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# Analysis of Students' Analytical Thinking Skill in Electromagnetic Induction Concept Using Mini Tesla Coil

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## Abstract

This study discusses about the effect of using Mini Tesla Coil on students' analytical thinking skill in solving physics problems. This research aims to improve students' analytical thinking skill and to classify students' analytical thinking skill level. The research used mix method with One Group pretest-posttest design. The respondents were 99 students consist of 34 students of 2nd semester, 34 students of 4th semester, and 31 students of 6th semester taken by purposive sampling technique. Demonstration and experiment with Mini Tesla coil were applied on this learning. Collecting data was done through tests and interviews. The significance difference of mean value of analytical thinking skill among student level is determined by ANAVA One Way test, while to know the improvement of analytical thinking skill using the normalized gain (N-Gain) test, and for clarification and deepening data of analytical thinking skill by interview. Based on ANAVA One Way test, $F_{count} = 5.61 > F_{table} = 3.09$. These results indicate that there are significant differences on analytical thinking skills among students. Based on the N-Gain test, value of N-Gain is 0.42 - 0.45 which indicates an enhancement on students' analytical thinking skills in the medium category. The result of interview classify the 2nd semester students tend to pre-analytical level, while students of 4th semester and 6th semester tend to partial analytical level. Thus the use of Mini Tesla Coil in the learning is effective to improve analytical thinking skills at all levels of students. Low-level students tend at the pre-analytical thinking whereas the higher level students tend at the partial analytical thinking.



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## INTRODUCTION

Students as an agents of change have strategic roles and functions in the acceleration of state development. One of the realization of change agents is by developing education, science, and technology according to the skills they have. The skills that required to perform the role are critical thinking skills, creative thinking skills, collaborative skills and communication skills. These four are 21st century skills. The 21st century skills are included in high order thinking skills. Based on Bloom's taxonomy, High order thinking skills include analyzing, evaluating, and creating (Churches, 2008). Such skills need to be trained and developed by students in school learning. Based on the results of TIMSS (Trends in Mathematics and Science Study) in 2011, high order thinking skills of Indonesian students are still relatively low. Teachers become one of the main factors in determining the quality of high order thinking skills of students (Aini & Adhitama, 2015).

Four teachers' competencies are needed to be implemented and developed in the learning process for candidate teachers at colleges. One of these competencies is professional competence. Professional competence is an ability of mastering the learning materials widely and deeply that guide students to fulfill the competence standards. The first competence must be owned by a teacher is the mastery of the subject matter. Mastery of the material is a teacher's cognitive ability such as knowing, understanding, applying, analyzing, evaluating and creating. Especially physics teacher, because physics is a subject that requires analytical thinking skills in solving problems (Rustaman, 2011). Physics teachers are required to be able to explain to students about physics phenomena that occur in everyday life properly and correctly appropriate to knowledge that they have. Candidates for physics teachers should be equipped with skills to explain the concept of physics as a whole to facilitate the candidate physics teacher in the learning process when later became a teacher (Muchsin & Khumaedi, 2017). The explanation of the physics phenomena can be done by a teacher if the teacher has a good analytical skills. The skill of analyzing is the ability to break down or detail the situation to a smaller part and to understand The relationships between the parts (Lorenz & Elefteriadou, 2001). The success of analytical thinking can be seen from explanations, decisions, and result that appropiate to knowledge and experience (King *et al*, 2010). By analytical thinking, people can understand a particular situation by knowing how the interactions between parts (Amer, 2005). Analytical thinking can prepare students to be a good problem solvers, mature decision-makers, and make students never stop to gain knowledge. However, Winarti (2015) in her research states that students haven't been able to analyze and explain a detailed phenomenon of physics. Same with research result of Kiong *et al* (2012) and Heong *et al* (2011) which states that the ability to analyze is a capability that has a low value in high order thinking. Therefore, an effort is needed to improve students' analytical thinking skills.

