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The Correlation Between Students' Formal Thinking Skills And The Capability To Solve Chemistry Olympiad Problems

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Abstract

This research aimed to determine the relationship the relationship formal thinking skills of chemistry olympiad participants with problem solving skills the chemistry olympiad questions. The study population was all students from high school or MAN in Banda Aceh and Aceh Besar province participating in the Olympiad. The data was collected using a test instrument. In addition, interviews were also used as supporting data in the study. Processing quantitative data used Spearman rank correlation coefficient, while qualitative in percentage form. The results of the analysis obtained r_s value about 0,94. Check the table of values r product moment with d_f of 14, at a significance level of 5% is obtained r table = 0,532, whereas the significance level of 1% is obtained r = 0,661 table. r_s value is greater than the price r table, both at significance level of 5% (0,94 > 0,532), as well as the significant level of 1% (0,94 > 0,661). Thus, the alternative hypothesis (Ha) is accepted. Therefore, it can be concluded that the ability of formal influence Olympiad participants in solving problems.

Keywords: *chemistry olympiade, chemistry problem, formal thinking, spearman*

INTRODUCTION

The Directorate of High School Development, the Directorate General of Primary and Secondary Education, the Ministry of Education and Culture consistently continues to develop students' thought-provoking development programs through the activities of the National Science Olympiad (from now onwards called OSN). Until now the OSN covers 9 (nine) scientific fields, namely: the fields of Mathematics, Physics, Chemistry, Informatics/Computers, Biology, Astronomy, Economics, Earth and Geography. The OSN was held in addition to being an effort to improve the competencies of science, technology and mathematics, this activity is also actually a vehicle to foster the character of students who are honest, disciplined, sporty, diligent,

creative, resilient and love the country. We also get the best students from the OSN candidates who will be included in the international science olympiad (Can, 2015).

OSN is carried out for three levels: elementary (elementary), middle (junior), and upper (high school). OSN can be regarded as the highest ranking as the most prestigious science competition in Indonesia for elementary school students to high school students. The first OSN was held in 1998 in Jakarta. Until 2001, the host for organizing the OSN had not changed, which was still in Jakarta. After that, in 2002 OSN was held in different cities, namely in Yogyakarta, and in the following years consistently carried out without interruption until now. This year, 2019, is the 9th OSN competition held by the Ministry of Education and Culture, and held in Manado, North Sulawesi on 30 June - 6 July 2019.To win the OSN medal, students must pass four stages of competition, namely the school, province/city, province and national levels. Starting at the province/city stage, students solve problems that are classified as "difficult" for most students in their respective levels.

Thinking strategies involve a variety of thought activities such as observing, comparing, grouping, imagining, evaluating, planning and investigating, submitting simple hypotheses, summarizing, interpreting, and drawing conclusions. Thinking can also be said as a mental activity to find problem solving. The discovery of problem solving can be done by presenting the object of the problem in a real way and doing trial and error. This way of thinking is physical or non-symbolic, or also called concrete thinking (Alessio, 2019; Dewaelsche, 2015; Garcia et al., 2015). Another way to find problem solving is to use imaginative symbols or in other words object problems cannot be presented in a real way. This method is called formal thinking (Fung, 2017)). Formal thinking is one type of ability which is an attribute of intelligence. This ability to think formally is an important aspect of intelligence, but not the only one. The aspect emphasized in the ability to formal thinking is the effective use of concepts and symbols in dealing with various special situations in solving a problem (Li et al., 2019; Pieterse et al., 2016).

Piaget created the theory that logical thinking develops gradually, between about two and about seven years of age. According to Piaget, the way children think is not at all like the way adults think. Children's minds seem to be organized differently from older people. Children seem to solve problems on an entirely different level. The difference between younger and older children has little to do with the issue that older children have more knowledge. But because the knowledge they get is different, with this discovery Piaget began to study the development of mental structures. The stages of development according to Piaget are as follows (Pieterse et al., 2016).

1) Sensorimotor stage

Lasts from birth to 2 years of age. At this stage, infants build an understanding of the world by coordinating sensory experiences (such as seeing and hearing) with physical motor actions, which are called sensorimotor.

2) Pre-operational stage

Thinking (Pre) Operation in Piaget's theory is a procedure to mentally act on objects. The hallmark of this stage is infrequent and logically inadequate mental operations. In this stage, children learn to use and represent objects with pictures and words. His thinking is still egocentric, that is, children have difficulty seeing from the other person's point of view. Children can classify objects using one feature, such as collecting all red objects even though they have different shapes or collecting all round objects even though they are different colors.

