Cognitive Profile of Highly Mathematically Able Students in a Mathematics Olympiad Preparation Class

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ABSTRACT

Seven highly mathematically able students (grade 6 and 7) from Papua regions were selected to get an extension program for a mathematics olympiad preparation class in Surya Institute. Tes Inteligensi Kolektif Indonesia or TIKI (Collective Intelligence Test of Indonesia) were used to determine those who had an IQ greater than 120 (which is equivalent to the Wechsler norm) with some very high level of mathematical abilities. Teachers rating scale based on Krutetskii predictive behaviors of mathematical ability were used to describe the students' profile. Of the 8 mathematical ability predictive behaviors proposed by Krutetskii, the highly mathematically able Papua students demonstrate all of the cognitive characteristics except the ability to be flexible in solving problems and to reverse the steps of mental processes. Cognitive aspects underlying mathematical ability predictive behaviors of the highly mathematically able Papua students will be discussed as the focus of this study.

Keyword: Mathematics, Highly mathematically able, Gifted, Cognitive characteristic, Papua

1. Research Background

Highly mathematically able students in Indonesia has not been focused as a priority in special education. Some regulations have been provided for developing intellectually gifted students (Departemen Pendidikan Nasional, 2007a) and talented students in non academic areas, such as sports and arts (Departemen Pendidikan Nasional 2007b). However, there are no regulation to guide the development of academically gifted students, especially mathematically gifted students. Lack of attention to mathematical giftedness disadvantaged highly mathematically able students at schools. Some schools misunderstood those students since they have been thought as similar to intellectually gifted students, so that their learning needs were not catered by their school.

In the ministry of education and culture guidelines for developing gifted and talented students in Indonesia, the three rings conception of giftedness proposed by Renzulli is used as the basic concept for defining giftedness and specific talents. Renzulli (1978, 2005, 2011) did not mention about specific characteristics of mathematically giftedness. Therefore, any studies concerning about characteristics of mathematical giftedness would be beneficial for identifying and providing provisions for mathematically gifted students.

Some studies focusing on characteristics of specific talented students categorising mathematically gifted students as a specific group since mathematical abilities was a specific domain and mathematically gifted students indicated different characteristics comparing to average students (Feldhusen et al., 1990; Gustin, 1985; Krutetskii cited in Piirto, 2007). Feldhusen et al (1990) distinguished 15 specific behaviors as highly mathematically able students' characteristics. Gustin (1985) in his study of 20 highly achieved mathematics researchers in the project of The Development of Talent Search (Bloom, 1985) found that those researchers showed different interest, playing style, and learning style. Piirto (2007) analyzed some cases of historical mathematician, such as Bertrand Russell, G. H. Hardy, Carl Friedrich Gauss, and Srinivasa Ramanujan and found some unique characteristics. Fast learning pace, love of numbers, and persistence in learning mathematics were some dominant characteristics. Those studies showed that the mathematically gifted have some specific characteristics.

For providing a clear explanation about highly mathematically able students in Indonesia, there should be any research focusing on specific behaviors as indicators of mathematical giftedness. Some studies conducted by Krutetskii (cited in Krutetskii, 1976) have been referred as a guideline for defining specific characteristics of mathematically gifted students. Those characteristics were focused on cognitive abilities in solving mathematical tasks, including; characteristics of information gathering, characteristics of information processing during problem-solving, and characteristics of information retention and characteristics of motivational component.

Cognitive characteristics that have been described by Krutetskii could be used to completing an explanation about Renzulli's above average ability component in a case of mathematical giftedness. Krutetskii (1976) also mentioned about mental flexibility as one characteristics of mathematical giftedness as Renzulli mentioned about creativity as a part of the three rings conception of giftedness. Therefore this research focusing on Krutetskii's cognitive characteristics of mathematical giftedness as a reference for describing cognitive profile of highly mathematically able students.

Provision for highly mathematically able students in Indonesia were given as an extension program. Surya Institute is one of the learning providers which specifically focused on highly mathematically able students from east region of Indonesia. This institution provide some programs for preparing students to compete in mathematics olympiads in national and international level. Papua districts are prioritized as the target since they found that a lot of students from Papua indicate high potentiality to get an outstanding achievement in mathematics and science. However, there are no specific provision for those highly mathematically able students in Papua. Therefore, Surya Institute colaborated with governments in Papua districts to provide scholarships for the highly mathematically able students who were prepared to compete in mathematics olympiad nationally and internationally. The aim of this reseach is to explore cognitive profile of highly mathematically able Papua students in the mathematics olympiad preparation program.

