Enhancing Students' Creative Thinking through Inquiry-Based Learning Integrating Mathematical Tools

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ABSTRACT
Students were demanded to be a creative problem solver in the career world. A mathematical learning following an inquiry-based learning approach and integrating mathematical tools was developed in this study. Students constructed original solutions about trigonometry ratio by using a clinometer and a meter as mathematical tools in allowing creative thinking. The product was designed through ADDIE methodology and applied to two classes in a Senior High School. A pre-test and post-test design measured cognitive knowledge as creative thinking variable. The result showed that this product with using mathematical tools was feasible and successful in enhancing students’ creative thinking. Inquiry-based learning was developed by involving three main components; providing students with a contextual mathematical problem-solving activity; involving student in an open-ended investigation with using a clinometer and a meter as mathematical tools to promote their creative thinking in creating original solutions; motivating students to build their own knowledge. This inquiry-based learning which had been developed significantly influenced students’ pre-knowledge scores. It could be concluded that creative thinking contributed, too. A recommendation for mathematics teachers in teaching mathematics was to involve students in problem-solving activity that facilitated them to conduct open-ended investigation whereas they could construct their own knowledge in building an original solution.

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1. INTRODUCTION.
Mathematics instruction is required by every education level as students need to be able to apply some mathematical ideas in solving problems related to real life (Kitchen, 2016; OECD, 2016). In mathematics instruction, teachers embed mathematical concepts needed by students to solving problem in real life. Consequently, encouraging students to solving contextual problems is important. Involving students in problem-solving activity can help them to understand when and how their knowledge should be used in real life.

Since mathematics learning connected to problem solving, students basically need to have higher order thinking skills. The main point that should be taught by teachers not only mathematical concept but also how to think in solving problem. The reason why students should be taught with higher order thinking skills is to establish them for confronting problems in real life, especially in working world (Trilling & Fadel, 2009; Fadel, 2015; Kementerian Pendidikan dan Kebudayaan [Kemendikbud], 2017).

In an effort to evaluate the high-level thinking skills of students, the Ministry of Education and Culture began to raise higher order thinking skill questions in national computer-based test 2018. In fact, the results of national computer-based test 2018 in high school students showed that there were still many students who claimed to have difficulty solving higher order thinking skill problems, especially in mathematics, with reasons not know about higher order thinking skill in previous mathematics learning (KPAI, 2018). But some of the other students at the school who had taught higher order thinking skill questions showed satisfactory results at national computer-based test 2018 mathematics subjects.

The description above gives the view that high-level thinking skills are very important. Creative thinking is one form of high-level skills needed by students to be able to become creative problem solvers. In the working world, individuals are required to be creative problem solvers. Therefore, creative thinking is very important for students to have.

Some studies consider inquiry-based learning can encourage students to think creatively in solving problems (Kadir et al., 2017). Learning following inquiry approach is a pedagogical approach that involves students in open investigations so that it is possible for students to construct a variety of problem solving. In this case, learning following an inquiry approach that directs students to use mathematical ideas in solving a non-routine mathematical problem is called mathematical inquiry-based learning.

According to above analyses, we really need a research to develop mathematical learning facilitating students to use their
creative thinking skill in solving problems. This study aims to develop a inquiry-based learning which can enhance students’
creative thinking in solving problems. Base on this study’s purpose,
research questions in this study were: (1) how the process of
developing inquiry-based learning integrating mathematical tools in
enhancing students’ creative thinking; (1) how the result of
developing inquiry-based learning integrating mathematical tools in
enhancing students’ creative thinking.

1.1 Creative Thinking

Every individual can be said to be creative, but the level of
creativity of each individual is different (Solso, 1995). Although
creative thinking and creativity are conceptually related, the two
terms are not identical. Creativity refers to the construction of an
umbrella that encapsulates creative thinking, and describes the
cognitive aspects of creativity (Puccio & Gonzalez, 2004). Creativity
is defined as the ability to produce meaningful original ideas (Liu &
Schönwetter, 20 04). Creativity is the result of creative thinking.
Creative thinking is one type of high-level thinking, commonly
known as higher order thinking (Kaur & Toh, 2012). There is no
generally accepted agreement regarding the theory of creative
thinking, both in terms of definition, characteristics, or the process of
creative thinking. According to Vanderbos (2006) creative thinking is
a mental process that leads to new discoveries, solutions, or
syntheses in any field. Learning that facilitates students to
rediscover a concept through problem solving or invites students to
apply concepts to solve problems related to real life can provide
opportunities to bring students creative thinking.

