The effectiveness of inquiry-based learning on computational thinking skills and self-efficacy of high school students

MA S Sulistiyo and A Wijaya

1 Student of Mathematics Education Program of Faculty of Mathematics and Science Universitas Negeri Yogyakarta, DI Yogyakarta, Indonesia

2 Lecturer of Mathematics Education Program of Faculty of Mathematics and Science Universitas Negeri Yogyakarta, DI Yogyakarta, Indonesia

E-mail: monicansella18@gmail.com

Abstract. The aim of this research was to investigate the effectiveness of Inquiry-Based Learning (IBL) on computational thinking skills and self-efficacy of 11th grade students with derivative as the learning topic. The type of this research was quasi experimental research. The population of this research was 191 of 11th grade students in a public high school in Yogyakarta. The sample was 42 students from class XI Natural Science 1 and XI Natural Science 3 which were chosen by random sampling. The data were collected from pre-test and post-test for computational thinking skills and survey for self-efficacy. The results showed that: (1) IBL was effective toward computational thinking skills, (2) IBL was effective toward self-efficacy, (3) scientific learning was effective toward computational thinking skills, (4) scientific learning was effective toward self-efficacy, (5) IBL was not more effective than Scientific Learning toward computational thinking skills, (6) IBL was more effective than Scientific Learning toward self-efficacy. IBL failed to become learning model that was more effective than scientific learning toward computational thinking skills because of the failure in developing asking skills, but succeed to be more effective than scientific learning on improving self-efficacy because IBL provided more diverse sources of self-efficacy.

1. Introduction

In Indonesia, the learning practices including mathematics learning are regulated by Regulation of The Minister of Education and Culture of Republic Indonesia Number 103 Year of 2014 [1]. The regulation stated that teachers are permitted to choose any kind of learning model that support scientific learning. One of learning models that is potential to support scientific learning is Inquiry-Based Learning (IBL).

Inquiry-Based Learning (IBL) is the learning model that focus on students’ activities in class [2] so students can construct their own basic concept knowledge [3]. The principles of IBL include orientation of learning, class interaction, questioning, and openness [4]. The essence of IBL is its process in inquiring and getting new knowledge [5]. [5] also added that questioning and investigating are the main points in IBL. This is supported by the statement from [6] stating that the thing that IBL emphasizes is how students developed their own questions. Through the questioning activities, IBL is believed could deepen students’ comprehension in learning [6] and improve the skills of analysing and solving complex problems [7].
The practices of IBL is proven to give positive effects in cognitive aspect in learning [8]–[10]. [11] explained that IBL give positive effects toward students’ comprehension. This is supported by the statement of [12] saying that IBL could help to increase concept understanding and modelling in mathematics. Besides, IBL also improve students’ scientific process skills [13], [14]. Beside the positive effects on cognitive aspect, IBL is also proven to improve students’ affective aspect. IBL showed could give positive effects on students’ self-efficacy [15], [16]. Moreover, IBL also could improve students’ attitudes in the process of learning [17].

Considering the characteristics if IBL, it has a potential to improve students’ skills in cognitive and affective aspects. If IBL bring bigger improvement than the usual learning practice then it will be beneficial for Indonesia to conduct the learning practice using IBL since Indonesian students’ skill is still in below rank compared to other OECD countries and partners.

Result of Programme for International Student Assessment (PISA) from 2000 until 2015 showed that Indonesian students’ aged 14-15 years performances in mathematics is always significantly below the average of Organisation for Economic Co-operation and Development (OECD) countries [18]. The data of PISA 2012 showed that only 0.3% of Indonesian students were able to solve level 5 and 6 mathematics problems [18]. The disability to solve level 5 and 6 PISA problems means that Indonesian students still find difficulties in working on complex problems [19].

Complex problem is a problem that comprises many sub-problems [20]. Complex problem needed to be broke down into sub-problems so the tasks will be simpler. By solving each of the sub-problems and connect it one to another, the complex problem will be solved. Seeing the fact that students in Indonesia facing difficulties on working with complex problem means the students still lack in breaking down the complex problem into sub-problems. One of complex problems in PISA (see Figure 1) can be solved completely if students succeed on breaking down the rate of growth before and after 12 years of age then compare it to each other.

