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GROUP INVESTIGATION BASED LEARNING IMPROVES STUDENTS' PRODUCTIVE DISPOSITION AND MATHEMATICAL POWER

Imam Kusmaryono[1], Hardi Suyitno[2], Dwijanto[2] and NurKaromah Dwidayati[2]

[1]Sultan Agung Islamic University,Semarang, Indonesia
[2]Semarang State University, Semarang,Indonesia

ABSTRACT: *International educational reformation has recommended the importance of investigation to enhance mathematics learning and develop mathematical power for children (Quinnell, 2010). This research used a qualitative approach involving teacher and student participation in junior high schools (state school and private school owned by an educational foundation) in Indonesia which applied group investigation based learning in mathematics class. The results showed that mathematics learning with investigation approach (group investigation) had succeeded to transform negative disposition into productive (positive) disposition and to enhance productive disposition toward mathematics and had affected the increasing of students' mathematical power. The students' mathematical power ability appeared in the reasoning actualization (providing reasons, mathematical communication in groups and connections between ideas in mathematics when they discussed about the investigation result. Result of this study was also in line with Flewelling and Higginson (2003) that investigation, and problem solving suggested an opportunity for students to use their imagination in order to obtain more powerful mathematics ideas and understanding about relationship between mathematical ideas.*

KEYWORDS: Investigation, Mathematical disposition, Mathematical power

INTRODUCTION

Mathematics learning has an important role in the development of a nation by implanting various thinking skills which effectively support students' ability to deal with science advance and change of world order. Mathematics is regarded as a "key" ability by which students should have to form a logical, systematic, analytical, critical and creative thinking pattern and to support the mastery of mostly other study fields.

In global era as to days, learning reformation in mathematics classes has been conducted around the world. One of reformations in field of mathematics learning in schools is that teachers are encouraged to create an open-task centered learning environment by allowing students to build their own mathematics knowledge (Duyen, 2014). A mathematics learning which is expected to encourage students to discover and experience themselves through a mathematics process is mathematics investigation activity (Quinnell, 2010). The investigation activities can be done by group investigation approach. This is to follow the mathematical views which tend to be inquiry, to be presented in relevant to students' thinking stage, and also to be a learning based on students' experience and needs (Zingaro, 2008).

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REVIEW OF LITERATURE

Group Investigation

Group investigation learning model involves students' ability to conduct an investigation, involving students actively seeking and answering some questions or problems through meaningful learning in groups and peers. Group investigation learning provides students the opportunity to be a resource for their peers (Zingaro, 2008). Michael Serra (2008) in his book "*Discovering Geometry: An Investigation Approach*" confirms that by an investigative approach, students can learn and elaborate their mathematical knowledge and skills through an integrated investigative activites in mathematics learning (Serra, 2008). In general, learning by group investigation approach gives students the opportunity to make a real inquiry in the context of mathematics. Investigations give students the opportunity to engage actively in authentic mathematician practices as they investigate, discover, and use mathematics to understand the world (NCTM, 2000b).

According to Daniel Zingaro (2008), implementation of group investigation learning model proceeds six stages (Zingaro, 2008). Table 1 describes more clearly the stages of group investigation and description of teacher and student activities at each stage.

Table 1. Stages of Implementing Group Investigation Learning

Stage of Investigation	Description of Investigation Activities
Stage 1 : Identifying topics and grouping students into investigative groups (*Grouping*)	○ The teacher presents a multi-faceted problem ○ The students identify the problem by studying some resources ○ The students join to their group to discuss the chosen topic based on their interest
Stage 2 : Planning an investigation in group (*Planning*)	○ Each group states the problems they will investigate on, decides how to carry out, and determines which resources are needed for the investigation.
Stage 3 : Conducting investigation (*Investigation*)	○ Each group carries out investigation as planned at stage 2 ○ The students collect information, analyze data, evaluate the information, discuss about, clarify, and synthesize all ideas and draw a conclusion ○ The teacher observes and follows the investigation process, and provides helps if needed.
Stage 4 : Organizing a report (*Organizing*)	○ Group members plan on what they will report, and how they will deliver their presentation
Stage 5 : Presenting the final report (*Presenting*)	○ Each group delivers a presentation of investigation result in front of classmates in various forms ○ The teacher ad students evaluate the clarity and performance of the presentations based on agreed criteria.
Stage 6 : Evaluating the results (*Evaluating*)	○ The teacher and students evaluate and give feedback each other about what they have done, and about the effectivity of their experiences in investigative activities.