Creative thinking is a thinking activity to gain new views or new
methods of understanding things (McGregor, 2007; Jonsson, 2014).
A person with creative thinking in this case is called an individual.
Individuals do not have to find big new things, like famous scientists
who produce great works. In the context of education, creative
thinking is associated with problem solving activities. An individual is
someone who is able to construct himself a method of problem
solving and is not fixated by an algorithm to solve known problems
in general.

According to Kampsilis & Berki (2014), "Creative thinking is
defined as thinking that enables students to apply their imagination
to generating ideas, questions and hypotheses, experimenting with
alternatives and evaluating their own and their peers’ ideas, final
products and processes" (p.6). Creative thinking is defined as
thinking which allows students to apply their imagination to generate
ideas, questions and hypotheses, experiment with alternatives and
to evaluate their own ideas and their friends, products and final
processes. Creative thinking is not only about the process of
creating things. Creative thinking is also used to find new ways of
looking at a situation, a new way of solving problems, identifying
alternative solutions, a new process to achieve goals (Brookhart,
2010; Allan, 2017). In a different context, the forms of creative
thinking are also different.

Wallas was a psychologist who first discussed the process of
Wallas argued that basically the creative thinking process consists
of four stages (commonly called Wallas’ The Four-Stage Model
of Creative Thinking), which involves preparation, incubation,
illumination, verification (Sadler-Smith et al., 2015; Peirce, 2018).
Briefly, Wallas (1926) describes the four stages of the creative
thinking process as follows.

1.1. Inquiry-Based Learning

Inquiry-based learning (IBL) is one of learning that teaches students
how to think (how to think), which is rooted in the work of John
Dewey and Jerome Bruner (Arends, 2012). This approach is
structured for mathematics learning, guiding students through a
series of problems and evidences that are increasingly challenging and
encourage students to build a coherent understanding of
mathematical ideas and concepts. Inquiry-based learning (IBL) is a
pedagogical approach that actively involves students in the
knowledge development process by generating questions that can be
answered (Harada & Yoshina, 2004; Hotchkiss et al., 2015).
Students not only listen to the teacher passively but also actively
participate in learning. IBL provides opportunities for students to be
more active in learning, such as asking questions, answering
questions, or conveying ideas related to learning.

Inquiry-based learning is a student-centered approach that
allows students to gain knowledge by involving them to form
questions about a topic, encouraging them to investigate and use
evidence to find or create solutions to problems, increase the use of
new knowledge in contexts that they can connect, and foster
sharing of knowledge with others (Hughes & Ellefson, 2013;
Sriwongchai et al., 2015; ECCE, 2016). In addition to encouraging
students to conduct investigations, inquiry-based learning also
directs students to collaborate with other students in constructing a
problem solution.

The role of the teacher in IBL is as a facilitator of information
processing by asking questions and guiding the construction of
student ideas (ECCE, 2016; Laursen, 2015). The teacher is not the
only source of information. Students can get information through
books, the internet, the surrounding environment, and so on. Inquiry
learning focuses on the process. This learning involves students in
the learning process so that they can seek knowledge by questioning and investigating the problems given by the teacher.
The process of this learning model usually begins by presenting
questions or problems. Then students try to produce strategies to
investigate, collaborate, justify (justify), and reflect on solutions to
problems or answers to questions. They then communicate and
share conclusions.

The purpose of inquiry-based learning is nothing but to
encourage students to be more courageous and creative in
determining methods that can be used in solving problems that
have never been encountered before (Anam, 2015). In this case,
the focus of the teacher is needed to direct students to construct the
hypothesis of a new problem for students so students can find the
right method to get a solution.