One of the ways to prepare students to think analytically is by learning used teaching props. The props used can provide problem solving solutions that are capable to representing students' analytical thinking skills. Electromagnetic induction is the concept in physics about the phenomenon of electric current on a conductor due to the effect of magnetic flux change. The concept of electromagnetic induction is very abstract and has a complex relationship that requires high analytical thinking skills to solve various problems (Dega *et al*, 2013). Abstract concept is a concept that can't be seen and found its real form in the environment. The concept comes from the imagination of scientists who can only be explained theoretically (Suseno, 2014). The concept of electromagnetic induction in college student of teachers candidate can be obtained in Electrical Magnetic lectures. The obstacles in the Electrical Magnetic lecture at the Institution for Teacher Education have been identified by Suseno (2010). The obstacles are very abstract magnetic electrical concepts, lack of teaching props and experiment or laboratory works to bridge the concept of abstract electrical magnetic to be factual, and the need for high order thinking to understand

electrical magnetic symptoms. In this research, Mini Tesla Coil as a teaching props is used to decrease the obstacles.

Mini Tesla Coil is a set of tools consisting of current amplifier circuits and transformer that can generate high voltage electricity which capable to turning on fluorescent lamps wirelessly or wireless transmission. Mini Tesla Coil is a teaching props in learning that shows a physics phenomena related to the concept of electromagnetic induction. Physics phenomena caused by Mini Tesla Coil require complex analysis. Students analyze by detailing, differentiating and organizing between electric concept and magnetism concept from phenomenon caused by Mini Tesla Coil. Thus, Mini Tesla Coil can be used to improve and classify students' analytical thinking levels about the concept of electromagnetic induction.

## METHOD

This research used mix method, quantitative research of One Group Pretest-Posttest design and qualitative design. The research was conducted at the Laboratory of Physics Department on one of State University in Central Java, Indonesia. Research respondents are 99 students consist of 34 students 2$^{nd}$ semesters, 34 students of 4$^{th}$ semesters, and 31 students of 6$^{th}$ semester. They are a college student of Physics Education Program from one of State University in Central Java, Indonesia. Respondents are obtained through purposive sampling technique. Research data are obtained through tests and interviews. A test consist of 40 questions that used to measure the improvement of students' analytical thinking skills, while interviews used as clarification and deepening of the students' analytical thinking skills test answers. Interview results are used to classify students' level of analytical thinking skills.

The study begins with a trial of research instruments. Testing of research instrument is conducted to know the validity, reliability, differentiation, and the level of difficulty of instrument used. After the instrument can be used in research, then the next step is to do pretest. Treatment is conducted after the pretest in the form of demonstrations, explanations of the use of Mini Tesla Coil and experiment using the equipment. Mini Tesla Coil that used in the research are shown in Figure 1**.**

**Figure 1**. Mini Tesla Coil

Mini Tesla Coil consists of five main coils. Coil 1, coil 2 and coil 3 have a secondary coil of 500 turns with variation of coil diameter, they are coil 1 = 3 cm, coil 2 = 2 cm, and coil 3 = 1 cm. Coil 3, coil 4, and coil 5 have a coil diameter of 1 cm with variations in the number of turns, they are coil 3 = 500 turns, coil 4 = 400 turns, and coil 5 = 300 turns. In coil 1, the primary coil is made flexible which aims to know the position of the primary coil which produces maximum induction.

Students in groups try to use Mini Tesla Coil according to the guidebook to retrieve observation data. Experiment is aimed to find out the working principle of Mini Tesla Coil and to

know what factors that influence the flame of fluorescent lamp caused by Mini Tesla Coil. The first experiment is diameter variation of Mini Tesla Coil. The steps performed are: 1) connecting the power supply 18 V to Mini Tesla Coil; 2) connecting the secondary port of the circuit to the secondary port of coil 1 with the connecting cable; 3) connecting the primary port of the circuit with the primary port of coil 1 according to the color of each with the connecting cable; 4) preparing the fluorescent lamp and luxmeter; 5) pressing ON button on power supply; 6) closing the lamp to aluminum foil ball until the lamp is flame and bring the luxmeter to the lamp; 7) observing and write the light intensity data of luxmeter measurement result; 8) taking the same steps as steps 1 to 7 for the diameter variations of coil in coil 2 and coil 3.

The second experiment is variation of the number of Mini Tesla Coil turns. The steps performed are: 1) connecting the power supply 18 V to Mini Tesla Coil; 2) connecting the secondary port of the circuit to the secondary port of coil 3 with the connecting cable; 3) connecting the primary port of the circuit with the primary port of coil 3 according to the color of each with the connecting cable; 4) preparing the fluorescent lamp and luxmeter; 5) Pressing ON button on power supply; 6) closing the lamp to the aluminum foil ball until the lamp is flame and bring the luxmeter to the lamp; 7) observing and write the light intensity data of luxmeter measurement result; 8) taking the same steps as steps 1 to 7 for variations in the number of turns on coil 4 and coil 5.