3) Concrete operational stage

Lasts roughly from the age of 7-11 years. At this stage children can carry out operations, and logical reasoning replaces intuitive thinking as far as thinking can be applied to specific or concrete examples.

4) Formal operational stage

Looks from the age of 11-15 years. At this stage the individual goes beyond the real world, concrete experiences and thinks abstractly and more logically. As part of more abstract thinking, teenagers develop a picture of the ideal state. They can think what the ideal parent looks like and compare their parents with this ideal standard.

Thinking is a human characteristic. Since being able to perceive, humans think and this process continues until the end of their lives. Humans are bestowed by the creator with thoughts, therefore the advantages of humans compared to other created beings are determined by the power of their thoughts which are manifested in their actions, after going through the process of appreciation. Thinking ability is a complex set of skills that can be trained from an early age. Thinking is an active, dynamic process that is ideational in the context of forming understanding, forming opinions, and drawing conclusions. Thinking is a mental process that occurs due to the functioning of the brain in order to find answers to a problem, find ideas, seek knowledge, or just to imagine. The thought process occurs by the functioning of the human brain, because the human brain is the center of consciousness, the center of thinking, behavior, and human emotions reflecting the whole of him, his culture, psychology, language and memory.

Thinking strategies involve various thinking activities such as observing, comparing, classifying, imagining, evaluating, planning and investigating, proposing simple hypotheses, summarizing, interpreting, and drawing conclusions. Thinking can also be said as a mental activity to find solutions to problems. The discovery of problem

solving can be done by presenting the object of the problem in real terms and doing trial and error activities. This way of thinking is physical or non-symbolic, or it is also called concrete thinking. Another way to find solutions to problems is to use imaginative symbols or in other words the object of the problem cannot be presented in real terms. This way is called formal thinking.

Students often state that the Olympiad question is difficult. Let alone to be answered, to understand the point of the problem is difficult. This was stated by Rachmajanti, (2017) who had done research by giving math olympiad questions to one of the high school students in Surabaya, namely FS (female). When given the question, the FS said he could not answer it. Even though the average math score of FS in the class is above 80 (scale 100). The results of the researcher interview on July 20, 2018 with a class III student at SMA 4 in the city of Banda Aceh with an average chemistry value of class II amounting to 90 (scale 0-100) stating that one of the problems he avoided to solve was an Olympiad question, the student said unable to analyze it. It has also been reported that the impact of formal thinking patterns on student achievement in mathematics (Slameto, 2017; Vong et al., 2017)). The ability of formal thinking has been reported to affect the increase in chemistry learning outcomes (Nugroho et al., 2018). Is there a relationship between the ability of formal thinking chemistry Olympiad participants with the ability to solve chemical olympiad questions?

Based on these questions, the purpose of this study is to determine the relationship of the formal thinking abilities of chemistry Olympiad participants with the ability to solve chemical olympiad questions.

METHOD

The approach used in this study is a quantitative qualitative approach, while the method used in this study is descriptive because in its implementation includes data, analysis and interpretation of the meaning and data obtained. The type of research used is a survey, where the researcher carries out a treatment to collect natural data from a particular place, for example by distributing questionnaires, tests, structured interviews and so on. The location of the study was carried out in the City of Banda Aceh and Aceh Besar. The selection of research locations is based on consideration of schools that often participate in OSN. Schools which for the past 5 years (2012-2018) were ranked in the top 3, both at province, provincial and national level. Coming from a high school/MAN school in the city of Banda Aceh and Aceh Besar province that participated in the Chemistry OSN.

Table 1.
Recapitulation of Validation Results of Research Instruments

Aspects	APCT Test			Olympiad Test		
	Expert Validator		Average	Expert Validator		Average
	1	2		1	2	
Contents	12	11	11,5	15	14	14,5
Language	10	11	10,5	12	12	12
Contructs	24	26	25	32	34	33

Total Score	46	48	47	59	60	59,5
Maximum Score	52	52	52	68	68	68
Response percentage (%)	88,46	92,30	90,38	86,76	88,23	87,49
Category	Very good			Very good		

Questions about the National and International Olympiads. Questions in the form of essays consisting of 8 questions, divided into 4 fields namely organic chemistry, physical chemistry, inorganic chemistry, and analytical chemistry. This test is conducted to measure students' ability to answer Olympiad questions. Questions about Formal Thinking Ability Tests. Questions in the form of multiple choice consisting of 60 questions, divided into 2 parts, namely the Academic Potential Test (APT) and Academic Potential Chemistry Test (APCT). This test is conducted to measure students' formal thinking skills. The time given to students to work on the problem was 90 minutes.

