ENHANCING STUDENTS’ MATHEMATICAL LOGICAL THINKING ABILITY AND SELF-REGULATED LEARNING THROUGH PROBLEM-BASED LEARNING

Euis E. Rohaeti
E-mail: e2rht@yahoo.com
STKIP Siliwangi, Bandung

Budiyanto, A.M
E-mail: bybudiam@gmail.com
SMAN Tegalsari Karawang,

Utari Sumarmo
E-mail: utari.sumarmo@yahoo.co.id
STKIP Siliwangi, Bandung

Abstract
This study was intended to investigate the development of students’ mathematical logical thinking ability and self-regulated learning through Problem-based Learning (PBL). This study was a part of a master thesis and a sub-study of a Postgraduate Research Grant from DGHE in 2013. This study was a pre-test-post-test quasi-experimental control group design involving 93 eleventh-grade students of a senior high school in Karawang which were chosen purposively. The instruments of this study were an essay test on mathematical logical thinking, a self-regulated learning scale, and a scale measuring students’ perception on PBL. The study revealed that students getting treatment on PBL attained better grades on mathematical logical thinking ability than students taught by conventional teaching, though the grades were at low level. However, there was no difference in grades of self-regulated learning between students in the two groups though the grades were fairly good. Also, there was no correlation between mathematical logical thinking ability and self-regulated learning with students’ positive opinions toward PBL.

Keyword: mathematical logical thinking, self-regulated learning, Problem-Based Learning, perception toward PBL.

Introduction
Basically, mathematical logical thinking ability as a component of mathematics learning outcomes should be developed by high school students. The reason is that mathematical logical thinking ability is included in the vision and the goals of mathematics teaching (BNSP, 2006, NCTM, 2000). As for the vision of mathematics, it includes developing mathematical thinking abilities which are logical, systematic, critical, accurate, and creative. In addition, other goals of mathematics teaching are to generate a reason based on mathematical patterns and features, to draw generalization, as well as to prove and to clarify mathematical statements which illustrate the essence of logical thinking in teaching mathematics.

Some experts defined the term of logical thinking differently. Capie and Tobin (as cited in Sumarmo, 1987) assessed logical thinking ability through the Test of Logical Thinking (TOLT) which covered five components, namely controlling variable, proportional reasoning, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. Other researchers defined logical thinking as to conclude using reasoning consistently (Albrecht, as cited in Aminah, 2011); to think causally (Strydom, as cited in Aminah, 2011); to think based on certain
pattern or rules of inference (Minderovic, Suryasumantri, Sponias, as cited in Aminah, 2011); and to think involving induction, deduction, analysis, and synthesis activities (love your eyes, as cited in Aminah, 2011). From these definitions, Sumarmo, Hidayat, Zulkarnanaen, Hamidah, & Sariningsih, (2012) summarized a activities related to logical thinking ability, such as conclude or estimate relevant proportion on probability, correlation, combinatorial computation, and on similarity or analogy; and to generalize, prove, analyze, and synthesis some cases.

Glasersfeld (as cited in Suparno, 1997), Nickson (as cited in Hudojo, 2002), and Polya (1973) state teacher’s role plays an important role in improving students’ thinking ability; teacher not only delivers information but also acts as a student, understands their way of thinking, assists them to build their knowledge, and improves their thinking ability. Essentially, these roles are in line with constructivism philosophy in which the learning process involves students’ active learning, connecting information to the prior knowledge for building a more complex and meaningful schemata, and emphasis on investigating and inventing. One of teaching learning models on the basis of constructivism philosophy is problem-based learning or PBL (Barrows & Kelson; Ibrahim & Nur; Stephen and Gallagher as cited in Ratnaningsih, 2004). Problem-based learning (PBL) starts the learning activities by presenting a contextual problem relevant to the learned material. Furthermore, Ibrahim and Nur (as cited in Ratnaningsih, 2004) listed five steps in conducting PBL; they are engaging students to the problem, managing them to learn, guiding them to explore it individually or in groups, helping them improve and present their work, and helping them analyze and assess the process of problem solving.