The third experiment is variation of the primary coil position. The steps performed are: 1) connecting power supply 18 V to Mini Tesla Coil; 2) connecting the secondary port of the circuit to the secondary port of coil 1 with the connecting cable; 3) connecting the primary port of the circuit with the primary port of coil 1 corresponding to the color of each with the connecting cable; 4) setting the height of the primary coil as high as 3 cm; 5) preparing the fluorescent lamp and luxmeter; 6) pressing ON button on power supply; 7) closing the lamp to the aluminum foil ball until the lamp is flame and bring the luxmeter to the lamp; 8) observing and write the light intensity data of luxmeter measurement result; 9) taking the same steps as steps 1 to 8 for the variations in the height of the primary coil (0 cm, 6 cm, 9 cm, and 12 cm).

Students do posttest after the experiment. The interview is conducted after the researcher analyzed the respondent's posttest answer. Interviews held for the respondents who had the lowest and highest posttest scores on each student semester. Data obtained from the instrument test were analyzed using validity test, reliability test, different power test, and difficulty test, while data obtained from pretest and posttest were analyzed quantitatively with normality test, homogenity test, ANAVA One Way test and N-Gain test. Normality test and homogenity test are used as a requirement of a data can be analyzed on the statistical parametic. The significance of the pretest, posttest, and N-Gain differences in the three student groups was determined by the ANAVA One Way test. The improvement of students' analytical thinking skill is determined by using N-Gain test. Interview datas were analyzed by analytical descriptive to determine student's analytical thinking level.

## RESULT AND DISCUSSION

The experiment with Mini Tesla Coil that students do in learning give influence to students' analytical thinking skill. The students' analytical thinking skills are increasing. The data on improving students' analytical thinking skills are presented in Figure 2.

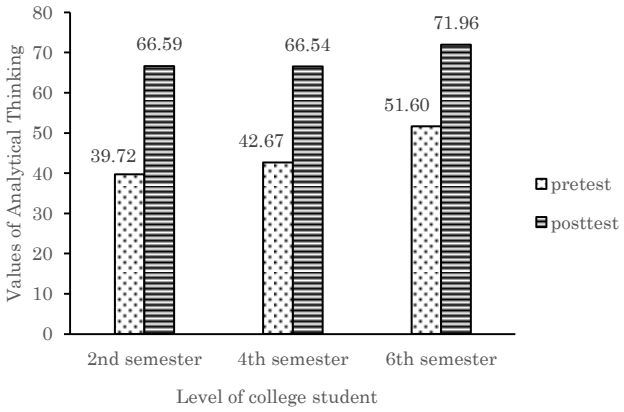


**Figure 2.** Graph of Increasing Students' Analytical Thinking Skills

In Figure 2 it appears that there is an increase in analytical thinking skills at all levels of college students. In the second semester students increased from 39.72 (predicate E) to 66.59 (predicate BC). In the fourth semester students increased from 42.67 (predicate E) to 66.54 (predicate BC) While in the sixth semester students increased from 51,60 (predicate CD) to 71,96 (predicate B). Based on N-Gain test, the value of N-Gain are presented in Figure 3.

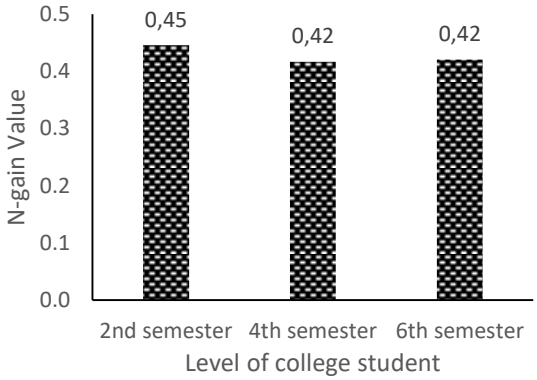


**Figure 3**. Graph of N-Gain Value

Figure 3 show that the N-Gain value in all level of college student were classified as a medium category. The significance test of N-Gain differences is presented in Table 1**.**

**Table 1**. The ANAVA One Way of The Increase Value

| Level of student | N-Gain | $F_{count}$ | $F_{table}$ |
|---|---|---|---|
| $2^{nd}$ semester | 0,45 | | |
| $4^{th}$ semester | 0,42 | 0,48 | 3,09 |
| $6^{th}$ semester | 0,42 | | |

with a significance level of 5%, we get $F_{count} < F_{table}$. The data showed no significant differences in N-Gain values among students. Although it doesn't show significant improvement differences, the data show that the learning with Mini Tesla Coil can improve students' analytical thinking skills. This Renault of ANAVA One Way test shows that the use of Mini Tesla Coil is effectively used in all levels of college students to improve analytical thinking skills.