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Mathematics learning is a much greater effort than simply helping students to acquire problem-solving skill and strategy. Therefore, teachers should also manage to develop positive dispositions for learning mathematics - aspects that will have long-term effects in many things from students' belief on mathematics (NCTM, 1989), including on whether mathematics will be their career choice.

Mathematical Disposition

Disposition not only refers to attitude but more to positive thought and actions. Students' mathematical characteristics are manifested in the way they treat tasks; on how their confidence, willing to explore alternatives, persistence, interest and tendency to synthesize their own thoughts. Disposition is not an attitude but rather an attitude determinant and represents the ways by which a person observes something (Mueller & Hindin, 2011).

National Council of Teachers of Mathematics (NCTM) states that mathematical disposition is a student's appreciation on mathematics (NCTM, 1989). The appreciation is a tendency to (a) be confident in using mathematics to solve problems, communicate ideas and reasons, (b) be flexible in exploring mathematical ideas and managing alternative methods of problem solving, (c) be willing to persevere in mathematics tasks, d) to be interested, curious, and creative in doing mathematics, (e) tend to monitor and reflect on their own thinking and performance, (f) assess the application of mathematics to situations happen in other disciplines and everyday experiences, and (g) appreciate the role of mathematics in our culture and its value as a means and a language.

Results of preliminary survey conducted in March 2017 obtained an information that there were still many mathematics learning classes in Semarang (Indonesia) in which teachers still implemented traditional (conventional) lessons focusing on lecturing methods to deliver mathematics lesson. Teachers who are not ideal on classroom learning will affect negative disposition for students in learning (Mueller & Hindin, 2011).

In the preliminary survey, data showed that 53% of total 40 mathematics classes still implemented traditional (conventional) learning. As a result, students were less interested in learning mathematics. It led to a negative disposition toward mathematics learning which surely correlated with the lower of students' mathematical power ability. It was reasonable to say that, as long as teachers still implemented conventional learning that was not innovative and creative, then the possibility of negative mathematics disposition would be greater. This data was reaffirmed through the preliminary survey, the students were given a mathematical disposition questionnaire. After being analyzed, the questionnaire result was shocking enough. Average score for mathematical disposition was only 54.7, meaning that the mathematical disposition tends to be not productive (negative). A previous research by Duyen indicated that challenges inhibited the use of this approach including limited time related to syllabus coverage, pressure to prepare students for exams, the lack of positive reactions by students, teacher's belief on traditional teaching, and the lack of pedagogic content (Duyen, 2014).

Based on the data from preliminary survey in March 2017, further research was conducted in April 2017 in mathematics classes by applying group investigation-based learning. This research is seriously an evidence for managing educational and teaching reformation, as stated by Robert E. Slavin that we should have an impetus to involve in a serious development and evaluation efforts (Slavin, 2008).

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Research Question

Considering the importance of educational reformation (especially in field of mathematics learning), teachers and students need to be encouraged and challenged to move in a better direction through an amazing learning experience. Applying group investigation-based learning will provide satisfactory answers. For this purpose, the research question leading this study is: "By applying group investigation learning in mathematics class, could it improve students' productive disposition and mathematical power ability?"