2. Research Methodology

2.1. Participants

Participants were seven highly mathematically able students of 6th and 7th graders who were taking a mathematics olympiad preparation program in Surya Institute Serpong, Indonesia. Those students were selected from some schools in Papua province of Indonesia. Participant have been taking the preparation program for 6 months.

Three teachers who taught the mathematics olympiad preparation class were included to rate those students' characteristics in mathematical giftedness. Each student would be rated by all teachers who teaches in his/her classroom.

2.2. Measures

Mathematical giftedness behavior rating scale based on Krutetskii characteristics of mathematical giftedness were designed for measuring cognitive characteristics of highly mathematically able students. Three alternative responses: 1 = never, 2 = seldom, 3 = frequently were provided. Cronbach's coefficient α was .79. The rating scale was rated by mathematics olympiad preparation class teachers who teaches each highly mathematically able students. Each student was rated by two teachers. The rating scale measured eight characteristics of mathematical giftedness, : 1). the ability to grasp the formal strucure of mathematical problems (4 items); 2). the ability to be logical in numerical and spatial ways, utisizing symbolic information and to think with mathematical symbols (5 items); 3). the ability to generalize rapidly using mathematical objects, relations, and operations (2 items); 4). the ability to learn efficiently by abbreviating and shortening steps in mathematical processes (2 items); 5). the ability to be flexible in solving problems, to shift strategies, and to take different roads to the desired end (2 items); 6). the ability to find clarity, simplicity and economy in solving mathematical problems (3 items); 7). the ability to reconstruct problems, to reverse the steps in the mental process during solving problems (2 items); 8). the ability to remember the main features of mathematical problems and solutions and store mathematical information (2 items).

Tes Inteligensi Kolektif Indonesia tingkat Dasar or TIKI-D(Collective Intelligence Test of Indonesia, basic level) were used to determine participant who had an IQ greater than 120 with some very high level of mathematical related abilities. There were 10 subtests in TIKI-D (Drent et al, 1978), including: 1). Computation. The test consist of simple numerical problems that require basic arithmetical operations. The test was considered to measure the ability to handle numbers and number relations. Factor: Number facility and convergent production (memory) of symbolic implications. Cronbach's coefficient α was .97; 2). Components. Two small figures (the components), and six complex figures were shown to the testee. Two of the six complex figures could be constructed by uniting the two separate components. The test was considered to measure ability to manipulate and transform figural material. Factor: spatial orientation (visualization) and cognition of figural systems. Cronbach's coefficient α was .92 ; 3) Figure exclusion. Four out of five geometrical figures were similar in some respect. The figure that did not accord with the principle must be indicated. This test was an adaptation of the test "Exclusie" (Flier, 1974). Factor: induction and cognition of figural class. Cronbach's coefficient α was .78; 4). Word relations. Each item consists of four words. The testee has to identify two words with either identical or contrasting meanings. Factor: verbal comprehension and cognition of semantic units. Cronbach's coefficient α was .92; 5) Figure comparison. Four figures in a row of six are identical to a key figure, given at the left of the row. The testee had to discover the two figures which are different. This test calls for speed and accuracy in visual perception. Factor: perceptual speed and evaluation of figural units. Cronbach's coefficient α was .97; 6). Mazes. There were 20 mazes, varying in the degree of difficulty. The testee had to find the quickest way out of each maze, requiring speed in the visual exploration of a more or less complicated spatial field. Factor: spatial scanning and cognition of figural implications. Cronbach's coefficient α was .90; 7) Letter multiplications. The answers to a large number of multiplications have to be examined for their correctness. The multiplications were represented by letters, which could be converted into numbers by using a simple code given at the top of the page. The test was considered to measure numerical skill and coding. The test was developed by Van der Flier and has not previously been published. Factor: number facility and convergent production (memory) of symbolic implications. Cronbach's coefficient α was .98; 8). Figure completion. Five simple key-figures are given, numbered from 1 to 5. Each problem shows a segment of one of these five figure of which a segment was shown, and then write down its number. Factor: flexibility of closure and convergent production of figural transformations. Cronbach's coefficient α was .82; 9). Word Exclusion. Each item consisted of five words, four of which are similar in some respect. The task was to indicate the word that did not belong with the rest. This test was considered to measure ability to abstract. Cronbach's coefficient α was .79; 10) Triangle Detection. Each item shows nine small circles. By drawing connecting lines between the circles, three (equilateral) triangles could be formed which were identical to a given triangle. Each circle might only be used once. An item was only counted as correct when all three triangles have been found. Factor: figural adaptive flexibility and divergent productions of figural transformation. Cronbach's coefficient α was .94. TIKI's norm was equivalent to the Wechsler's norm. Cronbach's coefficient α for TIKI was .98 for the whole test series.

