criteria
Lesson plan	97.69%	Valid
Student worksheet	93.52%	Valid
Student book	87.01%	Valid
Achievement test	95.83%	Valid

The validation result by three experts in Table 3 shows that all developed instruments meet the validity criteria and can be used in the classroom trial. The score of thinking skill before (pretest) and after (posttest) the treatment using IBL teaching device is presented in Figure 1.
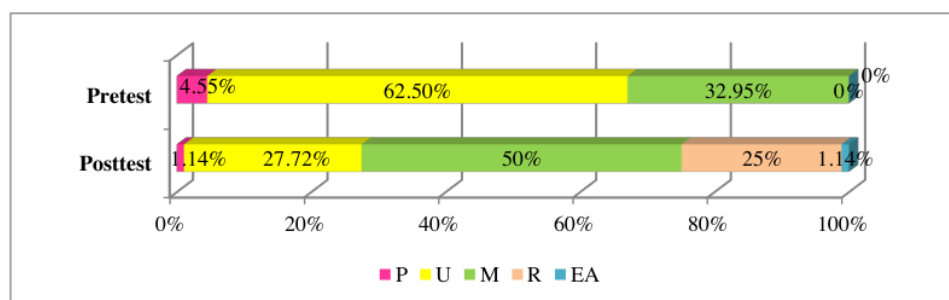
Figure 1. Increasing students' thinking skill graph in each level of SOLO taxonomy

Figure 1 depicts that before learning is implemented, students' thinking skill is only on the multi-structural level. In addition, 4.55% is on the pre-structural level, 62.50% is on the uni-structural level, and 32.95% is on the multi-structural level. These data show that students' thinking skill is still low. There are 70.05% of students whose thinking skill is between the pre-structural to uni-structural level. Following the implementation of the IBL teaching device, students' thinking skill increase. There is only 3.41% whose thinking skill is on the pre-structural level and 39.78% whose thinking skill is on the uni-structural level. In addition, the percentage of students whose thinking skill is on a multi-structural level increases by 17.05%. In addition, the percentage of students whose thinking skill is not under the relational level has increased to 25% within that level due to the implementation of the IBL teaching device. Only a small portion of students that can reach the extended abstract level. Overall, Figure 1 shows that IBL can train students' thinking skill into an extended abstract level in SOLO taxonomy level.

The result of this study is slightly different from the result of a study by [27] that most of SOLO taxonomy level is in pre-structural, multi-structural, and relational level, whereas only small portion of it is on the extended abstract level. In this study, most of the SOLO taxonomy level is on uni structural, multi-structural, and relational level.

On the other hand, Vrachnos & Jimoyiannis [28] in their study found that most students tend to provide responses in the lower level of SOLO, namely pre-structural, uni-structural, and multi-structural levels [28]. The study reveals that students are able to reach relational and extended abstract levels when the class is taught using IBL; thus, students' thinking skill properly develop. Further, to prove a significant increase in students' thinking skill, the data in Table 4 below present the analysis of the Wilcoxon test.

Table 4. Wilcoxon test

		N	%	Mean Rank	Z	Sig.
Posttest – Pretest	Negative Ranks	0[a]	0 %	.00	-7.941[b]	0.000
	Positive Ranks	64[b]	73 %	32.50		
	Ties	24[c]	27 %			
	Total	**88**	**100 %**			

Based on Table 4 above, it is proven that there is a significant improve in the students' thinking skill which shown by the value of $P < 0.05$. Table 4 shows that 73% of the students experience an increase of thinking skill, while 27% of them do not experience an increase in thinking skill. However, there are no students whose thinking skill decrease in IBL. Overall, it can be said that IBL can effectively increase students' thinking skill.

The result of this study corresponds to the result a seen in Jimoyiannis [29] that the SOLO taxonomy level only reaches to the rational level. He defines designing teaching instruction as an effort to assist students in reaching the SOLO taxonomy level. Therefore, we design IBL to assist students in achieving SOLO taxonomy level. Regardless of the result of our study that only 1.14% of learners that can reach the highest SOLO taxonomy level, extended abstract level. We would argue that when students learn,

they are able to think higher. Students' thinking is correlated with their cognitive. The result of his research shows there are no students who experience a decrease in their thinking skill during the administration of IBL teaching device. On the contrary, 73% of the students experience an increase in their thinking skill. It indicates that the developed teaching device can train high school students' thinking skill, especially for biology subject.

The developed IBL Teaching device demands students to be actively involved in a group investigation activity, where they are presented with problems to be solved. Hence, they discuss their problem at hands. When students are actively involved in experiment and discussion, it makes their thinking skill and teamwork skill increase [30]. One of the developed teaching devices is the student book. This students book is designed using IBL and to ease the implementation of IBL. 100 % of the students are interested in reading the inquiry teaching materials [31], and they agree to use IBL in Biology lesson [32]. Teaching material helps students to accomplish the inquiry stages of finding the answer, and it helps develop their thinking skills [33].

The developed teaching device consists of student worksheet, lesson plan, and student book, which complement each other for the success of the implementation of IBL. The success of this research is signified by the significant increase in students' thinking skill after the implementation of IBL. Utilization of IBL has a good chance to increase students' thinking skill. When students are oriented toward problems at the initial stage of IBL, they are demanded to create a formula and propose a hypothesis. This is the beginning for students to train their thinking skill up to when they discover the result of their inquiry, they start to make a correlation between the concept that they currently have and the concept they will discover. This connecting activity is a part of the rational level characteristic from SOLO taxonomy. In the beginning, students are unable to make a connection (evident from the pre-test answer), and during the post-test, they are able to make the connection.

IBL is a constructivism learning theory. When IBL is set in the class, students are demanded to be able to connect their existing knowledge with their newly discovered knowledge to create new knowledge. This is in line with the characteristic of extended abstract level in SOLO taxonomy. Even though there is only a small number of students who are able to reach this level, our argument stands that IBL can train students thinking skill. This needs a complete design in the future to increase the number of students who are able to reach this extended abstract level of thinking in SOLO taxonomy. The teacher can design an IBL learning to train his/her students' thinking skill.

4. Conclusion

This study concludes that the developed teaching device is effective to train students' thinking skill based on the level of SOLO taxonomy. Overall, 73% of the students' thinking skill is increased. In this study, students' thinking skill are spread all over the level of SOLO taxonomy, from pre-structural to the extended abstract. Most of students' thinking skill are on multi-structural and relational levels. This study is limited to the lack of students who are able to achieve the extended abstract level of thinking based on taxonomy of SOLO. The result of this study can be used as a baseline for further stage study. Better planning is needed to implement the next stage of the research by using control class as a comparison. It is also expected that the classroom teacher can design an IBL class to develop his/her students thinking skill

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