In approaches to teaching and learning, there are some variables that may affect students’ mathematics achievement, particularly on attaining good grades; one of the variables is self-regulated learning (SRL). Several researchers (Butler, 2002; Corno & Randi, 1999; Hargis, Paris & Winograd, 1998; Schunk & Zimmerman, 1998; Wongsr, Cantwell, & Archer, 2002, as cited in Sumarmo, 2006) defined SRL in different ways but principally they proposed three similar characteristics of SRL, namely, planning a goal, selecting a strategy, and monitoring cognitive and affective processes while answering an academic task.

Some studies reported that PBL is better on developing various mathematical abilities of senior and junior high school students than conventional teaching, such as Juandi (2008), Herman (2006), Permana (2004), and Ratnaningsih (2004). Those studies reported that students obtained fairly good grades on various mathematical abilities. Nevertheless, some of other studies employing various teaching approaches reported that senior high school students obtained low to average grades on mathematical logical thinking ability (Maya, 2005; Setiawati, 2014; Sumarmo, 1987; Sumarmo, Hidayat, Zulkarnanaen, Hamidah, & Sariningsih, 2012). These studies found out that mathematical logical thinking problems were relatively difficult tasks for most of students. Furthermore, Qohar (2010) reported that implementing reciprocal teaching made students obtained good grades on self-regulated learning.

Based on the aforementioned background, the research questions of this study are as following:

1. Are students’ grades of mathematical logical thinking ability and their N-Gaintaught by PBL higher than the grades of those who are taught by conventional teaching method?
2. Are students’ grades on self-regulated learning taught by PBL higher than the grades of students who are taught by conventional teaching method?
3. Is there any correlation between mathematical logical thinking ability and self-regulated learning?
4. What are students’ perceptions toward PBL?
Theoretical Review
Mathematical Logical Thinking and Self-regulated Learning
Capie and Tobin (Sumarmo, 1987) measure students’ mathematical logical thinking ability through the Test of Logical Thinking (TOLT) that consists of controlling variable, proportional reasoning, probabilistic reasoning, correlational reasoning, and combinatorial thinking. Other researchers proposed the definition of logical thinking as well (Albrecht, Minderovic, Loveureyes, Sonias, Strydom, Suryasumantri, as cited in Aminah, 2011). Logical thinking or thinking sequentially is defined as concluding through reasoning consistently (Albrecht, in Aminah, 2011), thinking causally (Strydom, in Aminah, 2011), thinking by following rules of logical inference to draw conclusion (Suryasumantri, Minderovic, Sonias, as cited in Aminah, 2011), and thinking involving activities on induction, deduction, analysis, and synthesis (Loveureyes, cited in Aminah, 2011).

Having analyzed ideas of several writers, Sumarmo et al. (2012) listed the indicators of mathematical reasoning as follows: a) to draw analogy and generalization as well as to generate conjectures; b) to draw conclusions logically through the rules of inference, to compose a valid argument, and to examine the validity of an argument; and c) to prove the argument directly and indirectly using mathematical induction. Moreover, Sumarmo (ibid) summarizes six components of logical thinking, namely logical reasoning, controlling variable, proportional reasoning, probabilistic reasoning, propositional reasoning, combinatorial reasoning, and correlational reasoning.

There are some variables in teaching and learning processes that might affect students’ mathematical ability; one of them is self-regulated learning (SRL). Bandura (as cited in Sumarmo, 2006) defines SRL as an ability to observe someone’s behavior. Furthermore, he suggests three phases in conducting SRL: observing and monitoring him/herself, comparing his/her position with a particular standard, and giving either positive or negative self-response. There are several activities related to SRL, including self-evaluation, managing and transforming, determining goals and planning, collecting information, noting and monitoring, drawing a consequence, thinking of and repeating, seeking social assistance, and reviewing some notes. Hargis (cited in Sumarmo, 2006) defines SRL as an attempt to deepen and manipulate associative network in a certain field, and to monitor the process. The SRL itself was neither a mental ability nor an academic skill, such as reading ability, but it is a self-directive process that is transformed into a particular mental ability. Yang (as cited in Sumarmo, 2006) found out that students with high SRL tended to learn better in their own control, to have the ability to control, evaluate, and manage their learning effectively, to save their time while working on their tasks, and to manage their time efficiently. Zimmerman (as cited in Zimmerman & Schunk (Eds.). 2001) defines SRL as a learning process affected by someone’s thinking, feeling, strategy, and behavior which are oriented to achieve his or her own goals. Moreover, they (as cited in Sumarmo, 2006) state three main phases in the cycle of SRL, namely planning for learning activity, monitoring learning progress, and evaluating learning outcome thoroughly. On the other hand, Woolfolk (as cited in Sumarmo, 2006) identifies some factors affecting SRL: knowledge, motivation, and self-discipline. In order to possess high SRL, students should be aware of themselves, the learned subject, tasks, and learning strategies, as well as application of the subject. Students with high SRL show high learning motivation and interest on completing their tasks, high self-discipline and awareness of the reason why they should learn, and show the capability on selecting and solving their tasks on their own control, not on their external control.