A good instrument must meet the validity criteria which consist of content and construct validity. The validity of the test instruments in this study was determined by the assistance of two experts using the validation sheet provided by the researcher. The average value of the percentage of responses from experts shows that the instrument meets the validity criteria. The results of expert validation are presented in Table 1.

To obtain more accurate data, the data collection process in this study is divided into two stages, namely: 1) the preparation stage, at this stage the things done are compiling research instruments, validating test instruments, testing the reliability of the test, taking care of permits, schedule data collection. 2) the data collection stage, at this stage the things that are done are giving a multiple choice formal thinking ability test, giving the test the ability to answer Olympiad questions in essay form, checking the test results, analyzing the research data.

Quantitative analysis is used to prove the presence or absence of the relationship between the ability of formal thinking with the ability to answer the Olympiad question Spearman level correlation coefficient, which is used to measure the closeness of the relationship between two variables whose data is ordinal (multilevel data). This coefficient is written as follows.

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$$

Information: rs = Spearman level correlation coefficient, d = difference in ranking, n = number of ranking (level) pairs

Furthermore, the obtained r_s is tested by comparing the r table values, but before the comparison is made, it is determined the free degree (db) or degrees of freedom (d_f) with the following formula.

$$d_f = n\text{-}2$$

Information: df = free degree, n = number of participants

By obtaining db, it can be searched for the magnitude of r listed in the Product Moment table, both at a significant level of 5% and at a significant level of 1%. If r count is greater or equal to r table, the alternative hypothesis (Ha) is approved or

accepted or proven to be true. Conversely, if r count is smaller than r table then H_o is approved or accepted. The hypothesis proposed is:

a) H_o: there is no relationship between the ability to formal thinking and the ability to answer Olympiad questions,
b) H_a: there is a relationship between the ability of formal thinking with the ability to answer Olympiad questions.

RESULT AND DISCUSSION

Thinking strategies involve various thinking activities such as observing, comparing, classifying, imagining, evaluating, planning and investigating, proposing simple hypotheses, summarizing, interpreting, and drawing conclusions. Thinking can also be said as a mental activity to find solutions to problems. The discovery of problem solving can be done by presenting the object of the problem in real terms and doing trial and error activities. This way of thinking is physical or non-symbolic, or it is also called concrete thinking. Another way to find solutions to problems is to use imaginative symbols or in other words the object of the problem cannot be presented in real terms. This way is called formal thinking.

Quantitative analysis in this study is used to test the research hypothesis, namely there is a relationship between the formal thinking abilities of Olympiad participants with the ability to solve Olympiad questions. In this test, each participant is given 2 packages of questions, the first is the test of academic potential which aims to measure the ability to think formally, then the questions whose purpose is to measure the ability to answer Olympiad questions. The scores on the formal thinking ability test and the Olympiad question test along with the test ranking can be seen in Table 2.

Table 2
Scores of Formal Thinking Ability Tests and Olympiad Tests

No	Participant	Formal Thinking Ability Test Score (X)			Olympiad Test Score (Y)
		APT	APCT	Total Score	Total Score
1	AP	26	22	48	70
2	SA	23	22	45	68,5
3	DA	28	24	52	74
4	AM	23	22	45	67,5
5	NC	25	23	42	59
6	TH	23	22	45	63
7	AH	28	23	51	73
8	HH	27	23	50	72,5
9	CR	24	23	47	67
10	GH	26	22	48	68
11	VJ	29	24	53	75,5
12	RE	26	21	47	72
13	AD	22	22	44	62
14	HF	27	24	51	72
15	TP	21	22	43	61,5

Information: APT (Academic Potential Test), APCT (Academic Potential Chemistry Test)

Academic potential tests using 2 types of questions. First, the type of question about academic potential which is generally used nationally. Type This first academic potential test contains measurements of verbal, numerical, and spatial abilities. Second, test the potential of academic types of questions related to chemistry. This test is specially designed and has been validated by 2 validators who have competencies in their field. Furthermore, for the chemistry olympiad test consists of 4 fields of science, namely organic chemistry, physical chemistry, analytical chemistry, and inorganic chemistry. The mapping of scores for each level of Olympiad participants can be seen in Table 2.