3. Result and Discussion

3.1. Ability to grasp formal structure of mathematical problem facilitated by inductive reasoning, synthesis, number facility, and visualization.

More than 50% highly mathematically able students indicated some cognitive characteristics as Krutetskii (1976) mentioned (see table 1), including: grasping formal structure of mathematical problems, logic in numerical and spatial ways, generalize fast by using m.athematical objects, relations and operations, learn efficiently by abbreviating steps in mathematical processes, finding clarity and simplicity in solving mathematical problems, and remembering mathematical nformation well.

Table 1. Characteristics of highly mathematically able students rated by teachers.

Dimension	Percentage of responses	Mean	SD
Grasping formal structure of math problems	57.14 to 100	2.88	0.12
Logic in numerical and spatial ways, utisizing symbolic information and to think with math symbols	71.43 to 100	2.83	0.50
Generalize fast by using math objects, relations, and operations	57.14 to 71.43	2.64	0.48
Learn efficiently by abbreviating steps in math processes	71.43	2.71	0.39
Flexible in solving problems	42.86 to 57.14	2.58	0.50
Finding clarity and simplicity in solving math problems	57.14 to 85.71	2.71	0.40
Reverse steps during solving problems	28.57 to 42.86	2.42	0.47
Storing mathematical information	71.43	2.67	0.45

Highly mathematically able students indicated ability to grasp formal structures of mathematical problems (found in 57.14% – 100% of respondent, mean of 2.88 see table 1). Finding the formal structure of a problems was facilitated by ability to reason inductively (see table 2: mean of 6.71, very high level) and to synthesize (mean of 6.14, high level). Inductive reasoning facilitated to find relations and principles among mathematical information in a problem, since think inductively means to find any general rules from any cases and knowledge (Abe, 2003).

As mathematics focus on numbers, ability to understand numbers and manipulate numbers is important as well in finding the formal structure of a mathematical problem. Understanding numbers requiring ability to identify numbers and skills to manipulate numbers through calculation (Desoete and Gregoire, 2006). As number is an abstract concept, it is important to involve abstract thinking such as generalization and synthesis (Dreyfus, 2002) for understanding number. Number as an abstract concept could be understood by finding the rules governing relations among numbers. When students could reason inductively, they could find basic principles behind numbers. Krutetskii (1976) found that mathematically gifted students in his research showed ability to analize and synthesize concepts, principles and relations in understanding the structure of a mathematical problems.

Table 2. Cognitive aspects underlying ability to grasp formal structure of problem in highly mathematically able students

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Grasping formal structure of the problems	3.00	Number facility	Computation	6.57	0.53
		Inductive reasoning	Figure exclusion	6.71	0.49
			Figure completion	5.00	2.77
		Synthesis	Components	6.14	1.07
		Vizualisation	Components	6.14	1.07
			Figure comparison	5.57	0.79
			Mazes	6.29	1.11

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of TIKI's intelligence test aspects (1=very low to 7=very high)