To answer this research question, the author will describe the students' investigative activities in mathematics class with discussion topic: polyhedra geometry. The author will also investigate teacher and student responses to the group investigation learning application in mathematics classes. Mission of this research result is to encourage mathematics teachers not to be doubt to implement group investigation-based learning in mathematics classes, in order to encourage the growth of productive (positive) disposition and improvement of mathematical power.

METHODOLOGY

Research Design

This research was conducted by qualitative research approach. This research involved state junior high schools (government-owned) and private ones (owned by an educational foundation) in Semarang city, Indonesia. In each school, two mathematics teachers were selected to conduct research missions. Before the teaching activity, the teacher had been given a brieffing in a mini workshop about how to apply a learning with group investigation approach and how to fill inlearning observation sheets. Research data were obtained from the teacher's observation while teaching and from students' activities in group investigation, questionnaires containing students' responses following group investigation learning, records of students' mathematical power tests in the end of learning, and interviews done to teachers and students.

Participants

Participants in this research were Mrs. Ani Wantini; as a model teacher conducting group investigation-based learning, and Mr. Irwan; as an learning observer (from the state school) and Mrs. Nurhayati as model teacher and Mr. Amirin as an observer (from the private school) in Semarang city, Indonesia. Mrs. Ani Wantini is a mathematics teacher with 12 years teaching experience in junior high school, and Mrs. Nurhayati has 3 years teaching experience in mathematics. There were sixty students participating in this research. The students were about 12 to 14 years old. They were 8th graders of the junior high school.

Data Collection

Research data were obtained through observation on teacher and students activities participating in group investigation learning. The observation was conducted for five weeks (five meetings) learning in the mathematics class. The observation focused on teacher and student activities in mathematics tasks by applying group investigation. Result of observation on teacher and student activities were recorded in detail in weekly journal. For data completion, additional data were obtained from the questionnaires of mathematical dispositions and in-

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depth interviews conducted toward student representatives as selected subjects by using purposive snowball technique.

Data Coding and Analysis

Research data including weekly journals and data of observation on learning implementation were analyzed in qualitative. The weekly journals contained brief descriptions of several observation parts which were either directly recorded or from the record of learning activities. Interview results were made in a transcript form and described through specific coding and analyzed carefully. The research data were examined its validity by using triangulation method (Creswell, 2014).

RESULTS AND DSCUSSION

The learning with group investigation model had been conducted for 5 (five) weeks. At each meeting, student activities were observed while having the learning and also teacher activities were observed on how the group investigation learning was managed. Observation on learning activities was guided with observation sheets. The results of the investigation activity are presented in Table 2 below.

Table 2. Investigation Activity

Students	Stage of Group Investigation							
	Grouping	Planning	Investigating	Organizing	Presenting	Evaluating	Mean Score	Category
Group 1	98%	77%	69%	51%	59%	70%	70.67%	High
Group 2	100%	82%	75%	67%	67%	79%	78.33%	High
Group 3	95%	73%	69%	59%	60%	72%	71.33%	High
Group 4	100%	78%	68%	72%	67%	76%	76.83%	High
Group 5	100%	77%	73%	64%	67%	76%	76.17%	High

Taking into account the data of Table 2, all students in group activities have high-level investigation activities. All stages of group investigation study are well implemented. If there is a low percentage of data, it is because the observations are made early in the meeting so that the students are still awkward and lack confidence. To complete this explanation, the teacher's weekly journal notes will also be disclosed in detail. The data in this journal also added the result of interviews with student representatives in a group. The following is all weekly journals recorded during group investigation learning.