Table 2
Mapping of Formal Thinking Ability Test and Olympiad Problem Score

Level	Participant	Formal Thinking Test Score					Olympiad Test Score				
		APT			APCT	Total Score	Organic	Physic	analytic	Inorganic	Total Score
		V	N	S							
Local	AP	8	7	11	22	48	15	21	13	21	70
	SA	8	7	8	22	45	11	21	16	20.5	68.5
	AM	10	6	7	22	45	10.5	21	16	20	67.5
	NC	5	7	7	23	42	11	18	15	15	59
	TH	7	7	8	22	45	12	17.5	16.5	17	63
	AH	9	8	11	23	51	15	22	18	18	73
	CR	7	6	11	23	47	13	21	15	18	67
	GH	7	7	12	22	48	16.5	20	13	18.5	68
	AD	5	7	10	22	44	11	19	17	15	62
	TP	7	5	9	22	43	12	18	13.5	18	61.5
Province	VJ	8	8	13	24	53	17	22.5	19	17	75.5
	HF	8	8	11	24	51	16	20	18	18	72
	DA	8	8	12	24	52	16	22	18	18	74
National	HH	8	7	12	23	50	16	23	18,5	15	72.5
	RE	8	7	11	21	47	14	22	17	19	72

Information : APT (Academic Potential Test), APCT (Academic Potential Chemistry Test), V = Verbal, N = numerical, S = Spatial

Determination Of Correlation Through Calculation

Based on Table 1 obtained d^2 as a total square of the difference in ranking. The next step is to calculate the correlation of the two results of the calculation to get the value of r_s (Spearman level correlation coefficient).

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$$

$$r_s = 1 - \frac{6(38)}{16((16)^2-1)}$$

$$r_s = 1 - \frac{228}{4080}$$

$$r_s = 0{,}94$$

The correlation coefficient shows that between variable X (ability to think formally) and variable Y (ability to answer Olympad questions) are positively strong. If the results are interpreted roughly or simply by matching the results of the calculation with the r product moment correlation index number, it turns out that rs (0.94) ranges from 0.80-1.00 means a positive correlation between variables X and variable Y is a very strong correlation. Next to find out whether the relationship is significant or not, then the r calculation results are compared with r table. Before comparing it, the degress of freedom is determined using the following formula.

$$d_f = n - 2 \text{ , } d_f = 16 - 2 = 14$$

Checking the table of r product moment values with df of 14, at the 5% significance level *r* table = 0.532 is obtained, while at the 1% significance level r table = 0.661 is obtained. The value of r_s is greater than the value of *r* table, both at a significant level of 5% (0.94 > 0.532), and at a significant level of 1% (0.94 > 0.661). Thus, the alternative hypothesis (H_a) is accepted, meaning that there is a very strong positive relationship between variables X and Y. After there is a correlation between the ability of formal thinking and the ability to answer Olympiad questions, its contribution is calculated using the coefficient of determination (CD), namely: CD = r^2 x 100%, CD = $(0{,}94)^2$ x 100%, CD = 0,884 x 100% = 88,4%

The coefficient of determination shows that the ability of students to answer Olympiad questions is determined by their formal thinking ability of 88.4% while 11.6% is determined by other factors. This can happen because each student has different abilities and experiences in answering Olympiad questions. There were some students who were participants in the previous year, some of whom had participated in other competitions outside the Olympiads such as quiz, debating English and project science.

The results of this study are in accordance with the results of research conducted by Ismail et al. (2018) which shows that students who have high formal thinking skills will influence their ability to solve Olympiad questions. In this case, the study was

conducted on mathematics Olympiad students. The same thing was done by Rahmat (2008: 8), who found that there was a formal relationship between students' thinking about chemistry learning achievement. This can be seen from the results of hypothesis testing which obtained F_{count} of 14.4691 while F_{table} for $\alpha = 0.05$ was obtained at 4.025. Thus, $F_{count} > F_{table}$ means H_0 is rejected or alternative hypothesis is accepted.

Formal Thinking Analysis

Based on Table 3 obtained information that, there are differences in the ability of formal thinking Olympiad participants at various levels. These differences provide a relationship that is in accordance with their ability to answer Olympiad questions. At the province level it is clear that many participants have weaknesses in spatial abilities, while at the provincial and national levels, all participants have high spatial abilities. This is because they are participants of the previous year's Olympiads. There are 2 participants who have the highest spatial values at the province level, namely AP and GH. They are province OSN level participants in 2017 and 2018, so they already have enough experience in answering Olympiad questions.

In the ability of formal thinking in spatial categories, it is clear that the values obtained affect their ability to answer Olympiad questions, especially in the field of organic chemistry. Participants with the initials HH, RE, VJ, HF, DA, AP, and GH have high spatial and organic chemical values. This is in accordance with the results of the study of Padalkar and Fong et al. (2017) which states that, spatial ability is a dimensional ability that is indispensable in visualizing organic chemical material, especially about molecular structure.