Pintrich (as cited in Sumarmo, 2006) proposes four kinds of strategies for improving
SRL: self-regulated thinking strategy, self-regulated motivation and feeling, self-regulated behavior strategy, and self-regulated contextual strategy. However, self-regulated learning cannot be taught but it should be developed actively and continuously (Ghozi, 2010). Aswandi (2010) and Sauri (2010) propose four steps for improving self-regulated learning in mathematics teaching and learning, those are giving the meaning of self-regulated learning, adjusting activities that portray the indicators of self-regulated learning, performing the model of self-regulated learning, and conducting integrated mathematics teaching and learning continuously.

**Problem-based Learning**

Some experts have conducted in-depth analysis on problem-based learning (Barrows & Kelson; Ibrahim & Nur; Stephen & Gallagher; as cited in Ratnaningsih, 2004). The researchers suggest that problem-based learning is a teaching learning approach which begins the classroom activities by presenting a contextual problem relevant to the learned content. The problem should have some characteristics, such as it should be connected to curriculum, structured or unstructured, open-ended; the process is carried out in stages; students actively solve the problem and teacher acts as a facilitator; students only receive guidance and not formulas or procedures for solving the problem; and teacher carries out authentic assessment.

The main differences between problem-based learning and conventional teaching approach are the phase and the role of the problem. In conventional teaching, a problem is presented at the end of an explanation and as an assignment or application of a particular concept. Whereas in problem-based learning, the problem is presented in the beginning of a learning activity for motivating students to acquire the concept through investigation, invention, problem solving, as well as for encouraging students’ self-directed learning. Here, the role of teacher as a facilitator are posing relevant questions, monitoring the lesson, assessing students’ thinking ability, motivating them to actively participate in learning activities, compiling relevant tasks, and managing the students to work in group enthusiastically. The role of students as an active problem solver are actively participating in learning process, communicating with other students, and constructing understanding toward the presented problem. Therefore, the problem should be challenging, unstructured, and motivating students to solve and create relevant context to the learning objectives.

Ibrahim and Nur (as cited in Ratnaningsih, 2004) listed five steps in problem-based learning: a) orientation students toward the problem, b) managing them to understand it; c) guiding them to work individually or in a group, d) motivate them to improve and present their work, e) analyzing and assessing the process of problem solving. Looking at the steps, problem-based learning follows the constructivism philosophy in which students learn actively through assimilation and accommodation processes. When discussion is not satisfactory enough, it is teacher’s role to carry out scaffolding activities such as proposing question for helping or directing students find the solution.

NCTM (1993) propose several important things that should be considered in mathematics teaching and learning: a) selecting the correct mathematics tasks which are relevant to the mathematics content, understanding, interest and prior knowledge of the students in order to stimulate the development of students’ mathematical ability, b) motivating students to obtain a meaningful learning and to develop their mathematical disposition, c) administering a discussion for reinventing and developing students’ mathematical ideas, d) participating in learning situation to motivate students for the escalation of mathematical power, e) analyzing students’ learning participation.
Related Studies