**M150: Growing Up** In 1998 the average height of both young males and young females in the Netherlands is represented in this graph. Explain how the graph shows that on average the growth rate for girls slows down after 12 years of age.

![Figure 1. Example of PISA complex problem](image)

Beside the difficulty to work on complex problem, [22] also found that Indonesian students find the difficulty to make mathematical model of context problems like PISA. In school, mathematics context problems are pure mathematics problems that manipulated in the words of real situation [23]. Hence, mathematical model which is the result of mathematising objects, data, relations, and conditions of world problem is needed to solve context problem [23].

The ability to break down complex problem and making mathematical model of context problems are parts of computational thinking skills. Computational thinking is an approach to problem solving that can help students to model [24], represent, and decompose [25] complex problems. Moreover, [26] also described that computational thinking is a problem-solving method that accentuates in modelling, reasoning, generalising, and analysing problem. Therefore, from the
fact that Indonesian students is lacking on the two things stated above, means that students in Indonesia still have to improve their computational thinking skills.

Another weakness of Indonesian students in mathematics is shown when students have to solve derivative problems. Result from Indonesia national examination (Ujian Nasional) for science program students in high school in Yogyakarta showed that between year of 2015 and 2018, students mostly find the hardest topic was derivative. The average of students that could answer correctly for derivative between those years was less than 50% [27]. Thus, beside of computational thinking skills, students in Indonesia also need to improve their understanding toward derivative.

The aspect that Indonesian students have to improve not only the cognitive one, but also the affective aspect since both aspects affected to each other. One of those affective factors is self-efficacy. [28] stated that, “[e]fficacy expectations determine how much effort people will expend and how long they will persist in the face of obstacles and aversive experiences. The stronger the perceived self-efficacy, the more active the efforts,” meaning that self-efficacy (SE) is defined to be the beliefs toward one’s own self to do efforts in order to master something.

Result from PISA 2012 showed that Indonesian students’ mathematics self-efficacy is improved by 0.11 points since PISA 2003 [19], making Indonesia ranked 10th for its self-efficacy improvement between OECD countries and partners. Even though the rank was quite high for the improvement, Indonesian student’s mathematics self-efficacy in 2012 was still at 32nd rank out of 39 countries [19]. The effect of self-efficacy toward students’ performance in mathematics in 2003 was strong and it remained strong in 2012 with correlation of 0.5 [29], meaning that it still has positive relationship toward students’ performance. That being said, it is likely that self-efficacy will keep on becoming affecting factor toward students’ mathematics performance in future.

Based on the description above, IBL have the potencies to improve students’ ability to understand concepts and make model of problems which are parts of computational thinking skills. IBL also have the potencies to improve students’ self-efficacy. Therefore, study about the effectiveness of IBL on computational thinking skills and self-efficacy of high school students with derivative as the learning topic is needed to be conducted.

2. Methods
2.1. Type of research
The research type for this research was quasi experimental. Two classes joined the research, one as the experimental group which learned using inquiry model and another as the control group which learned using the scientific model.

2.2. Place and time of research
Research conducted at a public high school in Yogyakarta on March 20th, 2019 until April 11th, 2019.

2.3. Population and Sample
Population of this research was the 11th grade students of a public high school in Yogyakarta. The number of populations were 191 students, consisting six of natural science classes and one social science class. Sample of this research consist of two of natural science classes based on random sampling technique.

2.4. Research design
The design of this research was non-equivalent groups pre-test – post-test design using experimental group and control group. Each group was given pre-test for assessing computational thinking skills and self-efficacy before the study. Then, the experimental group was given the treatment by learning using inquiry model, meanwhile the control group learned using scientific model. After given the treatment, each group was given post-test for assessing computational thinking skills and self-efficacy after the study.