***First (1st) Week Journal*:** The teachers had well-planned learning goals and structures. They were very ready to conduct the learning. They delivered the learning lessons with incisive explanation so that students could understand easily. The teachers succeeded as learning facilitators by giving clear explanation to students in small groups. Something different (implementing group investigation learning models) was succesfully done, feeling like becoming a new teacher for the first time. The teachers were satisfied to be able to conduct group investigation as a learning model. They also realized that, in order to go onto mathematical thinking, the learning conducted should be modified or needed innovations as to become a group investigation learning as was currently done then (*Source: Teacher Weekly*

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Journal, *April 7, 2017*). Based on the observation, the teachers had conducted the group investigation learning steps well and smoothly as planned. Students appeared not ready to have the learning. Students still felt awkward following the group investigation learning model. However, some students seemed to be encouraged in observing learning properties. The students performed group investigation activities smoothly and followed the instructions on the student worksheet. Some students still seemed to need teacher's help to explain problems to other members in group. Their efforts as resource for peers should be appreciated and encouraged to continuity of their confidence improvement. In presentation section, the students still seemed to be too nervous to deliver the result of group discussion in front of class, proven by their low volume voice (*Source: Teachers Weekly Journal, April 7, 2017*). Seemingly, to build a new culture (investigation) in mathematics class required high-level thinking and commitment from the teachers (Diezmann, Watters, & English, 2001).

***Second (2nd) Week Journal*:** The teacher asked the students to understand a lot of information in a short time. The teacher attempted to evaluate students' verbal explanation of each other in their group. The teachers really needed to figure out how to perform changes. Evidently, the investigation activity on students in group 3 occured very slowly. The teachers should wait to see if the student needs explanation and work checking. It took time for students to be onto mathematical thinking through the process of verbal and written reasoning. The students needed to understand clearly and then applied what was known as a problem-solving strategy and evaluate their own or other students' work. This change happened so slowly. Changes in students' reasoning could be seen in their learning and answers; they could correctly identify the data and issues, including explanations in providing reasons for drawing conclusions. Occasionally the teacher asked the students, "What do you think about the implementation of investigation in mathematics?" A student replied, "I am quite interested, because the lesson given is a real investigative challenge." (*Source: Teachers Weekly Journal, April 14, 2017*). As Zingaro (2008) pointed out, actually the goal of group investigation activities is a learning motivation, so that students are encouraged to learn because they are really interested in the lesson (Zingaro, 2008). This description is in line with Diezmann's study, that students should be helped to see that investigation activity is a challenge, not a problem. Likewise, teachers need to adapt to different teaching styles (Diezmann et al., 2001).

***Third (3rd) Week Journal*:** The teacher gave the students an opportunity to internalize everything. The teacher facilitated this process, allowing students to experience and construct their own knowledge. The teacher provided services to the students, including helping whomever having difficulty and needed verbal explanation.

The teacher occasionally asked the students, "How do you plan your group investigation?" Student named Maulana replied, "Tasks are fairly divided to group members." Even in another group, response to the question was clearly delivered, "working together in groups is a way to help each other." Furthermore, the teacher evaluated the learning by observing the record of student activities in group investigation. The greatest thing that teacher could learn was that it was not easy for students to have mathematical power (high-thinking) skills with unusual learning concept which was a novelty for them. (*Source: Master's Weekly Journal, April 20, 2017*). As Diezmann pointed out, "Involving young students with investigation, teachers need to reconsider their understanding about nature of mathematics and how to study mathematics."(Diezmann et al., 2001).

***Fourth (4th) Week Journal*:** The teacher seemed more patient in responding students' questions in problem-solving in small groups. The teacher provided directions of how the

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students could evenly divide group tasks. The teacher repeated the explanation for some things that students did not get it yet. The teachers provided learning evaluation record by suggesting that next week's lessons should be more effective. The students became more encouraged in learning. They discussed with more enthusiasm to find solutions for problem-solving. Distribution of the tasks in groups seemed fair to all students. During the presentation, students could deliver the result of discussion quite clearly. They could present the demonstration of polyhedron model even though their mathematical understanding had not increased well (*Source: Teacher Weekly Journal, April 21, 2017*).