Mathematics involving a lot of abstract concepts, so that is important to have visualization abilities for understanding the structure of a problem. Visual image would be required to facilitate students in understanding an abstract mathematical concept (Dreyfus, 2002) since it built and strengthened mental representations about the product of a generalized thinking. Mathematics is concerned about procedures or steps (Tall, 2002) in solving any mathematical problem. Therefore, dinamic visual order that work like a sequence of acts might support the process of abstraction that are required in understanding an abstract mathematical concept (Kautschitsch, 1988). Some studies (Wheatley, 1991; 1997; Presmeg, 1992) emphasized the importance of mathematical visualization or metaphorical reasoning in learning mathematics. Lee et al (2007) stated that visual image providing an important base to develop a structural analog in solving a mathematical problem. Using visual image as an analogy for understanding the thinking process in solving a mathematical problem is able to help students to understand the structure of the problem. This research finding also supported that highly mathematically able Papua students showed a high level of visualization ability (mean of components 6.14, mean of figure comparison 5.57 and mean of maze 6.29, see table 2). Visualization ability might help the students to imagine the mathematical thinking process they have to build in mind when they were dealing with a mathematical problem. Spatial orientation as was measured by components subtest in TIKI usually is used in identifying numbers (Lakoff and Nunez, 1997) and understanding geometry (Herszkowits et al, 1990).

3.2. Ability to reason logically in numerical and spatial ways facilitated by inductive reasoning and understanding symbols.

Table 1 indicated that teachers rating for highly mathematically able Papua students indicated that ability to reason logically in numerical and spatial ways was dominant (found in 71.43% – 100% of respondent, mean of 2.83). The ability to reason logically in numerical and spatial ways was facilitated by the existence of inductive reasoning (mean of 6.71, see table 3) and ability to understand symbols (mean of 5.86 see table 3).

Mathematical statements is represented in symbolic information including numbers and letters. Those numbers and letters is underlied by some relations and principles that arrange a mathematical statement. Every mathematical statement is true if only match with its definition and logical structures. Therefore mathematics needs some proofs (Nickerson, 2010) so that requires deductive reasoning processes to improve the validity of the statement (Hunt, 2011). Proofs is made by organizing a systematic logical thinking. Inductive reasoning is important as well since processes for discovering principles and patterns as the base of relations among numbers or symbols are required in understanding mathematical concepts (Neubert and Binko, 1992). The structure of mathematical problems could be understood well when students could apply some similar characteristics or principles in mathematical concepts they have learned into the new problem (Davydov, 1990; Dreyfus, 2002). From the description above, it is clear that mathematics required a reasoning ability, including deductive and inductive reasoning (Polya, 1954, 1962; Holyoak, 2012; Sriraman, 2003).

Table 3. Cognitive aspects underlying ability to logic in numerical and spatial ways in highly mathematically able students

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Using logic in numerical and spatial ways, utilizing symbolic information	3.00	Inductive reasoning	Figure exclusion	6.71	0.49
			Figure completion	5.00	2.77
		Understanding symbols	Letter multiplication	5.86	0.69

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of TIKI's intelligence test aspects (1=very low to 7=very high)

3.3. Ability to generalize rapidly in solving mathematical problem facilitated by inductive reasoning.

The other characteristics that teachers frequently found as a specific characteristic for the highly mathematically able Papua students is ability to generalize rapidly using mathematical objects, relations and operations. There were 57.14% to 71.43% of respondents (table 1) indicated ability to generalize rapidly, i.e. finding relations among previous knowledge for understanding related new concepts (Stacey, 2006). Ability to generalize rapidly in mathematics which characterized highly mathematically able Papua students was supported by their ability to reason inductively (high level, mean of 5.57 in inductive reasoning test, see table 4). Inductive reasoning could help the students to cover distance between previous knowledge and new knowledge since it provides some ways to find similarities between previous knowledge and the new learned concept.

Sriraman (2004) perceived generalization in mathematics as the end product of an inductive trial and error path started with providing examples for discovering patterns and lead to a process to build a formula. For Mason, Stacey and Burton (2010), generalization in mathematics is a process for discovering patterns and relations in some mathematical thinking level. Generalization helps students to get the essence of the learned concepts or patterns in a specific context and use it to solve mathematical problems (Hashemi et al, 2013). By generalizing, students are able to find a formula based on mathematical concepts that they have learned. Ability to generalize enabled highly mathematically able Papua students to analyze the characteristics of a mathematical problem in finding the formal structure of the problem even when they did not remember the mathematical formula which was related to the problem.