The same thing has also been reported regarding the relationship of spatial ability to organic chemical material (Gojkov et al., 2015). Meanwhile, for the numerical category, it is clear that the values obtained affect their ability to answer Olympiad questions, especially in analytical chemistry and physical chemistry. All provincial and national level participants have high numerical values for physical chemistry and analytical chemistry. On the other hand, province level participants with initials TP have low numerical values for physical chemistry and analytical chemistry.

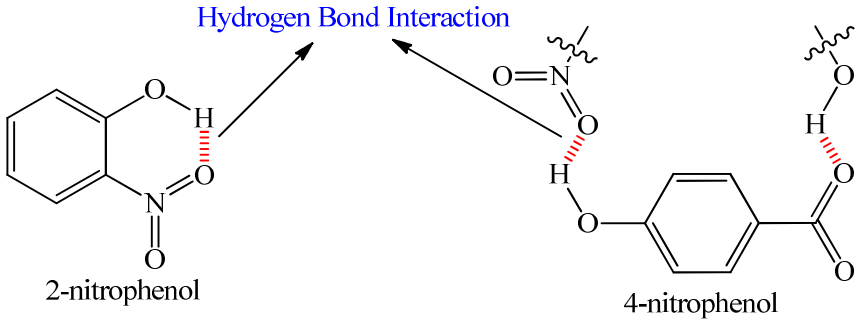
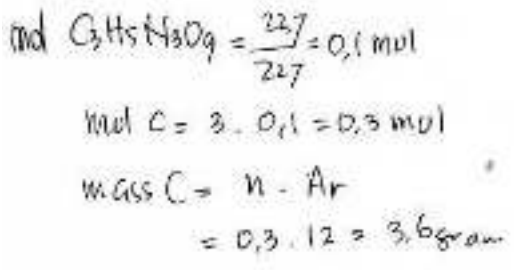
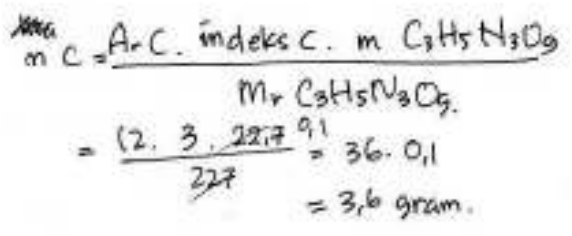


Figure 1. The difference of hydrogen bond interaction between 2-nitrophenol and 4-nitrophenol.

One of the Olympic questions in the field of organic chemistry is about why the 2-nitrophenol boiling point shows a lower boiling point than 4-nitrophenol. Students with the initials AM explained that, the phenomenon is related to the effect of steric barriers that occur at 2-nitrophenols, compounds with this form are unstable making 2-nitrophenol more volatile than 4-nitrophenol. The position of the alcohol and nitro groups in the 4-nitrophenol compound is in a state that is not close together so it is more stable. In contrast to AP students who explained the phenomenon based on aspects of hydrogen bond interactions. 2-nitrophenol compounds show intramolecular interactions, this interaction is not as strong as compared to intermolecular interactions that occur in 4-nitrophenol compounds (figure 1). So this causes the 2-nitrophenol compound to boil more easily than the 4-nitrophenol compound. Besides that, the spatial value of AP is higher than AM. In quality there is a sufficient correlation to show the relationship of formal thinking skills to solving Olympic questions.



(a)



(b)

Figure 2. Answers to Olympic chemistry questions (a) SA students and (b) AD students

Furthermore, the results of the analysis of student answers to the field of analytical chemistry are presented in Figure 2. In this section students are asked to determine the mass of C atoms of $C_3H_5N_3O_9$ as much as 22.7 grams. Students with the initials SA and AD make a solution with the same answer but use different operations. In this case, students need numerical skills so that they can solve the problem of the problem that applies calculations easily.

Based on these results, it can be seen that developments thinking someone is not only seen from the age factor. There are several other factors that influence a person's thinking ability, namely interaction with the physical and social environment. In addition to these two factors, gender, IQ and maturity can also affect the maturity of one's cognitive development. The interaction of social environments such as discussions with teachers and friends when getting difficulties in understanding learning can facilitate the learning process in school (Hyytinen et al., 2018).

CONCLUSION

There was strong correlation between students' formal thinking skills and the capability to solve chemistry olympiad problems. This can be seen the *r* product moment correlation index number turns out at 0.94. Then, from the results obtained F_{count} of 14.4691 while F_{table} for $\alpha = 0.05$ was obtained at 4.025. Spatial ability is needed in analyzing the matter of organic chemistry, verbal ability is used in analyzing the language of the problem, then numerical abilities are used for the entire field of chemical olympiad that uses numbers.

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