2.5. Data collection technique and instrument
The data for this study were collected using pre-test and post-test for assessing the computational thinking skills also initial and final survey for assessing self-efficacy.
2.6. Data analysis technique

The data analysis techniques used in this study were descriptive analysis and inferential analysis. The effectiveness of IBL toward computational thinking skills and the effectiveness of IBL toward self-efficacy were analysed based on the mean of post-test score. The same analysis was also done to investigate the effectiveness of Scientific Learning toward computational thinking skills and self-efficacy respectively. Each learning model was specified to be effective toward computational thinking skills if the mean of post-test score passed the passing grade, which was 73. Meanwhile, each learning model was specified to be effective toward self-efficacy if the mean of final survey score was more than the lower bound of good category, which was 67.2. The detail of each variables’ improvement was analysed based on the improvement from pre-test result to post-test result.

Further analysis was done using Independent Samples T-test to investigate the effectiveness of IBL and Scientific Learning toward computational thinking skills; and the effectiveness of IBL and Scientific Learning toward self-efficacy. IBL was specified more effective than Scientific Learning on computational thinking skills if the mean of post-test score from IBL class was significantly higher than scientific class; and IBL was specified more effective than Scientific Learning on self-efficacy if the mean of final survey score from IBL class was significantly higher than scientific class.

3. Results and discussion

In this research, the lesson that students learned was about derivative. The learning in experimental group conducted based on IBL, meanwhile the control group used scientific learning. For the next description, experimental group will be stated as IBL class (XI Natural Science 3) and control group will be stated as scientific class (XI Natural Science 1).

Pre-test to assess computational thinking skills and self-efficacy were given to students before learning about derivative. Then students learned about the concept of derivative, the basic rule of derivative, and the application of derivative in real life within three meetings (6x45 minutes). In the last meeting students were given post-test to assess computational thinking skills and self-efficacy after the treatment.

The learning steps of IBL class were asking, identifying, planning, and determining answer. In asking step, teacher gave situation or context-based problem that is related to the topic of derivative then students ask their questions toward the situation. The next step, identifying, was the step for students to sort information that could be used to answer the questions based on available information in the situation stated by teacher. Based on the information students had sorted, in planning activity students listed steps to answer their questions. The steps that students listed should be related to concepts or principles in mathematics that could be used. After planning the steps to solve the problems, students execute the plan to produce the calculation result in determining answer step. Students also had to transform the calculation result into applicable solution to the problems.

The learning steps of scientific class were observing, asking, collecting information, associating, and communicating (based on Regulation of the Minister of Education and Culture of Republic Indonesia number 81A year of 2013 appendix IV/Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia nomor 81A tahun 2013 lampiran IV). In observing, students read, listened, observed, or looked at object(s) (using or without equipment). Then, in asking students asked questions to get information about the object observed. Next, students did experiment, read other sources, or did interview in order to collect information. The collected information then being analysed in associating. The analysis had done in order to deepen the information or finding solution toward problems. Learning steps in scientific class ended by sharing the observation result and conclusion from the analysis in communicating.

Result showed that both classes improved on computational thinking skills, but the improvement in IBL class was 2.13 points higher than the scientific class (See Table 1). The increase of standard deviation in IBL was higher than scientific class after the treatment. This means that the gap among the students in IBL class became wider compared to scientific class. In IBL class, students that have been active during the lesson joined the discussion more than the passive students causing the gap between active and passive students became wider.
Table 1. Computational thinking skills score.

| Data               | IBL Class | Scientific Class |
|--------------------|-----------|------------------|
|                    | Pretest   | Posttest         | Pretest | Posttest |
| Mean               | 16.40     | 79.75            | 15.55   | 76.77    |
| Std. deviation     | 8.59      | 12.53            | 8.41    | 9.61     |
| Lowest Score       | 3         | 60               | 3       | 60       |
| Highest Score      | 29        | 98               | 28      | 95       |

In this study, the indicators used to assess the computational thinking skills consisted of pattern recognition (PR), decomposition (D), and abstraction (A). Students are said to have pattern recognition skill if students can choose the right concept or principle that is able to solve problems in an effective way. Meanwhile, students are said to have decomposition skill if students can identify the problem and solving multi-step problems in mathematics. Lastly, if students can make the right mathematical sentence toward problems and successfully transform their calculation result into applicable solution, then students are said to have abstraction skill. The change of computational thinking skills in a more detailed level for every indicator can be seen in Table 2.