Inquiry is defined as the search for knowledge, questions to
answer questions, and systematic investigation of problems related to
real life (Caliskan, 2012). Problems in real life are generally
non-routine problems. Non-routine problems are problems in which
steps or procedures for completion require planning, not just using
memorized algorithms (Wena, 2010). Non-routine problems in
inquiry learning usually contain a variety of real-life contexts.
Mathematical inquiry is the process of solving non-routine problems that significantly depend on mathematical ideas in the process of
solving them (Makar, 2012). Students in mathematical inquiry are
required to understand the relationship between mathematical ideas and contextual problems faced.
2. RESEARCH METHOD

2.1 Research Methodology

The research design used in this study was a developmental research. This research developed instructional design using ADDIE model in producing inquiry-based learning integrating mathematical tools. ADDIE model is one of the most common models used in the instructional design field a guide to producing an effective design (Aldoobie, 2015). ADDIE model composed of five phases were analysis, design, development, implementation, and evaluation.

2.2 Research Variables

In this study, the independent variable was provided as inquiry-based learning, and the dependent variable consisted of students’ knowledge scores as students’ creative thinking. In addition, the mathematics content used for this study was 10th grade mathematics of the 2013 Curriculum in Indonesia, entitled “Trigonometry Ratio on A Right Triangle”, which took 90 minutes for learning activities.

2.3 Participants

Participants were selected by the cluster random sampling method. Participants consisted of a mathematics teacher who taught in 10th grade level and 76 students (38 IBL, 38 non-IBL) in 10th grade level (mathematics and science program) in the academic year of 2019, from a school in Gresik, East Java, Indonesia. The remaining participants had a mean age of 16 (SD=.33). 38 IBL participants were involved in inquiry-based learning implementation and 38 non-IBL participants were only involved in traditional instruction implementation. Participants were assigned to balance low performing and high performing classes between the IBL and Non-IBL groups.

2.4 Research Instruments

In this study, an interviewing form was used to analyse students’ characteristics, an observing form was used to observe the implementation of the inquiry-based learning, a questionnaire form used to explore students’ responds of the inquiry-based learning, and a pre-post test was used to examine students’ knowledge scores. Those forms were evaluated by relevant experts and judging their quality. Pre-test and post-test was constructed by using real life based problem with rubric scoring for assessing.

2.5 Data Collection

2.5.1. Analysis Phase

Collecting data about the problems of mathematics learning to enhancing students’ creative thinking by using observing and interviewing forms for exploring creative thinking in mathematics learning for exploring an information from relevant students and a teacher. In addition, we observed teacher’s lesson plan which was used to teach trigonometry ratio.

2.5.2. Design Phase

Collecting data in this phase was conducted by reviewing theory about the syntax and characteristics of inquiry-based learning.

2.5.3. Development Phase

Collecting data about a valid aspect of developed lesson plan and worksheet by using assessing forms. The validators in this case are relevant experts.

2.5.4. Implementation Phase

In this phase, collecting data was conducted by researcher to get students’ knowledge score as well as students’ creative thinking skills by giving pre-test and post-test. This data was used to measure a effective aspect of developed instruction in enhancing students’ creative thinking.

2.5.5. Evaluation Phase

Collecting data about students’ responses of developed instruction uses a questionnaire form. This data was used to measure a practical aspect of developed instruction.

2.6 Data Analysis

The data results of pre-test and post-test were analysed by using the t-test (dependence case) to determine the level of significance different between the pre-test scores and post-test scores of creative thinking. Also the t-test (independence case) for determining the level of significance of difference in comparison of IBL group (as an experimental group) and non-IBL group (as a control group).

3. RESULT AND DISCUSSION

Either Non-IBL group or IBL group showed the students’ knowledge score improvement from pre-test to post-test. This study used the .05 level of the statistical significance. The findings of study indicated that there was significantly difference between Non-IBL Group and IBL Group that was showed on Table 2.