Table 4. Cognitive aspects underlying ability to generalize rapidly in mathematics in highly mathematically able students

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Ability to generalize rapidly using mathematical objects, relations, and operations.	3.00	Inductive reasoning	Figure exclusion	5.57	0.79
			Figure completion	5.00	2.77

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of TIKI's intelligence test aspects (1=very low to 7=very high)

3.4. Ability to shortened steps in solving mathematical problems and to find the most efficient solusion to problem.

Table 1 also indicated that highly mathematically able Papua students in this study showed ability to abbreviating and shortening steps when solving a mathematical problem (71.43% of respondents). They also had an ability to find clarity and simplicity in solving a mathematical problem (57.14 % to 85.71% of respondents).

Some researchers (Davis, 1984; Dienes, 1960; Dubinsky, 1986; 1991; Greeno, 1983; Sfard, 1988; 1989; 1991) stated the role of encapsulation process in learning mathematics. Encapsulation is transformation of a mental action which is representented in some steps or procedures into an object of conceptual thought (Dienes, 1960; Dubinsky, 1986; 1991; Sfard, 1988; 1989; 1991). When students has been mastering mathematical steps in solving a problem, they will be able to see it as a whole so that enables those steps in mathematical procedure to be compacted (Thurston, cited in Borovik, 2007). Therefore, they are able to use the concept of mathematical procedure they have learned in only one step of mental process.

O'Boyle et al (2005) found that the reasoning speed of the mathematically gifted students is supported by a very good math-fact retrieval ability and imagery-based memory representation (O'Boyle dalam Kalbfleisch, 2008). This research finding supported O'Boyle et al (2005) since highly mathematically able Papua students indicated a very high level of number facility factor (mean of computation 6.57) and a high level of visualization ability (mean of visualization around 6, see table 4). Visualization ability enables students to make a creative analogy during the process in understanding a mathematical concept. Mathematically gifted students are able to make a creative analogy due to active interference of frontal cortex during solving mathematical problem (O'Boyle et al , 2005). By using creative analogy through metaphorical reasoning, highly mathematically able students is enabled to get some idea from imagining the way of an object to work into their strategies to solve mathematical problems. This process might shortening mathematical procedure steps in solving a problem. Further, Knauff et al (2002) explained that imagining process and exploring mental models which is organized spatially is applied when solving a deductive inferential problem. Therefore, high ability in visualization ability is beneficial for the Papua students to do shortened reasoning.

Table 5. Cognitive aspects underlying ability to shortened mathematical thinking steps, and to appreciate parsimony and elegance in highly mathematically able characteristics

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Ability to learn efficiently by abbreviating and shortening steps in math solutions.	2.00	Number facility	Computation	6.57	0.53
		Inductive reasoning	Figure exclusion	6.71	0.49
			Figure completion	5.00	2.77
		Synthesis	Components	6.14	1.07
		Visualization	Figure comparison	5.57	0.79
			Mazes	6.29	1.11
Ability to appreciate parsimony and elegance in solving math problems	3.00	Number facility	Computation	6.57	0.53
		Inductive reasoning	Figure exclusion	6.71	0.49
			Figure completion	5.00	2.77
		Synthesis	Components	6.14	1.07
		Visualization	Figure comparison	5.57	0.79
			Mazes	6.29	1.11

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of TIKI's intelligence test aspects (1=very low to 7=very high)

Goel et al, (1997) found that mathematically gifted students were able to transform from linguistic system into visual system in understanding a problem by using mental spatial model and venn diagram. Mental spatial model might be able to provide a wholistic description about the problem that enabled students to find the most efficient solution for the problem.

The involvement of central executive function in mathematical thinking have been proved in some studies (Geake, 2003; O'Boyle, et al, 2005). Some relevant procedural knowledge will be retrieved when it is required to solve a mathematical problem. Ability to inhibit irrelevant information and ability to shift strategies supported highly mathematically able students to choose an appropriate strategy in a minute.

Highly mathematically able Papua students also indicated a high level of reasoning ability (mean of inductive reasoning, i.e. figure exclusion 6.71 and mean of figure completion 5.00 see table 5) and a high level of abstract ability which is indicated by the ability to generalize and to synthesize (mean of inductive reasoning around 6 and mean of synthesis 6.14 see table 5). These abilities might enable students to do the encapsulation process easily when dealing with mathematical concepts. Students might be able to shortened some steps into an algorithm by doing encapsulation process. High level of inductive reasoning supported for discovering an appropriate analogy in understanding the problem and finding an efficient way to solve the problem. High level of abstract thinking enabled them to generalize rapidly so they could be able to find patterns for proposing a formula in solving a problem.