Table 2. Detail of computational thinking skills score.

| Indicator | IBL Class | Scientific Class |
|-----------|-----------|------------------|
|           | Pretest   | Posttest         | Pretest | Posttest |
| PR        | 7.25%     | 69.00%           | 11.36%  | 67.27%   |
| D         | 28.67%    | 80.67%           | 22.88%  | 79.09%   |
| A         | 9.33%     | 85.33%           | 10.30%  | 80.00%   |

Result also showed that both classes had improvement on mathematics self-efficacy, but the improvement in IBL class was 13.2 points higher than the scientific class (See Table 3). After the treatment, the standard deviation in IBL class decreased, meanwhile it was increased in scientific class. This means that the gap of self-efficacy among the students in scientific class became wider compared to IBL class.

Table 3. Self-efficacy score.

| Data               | IBL Class | Scientific Class |
|--------------------|-----------|------------------|
|                    | Pretest   | Posttest         | Pretest | Posttest |
| Mean               | 60.65     | 76.35            | 60.23   | 62.73    |
| Std. deviation     | 9.98      | 9.06             | 6.70    | 7.32     |
| Lowest Score       | 41        | 57               | 50      | 51       |
| Highest Score      | 75        | 89               | 72      | 75       |

The change of self-efficacy in a more detailed level for every dimensions of self-efficacy, which are magnitude (M), strength (S), and generality (G) can be seen in Table 4. Magnitude shows
how students see different level of problems in mathematics. High level of magnitude students showed means that students see difficult tasks as challenge instead of something that are impossible to be solved. Meanwhile, strength dimension measured how students appreciated their effort. If students believe that their effort will not be wasted and will bring them into certain degree of success, then it can be said that students have great strength in their self-efficacy. Generality can be measured by looking at students’ perspective toward mathematics in general. Students are said to have great generality if they believe they can do well in mathematics and the knowledge of mathematics is useful for their life.

**Table 4. Detail of self-efficacy score.**

| Indicator | IBL Class | Scientific Class |
|-----------|-----------|-----------------|
|           | Pretest   | Posttest        | Pretest   | Posttest |
| M         | 59.22%    | 77.66%          | 61.93%    | 62.64%   |
| G         | 67.03%    | 83.13%          | 61.79%    | 64.77%   |
| S         | 63.28%    | 77.81%          | 64.49%    | 68.61%   |

3.1. *The Assumption Test Results*

The assumption tests were done using normality test, homogeneity test, and independence test. Result of normality test which was conducted using Shapiro-Wilk Test showed that the collected data were all normally distributed (sig. < 0.05). Result of variance homogeneity test was conducted using Levene’s Variance Homogeneity Test. The data of pre-test and post-test for computational thinking skills and self-efficacy were respectively homogeneous (sig. > 0.05). Result of independence test showed that the mean of computational thinking skills and self-efficacy score between two classes before the treatment was respectively equal (sig. > 0.05).

3.2. *The effectiveness of IBL toward computational thinking skills*

Mean of post-test score in IBL class was 79.75. Result from One Sample T-test showed that IBL was effective toward computational thinking skills (sig. 2-tailed = 0.026). This means that the mean of computational thinking skills post-test score was significantly higher than the passing grade, which was 73.

The highest development was in abstraction with 76.00% of improvement from pre-test to post-test. Following the improvement on abstraction, pattern recognition skill came as the second developed skill with 61.75% of improvement. Least development showed in decomposition with 52.00% of improvement.

These results showed that IBL had able to help students the most in making mathematical model from problems and producing applicable solution(s) to the problems. IBL also had the ability to develop students’ skill in choosing the right concept or principle to solve problems in effective way, even though the impact in this ability was not bigger compared to making models and producing solutions. In addition, the result showed that the least impact IBL gave to students was in identifying and solving multi-step problems in mathematics.

Looking at the arrangement of developed skills, steps of IBL that contributed the most in students’ improvement were planning and determining answer since both of it were the steps that supported abstraction improvement in direct. Asking was another step that contributed in students’ development, even though the contribution was not as big as planning and determining answer. The remaining step, which was identifying gave least contribution to students’ cognitive development, showed by the least development of decomposition in IBL class.