### Table 1. Comparison of Pre-test and Post test within Non-IBL Group and IBL group.

<table>
<thead>
<tr>
<th></th>
<th>Non-IBL</th>
<th>IBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>57,632</td>
<td>66,316</td>
</tr>
<tr>
<td>Variance</td>
<td>83,428</td>
<td>56,401</td>
</tr>
<tr>
<td>Observations</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Df</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>t Stat</td>
<td>-4.890</td>
<td>-13.440</td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.687</td>
<td>1.687</td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.026</td>
<td>2.026</td>
</tr>
</tbody>
</table>

### Table 2. Comparison between Non-IBL Group and IBL Group

<table>
<thead>
<tr>
<th></th>
<th>Non-IBL</th>
<th>IBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>66,316</td>
<td>85,789</td>
</tr>
<tr>
<td>Variance</td>
<td>34,708</td>
<td>100,711</td>
</tr>
<tr>
<td>Observations</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Df</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>-10,316</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.666</td>
<td></td>
</tr>
</tbody>
</table>
3.1 Phase 1: Analysis

Analysis of students
The first step of analysis phase was analysis of students. In this case, researcher observation and interview about the most difficult topic in mathematics. Observation and interview results showed that students got difficulty in solving problem about trigonometry ratio on a right triangle.

Developing Learning Objective
The learning purpose formulated in the instructional design here was to make the students able to solve problem dealing with right triangle using trigonometry ratio concept precisely when the students were given the non-routine problems in the real life that was relevant.

3.2 Phase 2: Design

Assessment's Design
The assessment instrument used to evaluate this developed instruction was based on students' performance.

Select a Form of the Course
According to the problems in this study, the developed learning used inquiry approach which guided students to investigate in solving problems. The syntax of inquiry-based learning used in this study consisted of orientation, conceptualize, investigation, conclusion, discussion (Adoption from Pedaste, 2015).

Creating Instructional Strategy
The instructional strategy used in this study guided students to solve contextual problems. Students were guided to measure a height of an object by using a clinometer and a meter as mathematical tools helping them to apply the trigonometry ratio concept.

3.3 Phase 3: Development

Create Factual Sample for the Instructional Design
In this phase, the researcher started to formulate a lesson plan on the inquiry-based learning. The teacher and students’ activity lesson plan contains what activities teachers and students will do in inquiry-based learning.

Develop the Materials of the Course
In addition to teaching strategies, researchers also compile students’ worksheets and design clinometers. Run through the conduction of the design. Lesson plan and students worksheets developed by researcher were validated by a mathematics-education lecturer.

3.4 Phase 4: Implementation

Training the Instructor
Inquiry-based learning trials are conducted by mathematics teachers and one-class students. The researcher explained to the teacher about the teaching design that had been prepared. The teacher performs a simulation in advance in applying inquiry-based learning that has been developed by the researcher. The researcher used the observation sheet to observe the implementation of inquiry-based learning.

Organizing the Learning Environment
The learning environment in the application of inquiry-based learning is outside the classroom and in the classroom. Students are invited to measure the height of a building or other object by applying the concept of trigonometry to a right triangle and using a clinometer to measure angles in measuring the height of the object.

3.5 Phase 5: Evaluation

One to One Formative Evaluation
Students are given a post-test after the implementation of inquiry-based learning. Questions given during pre-test and post-test are equivalent. The results of the pre-test and post-test function to determine the effectiveness of learning that has been developed in improving students' creative thinking. In addition, students were also asked to fill out a questionnaire regarding their response to the learning developed along with other learning tools. The results of the student response questionnaire were used to measure the value of the practicality of learning developed. The researcher made improvements to the learning developed based on student responses.

4. CONCLUSION

The teaching materials developed have been validated and showed valid results, the results of the student response questionnaire showed that students gave a positive response to inquiry-based learning, and the results of the t-test analysis showed that the level of significance of difference in comparison of IBL groups (as an experimental group) and non-IBL group (as a control group) was 10.361. Thus, inquiry-based learning that integrates mathematical devices (clinometers) is effective for enhancing students' creative thinking.

This inquiry-based learning which had been developed significantly influenced students' pre-knowledge scores. It could be concluded that creative thinking contributed, too. A recommendation for mathematics teachers in teaching mathematics was to involve students in problem-solving activity that facilitated them to conduct open-ended investigation whereas they could construct their own knowledge in building an original solution. For further research, we recommended to next researcher to explore how students' creative thinking in inquiry-based learning whereas we can evaluate the needed instruction.

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REFERENCES