Several studies conducted to high school students reported the benefits of PBL in improving various mathematical abilities and disposition better than conventional teaching (Herman, 2006; Nur, 2010; Permana, 2010; Ratnaningsih, 2004). These studies reported that the students taught by PBL obtained fairly good grades on various mathematical abilities in which the grades were better than the students’ grades in the conventional teaching group. However, on mathematical logical thinking ability (MLTA) employing PBL, Setiawati (2014) and Sumarmo (1987) found out that students’ grades were considered very low (40% - 45% out of ideal score). Moreover, Maya (2005) and Sumarmo et al. (2012) discovered that students of senior high school achieve average grades (60% out of ideal score) on MLTA. These findings demonstrated that problems of mathematical logical thinking were relatively difficult for most of senior high students. Different finding was reported in Qohar (2010) that reciprocal teaching made students obtain a high grade on SRL.

Regarding correlation between mathematical abilities and affective learning outcomes, many studies reported inconsistent findings. For example, several studies (Ratnaningsih, 2007; Sugandi, 2010; Wardani, 2010, Qohar, 2010; Yonandi 2010) reported there was a correlation between cognitive and affective components of mathematical learning outcomes. However, other studies (Permana, 2010; Sumarmo, et al., 2012; Sumaryati, 2013) reported there was no correlation between mathematical abilities and disposition.

Method

This study was intended to analyze students’ achievement on mathematical logical thinking ability and self-regulated learning through problem-based learning (PBL). This study is a part of master thesis (Budiyanto, 2014) and a sub-study of a Postgraduate Research Grant from Directorate General of Higher Education (DGHE).
together. How many permutations can be selected by the kids? Write the formula to answer the question!

Result and Discussion
Mathematical Logical Thinking Ability, Self-regulated Learning, and Students' Perception on Problem-based Learning

Students’ grades on mathematical logical thinking ability (MLTA), their N-Gain of MLTA, self-regulated learning (SRL), and their perception on problem-based learning (P-PBL) were presented in Table 1.

Table 1 shows that there was no difference in students’ grades of MLTA for both groups in the pre-test since the grades for both groups were considered low (about 25% out of ideal score). In the post-test, students’ grades of the group taught by PBL were better on MLTA (54.70% out of ideal score) than students’ grades of another group (48.70% out of ideal score), and both of grades were still considered low. Analysis of the mean differences of students’ grades on MLTA in both teaching approaches were presented in Table 2.

These findings were similar to the findings of Setiawati (2014), Sumarmo (1987), and Sumarmo et al. (2012). Also, the study revealed that some of the difficulties students faced during solving MLTA tasks were drawing an analogy of a case on permutation and combination, synthesizing information in a case of combination, and reasoning proportionally.

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**Table 1.**
Mathematical Logical Thinking Ability, Self-regulated Learning, and Students Perception on Problem-based Learning

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statist.</th>
<th>PBL</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre Test</td>
<td>Pos test</td>
</tr>
<tr>
<td>MLTA</td>
<td>Mean</td>
<td>5.06</td>
<td>10.93</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>20.24</td>
<td>43.72</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.15</td>
<td>3.85</td>
</tr>
<tr>
<td>SRL</td>
<td>Mean</td>
<td>100.41</td>
<td>98.49</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>66.94</td>
<td>65.66</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>11.03</td>
<td>7.99</td>
</tr>
</tbody>
</table>

Note: MLTA was mathematical logical thinking ability; Ideal score of MLTA was 25
SRL was self-regulated learning; Ideal score of SRL was 150

**Table 2.**
Testing of Hypothesis of Mean Difference of MLTA, N-Gain of MLTA, and SRL in PBL and in Conventional Teaching