3.3. *The effectiveness of Scientific Learning toward computational thinking skills*

Mean of post-test score in scientific class was 76.77. Result from One Sample T-test showed that scientific learning was effective toward computational thinking skills (sig. 2 tailed = 0.080). This
means that the mean of computational thinking skills post-test score was significantly higher than the passing grade, which was 73.

The indicator of computational thinking skills with biggest improvement in scientific class was abstraction with 69.70% of change. Different from IBL class, the second highest development in scientific class came from decomposition with 56.21% of improvement. Then, the least development was in pattern recognition, showing 55.91% of improvement.

These results showed that scientific class had able to help students the most in making mathematical model from problems and producing applicable solution(s) to the problems. Another ability that scientific learning had was to develop students’ ability to identify and solving multi-step problems in mathematics, even though the impact for this skill development was not as big as the impact to make models and produce solutions. The result also showed that the least impact scientific learning gave to students was to choose the right concept or principle to solve problems.

Based on this developed skills arrangement, steps of scientific learning that contributed the most in students’ improvement was associating since it was the step that supported abstraction improvement directly. Another step that contributed to students’ development was collecting information, even though the contribution was not bigger than associating. Observing and asking were the last steps that contributed to students’ cognitive development, showed by the least development of pattern recognition in scientific class. The remaining step, communicating, was not considered in giving impact in developing computational thinking skills of students because it did not affect directly to any indicator of computational thinking skills in this study.

3.4. The effectiveness of IBL and Scientific Learning toward computational thinking skills
Result from Independent Samples T-test showed that IBL was not more effective than scientific learning toward computational thinking skills (sig. 2-tailed = 0.390). This means that mean of IBL class post-test score was not significantly higher than scientific class.

The possible reason for this occurrence was the failure to develop skill of asking which is the step that IBL emphasize the most. The failure caused by lack of time for students to learn during the study. The treatment was too short and paused for a week in the middle of the process due to national examination, meanwhile improving question-asking skill in IBL [30] could take more time [31] than improving other skills. This was supported by the statement from [32] stating that the limitedness of study time could become the obstacle in learning.

Another factor that affected the post-test result was the cancelled steps in IBL class. During the study, only 93% planned lesson was done in IBL class. The cancelled step was planning. Two out of three problems that were solved in the third meeting were done without making the plan where students should determine the right mathematics concepts or principles toward the problems. Hence, this became another factor that made IBL class did not reach maximum learning outcome.

3.5. The effectiveness of IBL toward self-efficacy
Mean of final survey score in IBL was 76.35. Result from One Sample T-test showed that IBL was effective toward self-efficacy (sig. 2-tailed = 0.000). This means that the mean of self-efficacy was significantly higher than the lower bound of good category, which was 67.2.

The biggest improvement of self-efficacy dimension in IBL class students was magnitude with 18.44% of change. There was change in students’ perspective toward difficult mathematics problems. Before the treatment, students thought that they could only solve problems with low level of difficulty. The change came after the students were given treatment. Since in IBL class students had to solve complex problems, students experienced the success to solve different level of task than they usually did. This showed that the supporting factors that affect students’ self-efficacy was the cognitive rehearsal. It is in line with [28] founding that stated there are four sources of self-efficacy, which are mastery experience, reduction of emotional arousal, vicarious experience, and cognitive rehearsal.

The change of students’ perspective not only happen toward various level mathematics problems, but also the perspective toward learning. In students’ initial condition, students’ thought that mathematics learning only could be done if there is teacher, mentor, or expert to help students. After learning using inquiry model (IBL) where teacher let them use any other learning sources such as different reference books or internet, students’ respond toward statement of “I can learn
mathematics by myself using book, internet, and any other learning sources” – which belongs to strength dimension, significantly changed. It means that students experienced mastery in learning using IBL. This experience, as stated in the previous paragraph could be the supporting factor toward students’ self-efficacy.