3.5. Ability to store mathematical information effectively.

Highly mathematically able Papua students not only possessed exceptional abilities in acquiring and processing mathematical information. They also indicated an ability in storing mathematical information (mean of number facility 6.57, mean of inductive reasoning around 6, mean of synthesis 6.71, mean of visualization around 6, see table 6).

Table 6. Cognitive aspects underlying ability to store mathematical information in highly mathematically able students

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Ability to store mathematical information	3.00	Number facility	Computation	6.57	0.53
		Inductive reasoning	Figure exclusion	6.71	0.49
			Figure completion	5.00	2.77
		Synthesis	Components	6.71	0.49
		Visualization	Figure comparison	5.57	0.79
			Mazes	6.29	1.11

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of intelligence aspects (1=very low to 7=very high)

Some research conducted by Krutetskii (in Krutetskii, 1976) found that mathematically gifted students remember types and characteristics of operations in problems they have solved, but did not pay attention to specific data or numbers. Abstract thinking is required to remember the characteristics of the problem since grasping the essence of the problem would send the information into long term memory due to meaningfulness.

According to Krutetskii (1976) the essence of mathematical retention were included in a series of reasoning schemes and a series of generalized operations. What has been stored in memory were mathematical information which has been compacted through generalization process and mathematical information which has been processed through curtailed reasoning. Encapsulation process will influence the capacities in storing mathematical information in memory since a long steps of a mathematical procedure would be transformed into a concept. Therefore the chunk of information that should be stored in memory decreasing, providing more space for more storage of information. Math-fact retrieval from long term memory becomes an automatic process (Geary, 1999) since encapsulated concept is easier to be retrieved.

3.6. Ability to be flexible in problem solving

Papua students with highly mathematical ability showed all of cognitive characteristics of mathematically gifted students proposed by Krutetskii except cognitive characteristics related to creativity. Flexibility in solving problems and reversibility in thinking only characterized 28.57% to 57.14% highly mathematically able Papua students. Flexibility in thinking is one of the facets in mathematical thinking (Dreyfus and Eysenberg, 1996). It will develop more when there are some ways to represent concepts that have been learned (Spiro, Coulson, Feltovich, and Anderson, 1988) so that will enable to view some different ways in understanding a problem.

Sriraman (cited in Liljedahl and Sriraman, 2006) mentioned about the importance of flexibility in mathematical thinking. Flexibility in thinking enabled students to formulate a new question and some alternatives to view a problem from a new perspective (p. 19). Possibilities to find some alternative solutions to mathematical might be facilitated by the ability to use some perspectives in viewing a problem as have been found in mathematically gifted individuals (Jausovec, 1994; Sriraman, 2003). Flexibility in mathematical thinking might be facilitated by the amount of mathematical knowledge that have been stored in mind (Ionescu, 2012).

Knowledge in memory could be retrieved providing some alternatives for solving any mathematical problems. Knowledge is important for reasoning process in solving problems since knowledge providing information that is required for finding the formal structur of a problem. When knowledge were accessible, there would be more possibilities to make some strategies in solving the problem. Shafto and Coley (2003) mentioned the influence of expertise in using different types of information that would facilitate reasoning during problem solving.

Highly mathematically able Papua students indicated a very high level of number facility (mean of number facility 6.57, see table 7), representing fluency in retrieving arithmetical facts from long term memory. This condition was reached after they have been providing mathematics olympiad preparation class for 6 months. Before staying in Serpong for taking the mathematics olympiad preparation program, Papua students used to stay in the village interacting a lot with nature. Information about mathematical knowledge were not easily accessible. Therefore, they did not have a lot of mathematical knowledge that enabled them to have varried perspectives when they have to deal with a mathematical problem.

Table 7. Cognitive aspects underlying ability to be flexible in solving problem in highly mathematically able students

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Ability to be flexible in solving math problems	2.00	Figural flexibility	Triangle detection	6.14	0.90
		Number facility	Computation	6.57	0.53

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of intelligence aspects (1=very low to 7=very high)

Teacher reported that before they have been selected in the program, those students' mathematical ability was not so good (unfortunately there are no documented data about previous mathematical achievement in Papua), but they were selected as the candidate of the program since they indicated any capacities to learn mathematics faster than average students in their village.