On this 4th week (*April 21, 2017*), it seemed that students were getting comfortable and enjoying investigative learning. It could be seen when many students spent much time in class to solve problems in group tasks. They worked together to discuss problems and criticized each other's work among group members. In interview section, represented by upper group students (above-average), middle group (average ability) and lower group (average ability), when they were asked, "Why do you like group investigation work?" Hervina replied, "Many ideas to consider." Rafi replied, "I can tell my ideas to the group." Adrian said, "Yes, I am glad that they can help me and I can get help." The students' responses were in line with Sharan Yael's (2010) statement saying that group investigation triggered and reinforced cooperative behavior (such as willingness to listen and to be influenced by peers, and commitment to mutual learning) caused by the increasing of students' collective involvement based on joint decision making (Yael, 2013).

***Fifth (5th) Week Journal*:** At the 5th week meeting (*April 27, 2017*), the teacher seemed to be increasingly confident in the performance of conducting group investigation learning. The group investigation steps were well executed. At this week, more students showed an improvement in problem-solving activity than in the previous week. They felt comfortable doing group investigation activities. They actively worked together in groups. However, they needed a lot of practice and time to work in developing mathematical thinking. They realized that other people had different ways and tried other ways, even they were stucked up in thinking. While Salma replied, "There are many ideas to choose as task solutions." Rafi as group chairman also added that among many different ideas the reasonable and valid answer would be chosen as the solution. It seemed that students were aware of it by saying "It's not like that". Once confirmed with the right explanation, most students had changed their answers during the problem-solving process.

They had had a strong and deep learning experience by finding different problem solving ideas (Zingaro, 2008). Thus, it showed that when students found mathematical ideas and create mathematical procedures, they had a stronger conceptual understanding about the relationship among mathematical ideas (Quinnell, 2010).

Reviewing journal records from week 1 to 5, students generally had a positive attitude towards the application of group investigation learning that had changed the way they learned in the classroom. They also reported some positive learning outcomes from the implementation of group investigation model in mathematics class. The investigations brought a sense of curiosity that moved situations, problems, and questions which encouraged students' interest and attention. In the beginning, there were some students who considered group investigation learning inappropriate for them because it took much time. Sometimes, students got difficulties and problems coming up from the application of group investigation learning. Students were not able to solve some problems because they found it complicated, and often needed an

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initiative to complete the tasks. Therefore, investigative activities were often designed for students working in pairs or groups and for quite a long time.

Teacher participation in this research was not only as a model teacher conducting a learning in mathematics class and as an observer on the implementation of this program, but also as interviewee to give responses on the implementation of group investigation learning. When asked about impression on group investigation in mathematics class, the teachers gave amazing answers. Mrs. Ani Wantini (as model teacher 1) responded: "I am quite proud to be given this role. I feel like a new teacher with a new experience doing this program." Mrs. Nurhayati (as model teacher 2) said, "For this program, I am quite satisfied. The students are very active and passionate.

The actual students' mathematics skill is just like this." Mr. Irwan (as observer), "This program is a real worthy example of learning to do in all classes of subjects." Understanding the answers conveyed by teachers in interviews, it was like what Marshman et al., said that investigation is a real learning activity for teachers and students, like an open life and gives students the opportunity to use multiple paths to investigate situations / problems (Marshman, Clark, & Carey, 2015).

Teacher activity and student improvement in applying group investigation learning were quite satisfying, as mentioned earlier in this study. The learning improvement was because of students' intrinsic motivation influence (mathematical disposition) during the learning with group investigation approach. To support the statement, the following is data of mathematical disposition questionnaire obtained from students. Notice Figure 1 below.

