Capability of mathematical strategic thinking through quantum learning based on creative problem solving

Julita, Darhim and T Herman
Postgraduate Program of Mathematic Education, Universitas Pendidikan Indonesia, Jl Setiabudhi No. 229, Bandung, Indonesia

Corresponding author: Julita3370@gmail.com

Abstract. The object of this research is to study the quality of quantum learning based on creative problem solving concerning about an enhancement of mathematical strategic thinking of senior high school students. This research is focusing on each level of students’ initial ability of mathematics (high, middle, low) between the students who acquired quantum learning based on creative problem solving and those who have received expository learning. The author used quasi-experimental method with pre-test and post-test control group design to conduct this research. And also, its population are senior high school students class X in SMAN 10 Bogor. The results showed that students with high initial mathematical abilities and through quantum based creative problem solving (QBCPS) learning had a higher improvement in mathematical strategic thinking ability than students who received expository (EPSTR) learning.

1. Introduction
Mathematic education in the 21st century is focusing on critical thinking, creativity, and problem solving ability. It also focuses on cooperation and collaboration skills. Strategic thinking is one of thinking ability which is needed in problem solving [1]. Through strategic thinking, complex problem can be outlined and created innovative solution [2]. Strategic thinking is a temporary postpone of analytical decision and critical thinking. Decision delay in the problem solving process involves creativity to identify and define alternatives, as well as choices before decision making. Weak strategic thinking have an impact on students’ ability to solve problem. When students do mathematical problem solving, thinking activities occur in their brain. It is happened in problem solving, including logical thinking, lateral thinking, synthesis, analysis, and evaluation [3]. Problem solving becomes a focus in learning mathematics for students [4]. This is one of the objectives of learning mathematics in the education curriculum in Indonesia [5].

The weakness of strategic thinking in creative problem solving needs quantum learning process based creative problem solving method (QBCPS) to resolve it. The reason is because the steps in CPS learning can increase thinking ability of student in problem solving correspond to the available data or fact [6]. In natural phase of QBCPS, teacher gives opportunity to the students to do brainstorming. Teacher motivates students to create solving strategy ideas by developing his initial knowledge. And also, in this learning, the students expand their analysis and synthesis problem skills by evaluating and selecting problem solution. The QBCPS develops the students’ MSTA in a comfortable and pleasant learning atmosphere without pressure. So, the object of this research is to study the quality of quantum learning based on creative problem solving concerning about an enhancement of mathematical strategic thinking.
of senior high school students. It will measure the capability of Mathematical Strategic Thinking Ability (MSTA) in students

2. **Strategic Thinking and Quantum Based Creative Problem Solving (QBCPS)**

Strategic thinking is a combination of rational and creative thinking in problem solving [7]. Unlike Beaufre [8] who views strategic thinking in problem solving as a mental, abstract, and rational process that combines psychological and material values. The faced problem is the gap between the real condition and the expected conditions (desired). Meanwhile, complex problems are problems that are sustainable and not transparent accompanied by various obstacles in their resolution [9] in [8].

The mental process in mathematical thinking is an activity in the brain that cannot be observed in the process, but the results of its activities can be analysed [10]. Thinking activity as a mental process is using cognitive strategies in processing information.

Strategic thinking process in problem solving is started with complying the problem to be simpler, then it is analysed to find out the possible problem solving step to be pursued, and it is continued with synthetic process by draw the truth from every solution step taken [8]. Indicators of mathematical strategic thinking in this research are the ability to design, analyse, and synthesize problems. So, the ultimate goal of strategic thinking is to solve problems as effectively and efficiently as possible.

Given the importance of Mathematical Strategic Thinking Ability (MSTA) in problem solving, it is necessary to design an atmosphere of mathematics learning that builds creativity. One of the learning strategies that push up student creativity is by developing brainstorming, encouraging flexible and relaxed thinking [11]. The appropriate learning that fits this goal is Quantum-Based Creative Problem Solving (QBCPS) which is carried out in a fun and effective way. Effective learning is a learning process that is able to actively involve all students [12].