Teachers reported some learning problems due to different language. Papua students used to communicate in their Papua languages that makes them difficult to understand learning materials which were conducted in bahasa Indonesia. Purpura and Ganley (2014) explained the role of language in mastering initial mathematical skills in elementary level. Those language related abilities including: identifying number words, relating a number word with a specific quantity, relating number words with number representations, and understanding the meaning of comparative terms. LeFevre et al (2010) and Purpura et al (2011) found verbal ability as a strong predictor for early development in mathematics. Difficulties in understanding language could be an obstacle in mastering mathematical skills. Since majority of those highly mathematically able Papua students in the mathematics olympiad preparation program have difficulties in understanding bahasa, before starting to learn mathematics teachers focusing on strengthening students' ability to understand bahasa in order to help them learning mathematics.

Difficulties in learning due to language problem might be one of the factors inhibiting flexibility of thinking in problem solving. Limited expression in verbal language might be the source of difficulty in expressing mathematical language as well which in turn inhibiting fluency in mathematical thinking. However this issue should be investigated further to get more valid conclusions about factors influencing flexibility of thinking in solving mathematical problem.

Poor study habits in Papua students when they started the program were reported by teachers of the mathematics olympiad preparation class. Teachers reported that during the first three months of the program those students behaved poorly in the classroom. They showed a very short attention span, did not pay attention when teachers were explaining learning materials, walking around the classroom, chatting along the school hours, daydreaming, etc. They learned better when teachers explained mathematics in a real life or playing situation. Teachers also reported that those Papua students use to be disciplined by corporal punishment when they were in their hometown so they did not develop self regulation.

Cahill and Beadle (2013) reported that corporal punishment for disciplining students at school is common and remains an accepted norm in Papua. Methods of punishment included slapping, hitting, retaining food and allowances, hitting children with brooms, and burning children with cigarettes (Bureau of Women's Empowerment and UNICEF 2011). Those methods of punishment is used since most adults (parents and teachers in Papua) believed the effectivity of corporal punishment as a method for disciplining children (Bureau of Women's Empowerment and UNICEF 2011). One of the impact of corporal punishment toward children were immediate compliance (Gershoff and Bitensky, 2002). Children showed compliance only when authority figures were around them. They did not develop the motivation to behave well of their own responsibility and they learned that it is desirable not to get caught.

For managing the classroom during the first three months Papua students in the olympiad preparation class were monitored along their learning time, so they were able to behave properly in the classroom. They were exercised to sit in a longer time for doing their school works, reading, and writing. Expanding their attention span became a priority for supporting those students to cope with learning demands in the mathematics olympiad preparation class.

After they have been struggled for keeping their attention during the learning process, teachers changed their focus into preparing those students getting more mathematical knowledge and mastering more mathematical skills. Teachers applied some behavioral approaches techniques, such as providing token for positive behaviors to build positive learning habits. Some rules were made to provide guidelines in behaving. As the consequences, students perceived learning as a strict situation that limiting their behaviors. Their thinking is developed as rule oriented, so that might be an obstacle to develop flexible thinking.

The other characteristics that were not shown in highly mathematically able Papua students were ability to reconstruct problems or reversibility in mental steps. Reversibility refers to "... *the permanent possibility of returning to the starting point of the operation in question*" (Inhelder and Piaget, 1958, p. 272). Reversibility involves a sequence that can go forward and backward or go on to a state equivalent to going back since it involves interiorized schemes (an act on representations of experience without enacting the entire process in visualized imagination). In doing mathematics, an interiorized scheme enables the operations that were used to produce the results of a mathematic statement can be taken as input in further operating since the situations and activities of that scheme could be replayed (Hackenberg, 2010). Steffe and Olive (in Steffe, 1994; Olive, 1999; Olive and Steffe, 2002) explained reversibility in the case of arithmetic as finding the missed information using the available data as raw material by given an end how do we work back.

Ability to reverse steps in solving mathematical problems mentally is supported by ability to reason from the end process into many ways that could solve the problem (Hackenberg, 2010). Lack of ability to solve problems only leads to collecting end products in mind, but not finding some alternative strategies or developing some structures (mathematical concepts) to reach any end products. Teachers rating indicated that only 28.57% to 42.86% of highly mathematically able Papua students frequently reverse the steps in mental process during mathematical problem solving (see table 1) even they showed a high inductive reasoning ability (mean of inductive reasoning around 6, see table 8) and 57.14% to 100% students reported to frequently grasp the formal structure of mathematical problems (mean of 2.88, see table 1).