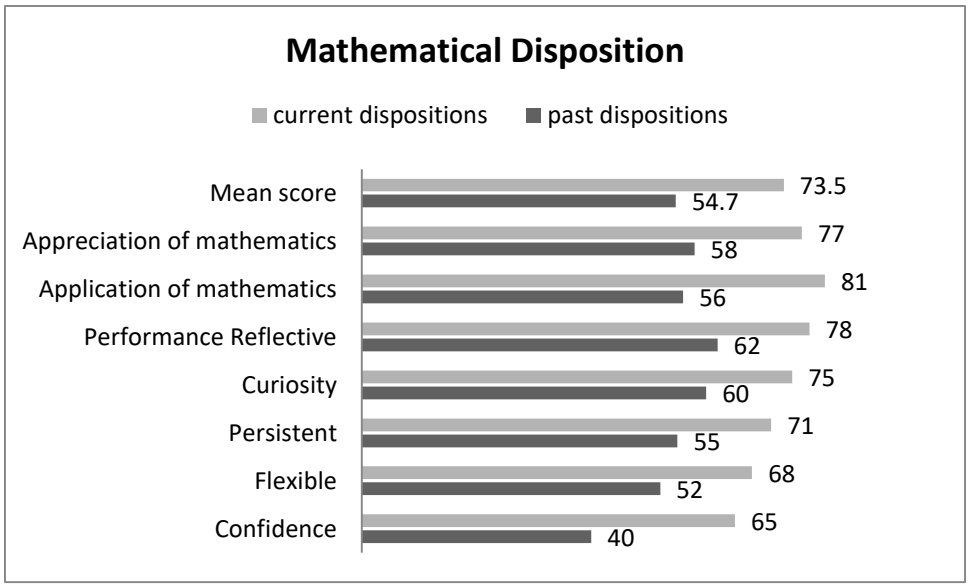

Figure 1. Graphic of Student's Mathematical Disposition

From Figure 1, it could be explained that mathematical disposition questionnaire data obtained at the beginning of the survey, before the application of group investigation learning in the mathematics class (past disposition), showed a score of 54.7 with low position category in mathematical disposition. It meant that students had a negative disposition toward mathematics learning. It was because the teachers still conducted conventional learning, mathematics

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learning focused only on procedural ability, and they had not applied innovative and creative learning. Achievement of their confidence indicators in mathematics learning was very low (only 40 points). Persistence and diligence were the most influential mathematical disposition component for problem solving (Rahayu & Kartono, 2014). In fact, the students were not confident in their abilities. This affected the persistence level which was still low (only 55 points). Students with a negative mathematical disposition generally showed low self-confidence and were less motivated to learn mathematics (An et al., 2015). Students easily gave up if they found complicated mathematics problems. Most worrying thing was when they considered mathematics lessons had no effect on selecting a career in the future.

After group investigation learning conducted in the mathematics class during five meetings (five weeks), students filled out the mathematical disposition questionnaire again, in order to know whether there was any change in their level of mathematical disposition. Considering Figure 1, it was found that average score of the disposition mathematical (current disposition) was 73.5 and included high disposition category. It meant that students had a productive (positive) disposition toward mathematics. This was surely because of their positive impression and responses to the application of investigation-based learning in mathematics classes. It had supported significant score changes. The students had gained a meaningful learning experience. According to Feldhaus, a person's (individual) experience could form a mathematical disposition (Feldhaus, 2014). Increased disposition was an evident in all mathematical disposition indicators: confidence, flexible, curiosity, reflective, application and appreciation of mathematics, with an average score increase between 15 to 20 points (see Figure 1).

The successful application of this learning was a joint success among teachers, students, and researchers. Investigation-based learning had encouraged students to actively participate in learning, so it developed their unseen mathematical power. The students succeeded to act as an active constructor of their own knowledge. It was proved by that mathematical inquiry could be useful for teaching mathematics (Quinnell, 2010). All these events occured due to the teachers succeeding in the creation of a learning environment that supported students' opinion diversity in learning activities (Zingaro, 2008). As Duyen suggested that student-centered and investigation-based environment offered an opportunity to develop the ability to think, speculate, ask questions, communicate and reflect to become an active constructor of mathematical knowledge (Duyen, 2014).