Quantum learning based on creative problem solving (QBCPS) is a combination of quantum learning and creative problem solving. It is a learning phase which is creative in solving problems with conducive and fun atmosphere. Its learning phases is referred to De Porter and Pepkins [13]; [14]; [15]. The learning phase is carried out in accordance with the following table.

| Phase          | Teacher Activity                                                                 | Students Activity                      |
|----------------|----------------------------------------------------------------------------------|----------------------------------------|
| **Foster**     | Problem Clarification: Foster motivation and interest in student learning by posing contextual problems | Identify the problem given.           |
| **Natural**    | Brainstorming: Motivate students to create problem solving strategy ideas by developing their initial knowledge. | Trying to produce as many problem solving strategies as possible. |
| **Named**      | Evaluation and Selection: Scaffolding students in determining the most appropriate strategy. Embedding (teaching) concepts, practicing thinking skills and learning strategies through worksheets. | Discussing, evaluating and selecting suitable strategy ideas. |
| **Demonstrate**| Implementing: Give students the opportunity to implement a predetermined strategy to solve problems | Demonstrate (show) the level of understanding of the material being studied by implementing a predetermined strategy in solving the problem. |
| **Repeat**     | Provide post-tests or exercises to repeat (reflect) the learning objectives to be achieved. | Do Post-test or practice.              |
| **Celebrate**  | Give appreciation for effort, perseverance, and success of students in learning activities. | Celebrate the success of learning      |

Table 1. Quantum Learning Syntax Based on Creative Problem Solving.
The stages of mathematics quantum learning based on creative problem solving (CPS) are as follows:

- First phase, the teacher rises student motivation to learn mathematics by conveying learning objectives and inviting students to actively think by proposing a contextual problem to be discussed in small groups of heterogeneous mathematical abilities, gender, economic and ethnic level. The teacher explains the problem proposed so that students can solve the problem as expected. Students discuss and clarify the problem given by the teacher.

- Second phase, natural means that the teacher motivates students to create ideas for problem solving strategies by developing initial knowledge that students already have.

- Third phase, named. In this phase, students evaluate and select suitable problem solving strategy ideas. The teacher does scaffolding in determining the most suitable strategy in solving problems. Students are divided into heterogeneous small groups. Teachers embedding (teach) concepts, practice thinking skills and learning strategies through worksheets.

- Fourth phase, Demonstration. Students show their level of understanding of the material being studied by implementing a predetermined strategy to solve the problem.

- Fifth phase, repeat. The teacher gives a post-test or exercise to repeat (reflection) the learning objectives to be achieved.

- Sixth phase, Celebrate. Give appreciation for the effort, perseverance, and success that students have made during the learning activities. Maximum effort needs to be celebrated.

3. Methods

Conducting methodology in this research is quasi experiment with pre-test – post-test control group design which involves two randomly selected groups. They are called experiment group and control group. Pre-test and post-test is given to both of the groups before and after the test. Its objective is to identify the increase of students’ Mathematical Strategic Thinking Ability (MSTA). And also, experiment group gets Quantum Based Creative Problem Solving (QBCPS) learning. Meanwhile, control group gets Expository (EPSTR) learning.

This research calculate Initial Mathematical Abilities (IMA) of students which is the high, intermediate, and low level of average daily test in experiment and control class. The purpose is to explore deeper the impact of QBCPS quality on MSTA. Moreover, this research implicate independent, bound, and control variables. Independent variable consists of QBCPS and EPSTR learning, bound variable consists of MSTA, and control variable is IMA.

The research subjects are some students from two X class from one high school in Bogor which is chosen randomly. In addition, the instrument in this research is a series of MSTA ability test and observation sheet of learning activity. Observation during the learning activity intend to expect the respond or attitude of the student when they learned.

4. Result and Discussion

Normalized gain (N-gain) is calculated from the result of pre-test and post-test of MSTA. This data is analyzed based on the QBCPS and EPSTR learning factor, and also based on the level category of students’ IMA (high, intermediate, and low). The difference improvements of students’ MSTA for every subject and every IMA category can be seen in the Table 2 below.

Table 2. The result of the difference improvement of students’ MSTA for every IMA category.

| IMA Category | Learning Subject | Average | Average Difference | Sig. | Conclusion  |
|--------------|------------------|---------|---------------------|------|------------|
| High         | QBCPS            | 0.34    | 0.17                | 0.0195 | H₀ Refused |
|              | EPSTR            | 0.17    |                     |      |            |
| Intermediate | QBCPS            | 0.27    | 0.14                | 0.083 | H₀ Accepted|
|              | EPSTR            | 0.13    |                     |      |            |
| Low          | QBCPS            | 0.27    | 0.15                | 0.085 | H₀ Accepted|
|              | EPSTR            | 0.12    |                     |      |            |
| Combined     | QBCPS            | 0.29    | 0.15                | 0.007 | H₀ Refused |

3
Descriptively, Table 1 shows that the average of students’ MSTA who got QBCPS and EPSTR learning for every IMA category is experiencing an enhancement. It also can be seen from the table that the average students’ MSTA who get the QBCPS learning for every category, is experiencing higher step up than the students who get EPSTR learning. Although, the improvement like this is still categorized low by [16]. This indicate the learning process to both group has stimulated the students’ MSTA. This situation is a natural thing as an effect of the learning process [17].