The dimension that came with least improvement was generality. This showed that after given the treatment, there was no significant change toward students’ perspective toward their skills to master mathematics in general. The hypothesis was grounded based on the questionnaire statement of generality that received least improvement, which was “I can solve mathematics problems in each material/chapter”. Possible reason to this circumstance was the experience of encountering numbers of failure in mathematics.

3.6. The effectiveness of Scientific Learning toward self-efficacy
Mean of final survey score in scientific learning was 62.73. Result from One Sample T-test showed that scientific learning was effective toward self-efficacy (sig. 2 tailed = 0.009). This means that the mean of self-efficacy was significantly higher than the lower bound of good category passing grade, which was 67.2.

In scientific class, biggest change happened in strength dimension with 4.12% of improvement. This showed that scientific learning helped students the most in appreciating their effort in learning. Looking at the statement with highest improvement in strength dimension, which stated that “I can solve mathematics problems if I work on problem solving diligently”, it can be seen that students believed that the more often they solved problems, the better result they would get in their study. Following the improvement of strength, generality dimension improvement in scientific class came as second place with 2.98% of change. It means that students’ perspective toward mathematics in general slightly changed after joining scientific class. Even though the change came in small scale, most of students showed the belief that they could improve mathematics score that was still lacking.

The remaining dimension, magnitude, changed only for 0.71% after the treatment. The smallest improvement showed in the statement that said “I am not sure if I can master difficult mathematics material” indicated that students in scientific class did not develop their belief to do various level of tasks in mathematics.

This result showed that out from four sources of self-efficacy, which are mastery experience, reduction of emotional arousal, vicarious experience, and cognitive rehearsal, students in scientific class got their self-efficacy solely from exercises that belong to cognitive rehearsal.

3.7. The effectiveness of IBL and Scientific Learning toward self-efficacy
Result from Independent Samples T-test showed that IBL was more effective than scientific learning toward self-efficacy (sig. 2-tailed = 0.000). This means that after given the treatment, self-efficacy of students in IBL class became significantly higher than students in scientific class.

The factors that played roles toward the improvement of self-efficacy were experience of mastery and cognitive rehearsal. This is supported by the explanation from [28] which stated that mastery experience is one of factors that increase self-efficacy. Even though both classes experience the improvement of self-efficacy, students in IBL class got mastery experience of learning by themselves and experienced cognitive rehearsal, meanwhile students in scientific class only experienced the cognitive rehearsal.

The variety of self-efficacy sources students got during learning process became the factor that make IBL more effective toward self-efficacy. While IBL facilitated students to feel the experience from two sources of self-efficacy, scientific class allowed students to experience only one source of self-efficacy. This possibility is in line with result from [33] stating that more diverse sources of self-efficacy students found will support bigger improvement of self-efficacy.

Another possibility for the higher improvement of self-efficacy in IBL class was the cognitive rehearsal. Since the problem IBL class solved from the beginning was complex problems, students experienced the higher level of success they could achieve than in the usual lesson that used Scientific Learning. This possibility also supported by [28] stating that the more higher level of success one could achieved, the improvement of self-efficacy became bigger.
4. Conclusion

Inquiry-Based Learning (IBL) and Scientific Learning were effective to improve 11th grade students’ computational thinking skills. Planning and determining answer were the steps that gave biggest contribution in IBL class cognitive development. It was showed by 76.00% of abstraction dimension improvement which was supported directly by planning and determining answer. In the other side, associating gave the biggest contribution to the development in scientific class, proven by 69.70% of abstraction improvement which was supported directly by associating step. Even though both learning model was found to be effective for improving computational thinking skills, it was proven that Inquiry-Based Learning was more effective than Scientific Learning for improving computational thinking skills. The possible reason for this occasion was the failure to develop question-asking skills in IBL class, which should be the main focus in inquiry learning.

Alongside with the effectiveness of both learning models toward computational thinking skills, IBL and Scientific Learning were also proven to be effective in improving 11th grade students’ self-efficacy. However, IBL was more effective than Scientific Learning in improving self-efficacy. The factor that contributed to this effectiveness was the number of self-efficacy sources that was found in each learning models. In IBL, students got the mastery experience and cognitive rehearsal as the sources of their self-efficacy, meanwhile students in scientific class only got the cognitive rehearsal.

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