Table 8. Cognitive aspects underlying ability to reconstruct problem in highly mathematically able students

Characteristics	Mean *	Underlying cognitive aspect			
		Aspect	TIKI	Mean **	SD
Ability to reconstruct problems, to reverse the steps in mental process	3.00	Inductive reasoning	Figure exclusion	6.71	0.49
			Figure completion	5.00	2.77
		Synthesis	Components	6.14	1.07
		Figural flexibility	Triangle detection	6.14	0.90

*) Mean of the rating scale for highly mathematically able behaviors (1=never, 2=seldom, 3=frequently)

**) Mean of the degree of intelligence aspects (1=very low to 7=very high)

In this case, lack of ability to reverse the steps in solving mathematical problem might due to the habit to follow the rules that have been conditioned in the classroom. However, there are no quantitative data to strengthen this assumption. Therefore it should be explored in further research to find the impact of classroom climate into reversibility of thinking in solving mathematical problems.

4. Conclusion

One of the main findings of this research is that it shows some cognitive characteristics in solving mathematical problems of highly mathematically able Papua students that were specified by teachers of the mathematics olympiad preparation program. Some findings also shows how some cognitive aspects underlied a specific characteristic of highly mathematically able Papua students.

Comparing to the cognitive characteristics of the mathematically gifted students proposed by Krutetskii (1976), this research found that highly mathematically able Papua students indicated all of the cognitive characteristics that Krutetskii proposed except flexibility in mental process and reversibility of mental steps in solving mathematical problems. This research finding shows that inductive reasoning, synthesis, vizualisation, understanding number and number facility were some cognitive aspects underlied cognitive characteristics of highly mathematically able Papua students in the mathematics olympiad preparation program. Inductive reasoning is a cognitive aspect that is most dominant in underlying characteristics of highly mathematically able Papua students. It is reccomended to investigate how each cognitive aspect correlates with each highly mathematical ability characteristic.

The impact of language and cultural background of the Papua in disciplining children by corporal punishment toward students' flexibility of thinking is reccomended to be explored in further studies. Further studies were reccomended to explore the impact of classroom climate into reversibility of thinking of highly mathematically able students. Findings of this research should be taken into consideration carefully since its limitation in generalizability.

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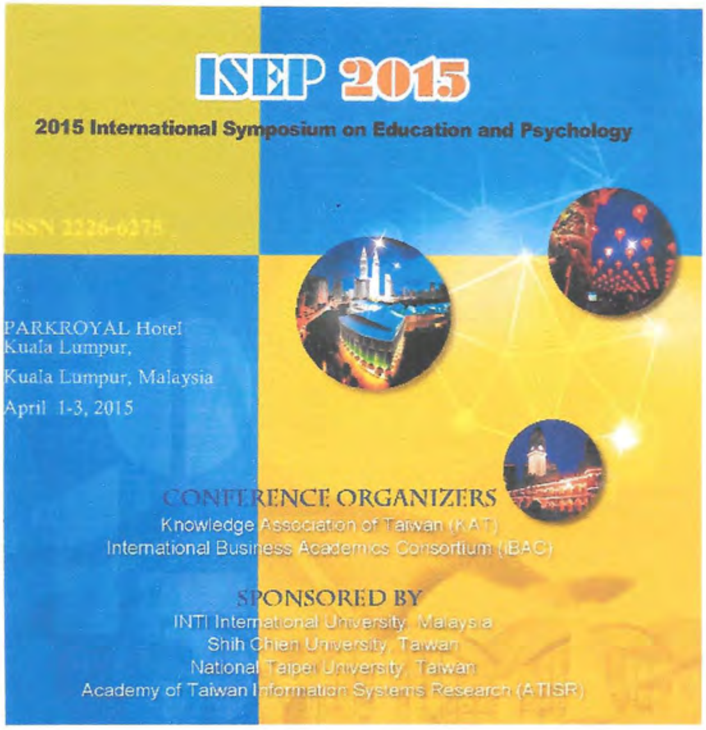
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