According to National Council of Teachers of Mathematics (NCTM, 2000a), while learning to perform mathematical thinking, mathematical power was termed as *higher order thinking skill*. Considering the importance of *higher order thinking skills* was needed by young people to overcome challenges of the 21st century, developing mathematical power starting from the youth level had become an important objective of today's mathematical learning (Phillips & Anderson, 1993).

After reviewing related literatures (NCTM, 1991; Walker, 1999; (Baroody, 2000; Şahin & Baki, 2010; Pilten, 2010), mathematical power was defined as "an individual's belief to use conceptual and operational knowledge in content outline, determined in problem-solving situations using reasoning, communication and connection skills together." According to Baroody (2000), there were three constructing components of mathematical power (1) mathematical disposition, positive disposition to learn and use mathematics. These included the belief and confidence needed to overcome challenging problems, (2) mathematics understanding, these included appreciation, how school mathematics related to daily life, saw the relationship between mathematical concepts, and procedures to relate their conceptual

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reasons, and (3) investigation, developing the ability to engage in the process of mathematical inquiry (Baroody, 2000). So, it is very clear that in order to have a high mathematical power required constructing components, they are productive (positive) disposition toward mathematics, appreciation on mathematics, and student involvement in the process of mathematical investigation.

On the other hand, group investigation also provided a context for students to give reasons (*reasoning*), explain their thinking, justify conclusions and analyze situations based on their reasoning (*communication*). In an investigation, it requires students to apply concepts from different areas of mathematics, and to some problems from other disciplines (*connections*). Here, students could learn mathematics better if they worked on high mathematical tasks that required more than just recalling information or applying procedures, formulas, or existing rules. However, they could learn to actively explore mathematical tasks, and allow for reasonable solutions (Sullivan, Doug & Clarke, 2013). In short, learning with an investigative approach had increased the ability of reasoning, communication and connection, all of which are main requirements of mathematical power.

Flewelling and Higginson suggested that investigation and problem solving provided students the opportunity to use their imagination to find stronger ideas and understanding of mathematics about relationships among mathematical ideas (Flewelling&Higginson, 2003).

It was increasingly important to us that investigations were essential for internationally recommended reformation to improve mathematics learning and develop students' mathematical power (Quinnell, 2010). Quinnell's statement (2010) was in line with the result of this study confirming that students who had positive disposition and high investigative activity levels tended to have highly increasing cognitive abilities (mathematical power) (Quinnell, 2010). Students' mathematical power ability appeared in the actualization of reasoning (giving reasons), mathematical communication in groups and connections between ideas in mathematics while having problem-solving (Pilten, 2010). Meanwhile, students with negative disposition had low investigative activity level which led to a low cognitive ability (mathematical power). Thus, negative mathematical disposition has been shown to inhibit the students' mathematical achievement.

CONCLUSIONS

Based on the discussion, the authors could draw a conclusion, that mathematics learning with investigation approach (group investigation) had succeeded to transforming negative disposition into (positive) productive disposition and to improve the productive disposition toward mathematics. Students who had positive disposition and high investigative activity levels tended to have higher cognitive abilities (mathematical power). Students' mathematical power ability appeared in the actualization of reasoning (giving reasons), mathematical communication in groups and connections between ideas in mathematics while having discussion on investigation result. Investigation-based learning involved maximum students' learning activities into students' interest in mathematics learning lessons (Zingaro, 2008).

Research Implications

The findings of this study have implications for the importance of implementing group-based learning investigations. Result of this research was in line with research missions of experts to

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promote investigation-based teaching (Quinnell, 2010; Sullivan, Doug & Clarke, 2013; Duyen, 2014).

Recommendations

Classes conducted with investigation-based learning requires teachers who have fine commitment and wide thought to help students constructing their knowledge. Teachers need to help students develop a belief that everyone is able to understand mathematics and solve mathematics problems. Teachers need to connect problems with examples of everyday life situations, so their learning experiences are more meaningful and permanent (Özyildirim-Gümüş & Şahiner, 2017).

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