<table>
<thead>
<tr>
<th>Variables</th>
<th>Teaching Approach</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
<th>Sig.</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLTA</td>
<td>PBL</td>
<td>10.93</td>
<td>3.85</td>
<td>46</td>
<td>0.002</td>
<td>MLTA&lt;sub&gt;PBL&lt;/sub&gt; &gt; MLTA&lt;sub&gt;Conv&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>9.72</td>
<td>2.59</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-Gain</td>
<td>PBL</td>
<td>0.41</td>
<td>0.14</td>
<td>46</td>
<td>0.000</td>
<td>N-Gain&lt;sub&gt;PBL&lt;/sub&gt; &gt; N-Gain&lt;sub&gt;Conv&lt;/sub&gt;</td>
</tr>
<tr>
<td>MLTA</td>
<td>Conventional</td>
<td>0.32</td>
<td>0.16</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRL</td>
<td>PBL</td>
<td>100.41</td>
<td>11.03</td>
<td>46</td>
<td>0.148</td>
<td>There was no different</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>98.49</td>
<td>8</td>
<td>47</td>
<td></td>
<td>SRL&lt;sub&gt;PBL&lt;/sub&gt; and SRL&lt;sub&gt;Conv&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Note: MLTA was Mathematical Logical Thinking Ability; Ideal score of MLTA was 25
N-Gain was normalized gain
SC was Self-confident; Ideal score of SRL was 150
PBL was Problem-based Learning
On normalized gain (N-Gain) of MLTA, the result showed that students taught by PBL obtained better grades (N-Gain) of MLTA (0.41) than those who were taught by conventional teaching (0.32), and their grades in N-Gain of MLTA were classified as medium. Analysis of mean difference of N-Gain on MLTA was presented in Table 4. Besides, Table 3 showed that there were no difference in SRL grades between students of the two groups though the grades were fairly good (100.41 and 98.49 out of 150). Analysis of SRL mean differences was presented in Table 4. The finding on SRL in this study was similar to the findings of previous studies (Mulyana, 2008; Permana, 2010; Qohar, 2010; Ratnaningsih, 2007; Setiawati, 2014; Sumarmo, et al., 2012; Sumaryati, 2013).

Correlation between Mathematical Logical Thinking Ability and Self-regulated Learning

The correlation between mathematical logical thinking ability and self-regulated learning was analyzed using contingency tableas presented in Table 3. The result indicated that there was high correlation between mathematical logical thinking ability and mathematical disposition (C = 0.655). Analysis of the correlation and \( \chi^2 \) testing hypothesis were presented in Table 4. This finding was similar with the findings of earlier studies (Qohar, 2010; Sugandi, 2010; Wardani, 2010). However, other studies reported that there was no correlation between hard skills and soft skills of mathematics (Permana, 2010; Sumarmo, et al., 2012; Sumaryati, 2013; Yonandi, 2010). This finding illustrated inconsistent findings with the previous studies which highlighted the existence of correlation between hard skills and soft skills of mathematics.

Students’ Perception on Problem-based Learning

Students’ perception toward PBL was fairly good (132.28 or 66.14% out of ideal score). They demonstrated positive opinions toward PBL. Positive statements, such as “Students’ worksheet comprises challenging mathematics problems” or “Students’ worksheet asks me to examine the accuracy of my own work,” were responded positively (strongly agree or agree). Moreover, negative statements, such as “Teaching and learning mathematics restrict me to choose exercises myself” or “The situation during teaching and learning mathematics is boring” were responded contradictory (disagree or strongly disagree).

Conclusion

Students’ grades in the group taught by PBL on mathematical logical thinking ability and their N-Gain were better than the grades of students of the group taught by conventional teaching. However, students’ grades of mathematical logical thinking ability were at a low level though their N-Gains were fairly good. Furthermore, there was no difference in grades on self-regulated learning between both groups though students’ grades were categorized as medium. Some difficulties students faced during solving the tasks on mathematical logical thinking were drawing an analogy in cases related to permutation and combination, synthesizing...
information in a case of combination, and reasoning proportionally. However, there was high correlation between mathematical logical thinking ability and self-regulated learning with students’ positive perception toward PBL.

Problem-based learning is accounted successful in fostering students’ mathematical logical thinking ability. However, teaching and learning activity were not sufficient enough for obtaining a high grade on self-regulated learning, since acquiring self-regulated learning required a continuous process. Although mathematical logical thinking ability was a difficult task for most of the students, this ability should be improved. Due to the limited time in conducting this study, it is recommended for further study that teaching and learning process for the improvement of mathematical logical thinking and other high-level mathematical thinking abilities should be arranged for acquiring essential mathematics substances, such as by providing the appropriate learning materials to fit with students’ need. Improvement in mathematical hard skills and soft skills should be conducted appropriately through accustoming students to materials and teacher’s modelling.

References