The statistical test results in Table 1 show that students’ MSTA in all IMA categories, who received QBCPS learning, did not increase significantly compared to the students who received EPSTR learning, except students with high IMA. But, students’ MSTA with high IMA are raised higher than students who received EPSTR learning. This could be due to the ability to learn, among others, determined by the nature, habits and intelligence of students like what [18] stated in his research. Students who have a high level of intelligence, usually have a high interest in learning too. This condition will apply otherwise for students who have an average or below average intelligence level.

In addition, the results of the statistical tests in Table 1 also show that the overall MSTA of students who received QBCPS learning increased significantly compared to students who received EPSTR learning. This means that overall quantum based creative problem solving learning is better at improving students’ mathematical strategic thinking skills compared to expository learning.

The success of the learning process is greatly influenced by the potential of all involved and interactions created in the classroom. The higher the potential of all involved and the more optimal interaction activities in the learning process with a conducive and pleasant atmosphere, the more effective the learning process will be. The effectiveness of learning cannot be separated from activities in design, implementation, and evaluation which is conducted by teachers [19]. The real differences of the students’ MSTA improvement in terms of MSTA category and learning group is shown in Table 3 below.

Table 3. The result of MSTA difference in terms of MSTA Category and learning group.

| Source          | Type III Sum of Squares | df | Mean Square | F     | Sig.  |
|-----------------|-------------------------|----|-------------|-------|-------|
| Corrected Model | 917.134                 | 5  | 183.427     | 6.563 | 0.000 |
| Intercept       | 46334.911               | 1  | 46334.911   | 1.658 | 0.000 |
| Level           | 664.207                 | 2  | 332.103     | 11.883| 0.000 |
| Class           | 250.861                 | 1  | 250.861     | 8.976 | 0.004 |
| Class Level     | 22.273                  | 2  | 11.136      | 0.398 | 0.673 |
| Error           | 1928.413                | 69 | 27.948      |       |       |
| Total           | 52100.000               | 75 |             |       |       |
| Corrected Total | 2845.547                | 74 |             |       |       |

* R Squared = 0.322 (Adjusted R Squared = 0.237).

Table 2 shows that MSTA F calculated level is 11.883 with a probability of 0.000 which means that there is a real difference in the average MSTA based on the level of IMA. In addition, it appears that the MSTA F count for the learning group is 8.976 with a probability of 0.004 which means that there is a significant difference in the average MSTA for the learning group. Furthermore, for MSTA between IMA level and learning group, there is no interaction. This can be seen from the F count of 0.398 with a probability of 0.673.

The success of the learning process is also influenced by student attitudes. It includes activity, cooperation, and tolerance in learning. The attitude of students in QBCPS learning from the first to the eighth meeting is shown in Figure 1 below.
Figure 1. Observation Result of attitudes students in Learning

Based on Figure 1, the activity and cooperation of students in learning is higher than tolerance in each learning process. Activity, cooperation and tolerance in problem solving are incredibly good. The attitude of tolerance, mutual respect in expressing opinions has been embedded very well in students. The activity of students during brainstorming in their groups was very good. This is indicated by the high activity of students in expressing their opinions and working together to solve problems.

Student responses to QBCPS learning are incredibly good, only 18% of students give good responses. This means that the student response is classified as positive. The interview result shows that almost all students were approved during the QBCPS study. Students can help solve problems, so they can resolve difficulties.

The overall results of the study indicate that quantum based creative problem solving learning can significantly improve students’ mathematical strategic thinking skills rather than expository learning. The effectiveness of creative problem solving quantum learning in improving learning outcomes, the ability to understand concept, creative thinking and solving mathematical problem of students is reflected in the results of research by [17]; [20]; [21]; [22]; [23].

5. Conclusion

Based on the results of the research and discussion, the following conclusions were obtained: 1) There is an increased from overall mathematical strategic thinking skills of students who got quantum based creative problem solving (QBCPS) learning than students who received expository learning. 2) There is no difference in students' mathematical strategic thinking skills with medium and low IMA categories that get quantum based creative problem solving (QBCPS) learning with students who get expository (EPSTR) learning. Whereas for students with high IMA who got quantum based creative problem solving (QBCPS) learning is higher than students who get expository (EPSTR) learning. 3) Students’ attitudes and responses to creative problem solving based quantum learning are positive.

The results of this study provide one solution in improving the mathematical thinking ability to solve problems. And also, this research introduces one method that can be applied in mathematics learning in accordance with the demands of 21st century development.

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