The use of teaching props is an attraction for students because learning becomes varied, not monotonous and involves the active role of students (Setyowati *et al*, 2016). Teaching props make easier for students to understand the material and students get more knowledge. Good mastering and understanding of the material will have an impact on students' analytical thinking skills. Analytical

thinking is the fourth level of cognitive activity of the Bloom taxonomy, while knowing, understanding, and application of matter are at a lower level than analytical thinking. Cognitive activity at low levels becomes the foundation for higher level cognitive activity (Anderson, 2001) so that when good mastery and material understanding will have a good effect on analytical thinking skills. In line with the research result of Cano-Garcia & Hughes (2000) which stated that there is a positive relationship between learning achievement with thinking skills. The success of thinking depends on the knowledge he has.

The use of teaching props according to Bruner learning theory, that human intellectual development includes three stages, there are enactive, iconic, and symbolic (King *et al*, 2010). Enactive stage is the stage of manipulation, construction, and preparation by utilizing concrete objects. Through teaching props, students are able to manipulate events to understand a concept and students will see directly how the regularity and the structures patern contained in the objects he noticed. Mini Tesla Coil that used in research help students construct the concept of electromagnetic induction. The process of constructing student concept through inquiry process, that is finding the concept independently. The inquiry process requires students to investigate a problem systematically, critically, logically. Nuangchalerm (2009) stated that inquiry based-learning is able to improve cognitive ability, analytical thinking ability, and student's learning satisfaction. In line with the research result of Sumarli et al (2018) which stated that inquiry approach can train students' problem solving skill and student active to construct knowledge independently through interaction with environment. Students who are able to construct their own knowledge will find it easier to remember concepts because they feel proud and happy to have been able to find concepts. Emotional factors of feeling proud, happy, or sad may affect cognitive activity and memory, so the concepts he has found will be retained in long-term memory (Frederickson, 2003). Therefore, the use of Mini Tesla Coil based on inquiry can improve students' analytical thinking skills.

In his book entitled "Alat Peraga dan Media Pembelajaran", Anas (2014) stated that the use of teaching props as a medium of learning will make the learning process motivated. Teachers will be proud and confident and students will arise the desire to try. In addition abstract concepts can be present in concrete form. Therefore the concept can be understood. Berk (2009) states that the teaching props are part of instructional media that serves to deliver the message from teacher to student so that it can stimulate students' thoughts, feelings, attention, and interest. Based on the interviews, students have a positive response to the Mini Tesla Coil because Mini Tesla Coil is a new and innovative tool on the concept of electromagnetic induction they first saw and used. This is in line with the research results of Hartati (2010) which states that the use of teaching props can improve the ability of critical thinking and student learning interests. Students who have an interest in a lesson, then the student will tend to seriously learn, while students who are less interested in a lesson then tend to be reluctant to learn it (Palmer, 2009). Interest in learning will arise when students can feel the benefits of what is learned, both for the present and the future.

The demonstration in the study was conducted as an introduction and explanation of the use of Mini Tesla Coil, with this method will facilitate the learning process and avoid the risk of damage to the tools used. In addition to the method of demonstration, the research also uses active learning method, in which students must play a role physically, mentally and emotionally. The active learning method used by experiment using Mini Tesla Coil. Active learning method needs to be done because if the learning is only by the lecture method (expository) it will tend to lead to verbalistic i.e. the message that is delivered by teachers is not the same as the student's perception. Using teaching props means that the learning do with hands-on activity. Uki et al (2017) stated that the implementation of hands-on activity can optimized the ability of students' critical thinking. Analytical thinking is include in critical thinking, so with hands-on activity can optimized students' analytical thinking too. Kutbiddinova *et al* (2016) said that the use of interactive methods such as active learning, group discussion, and simulation like demonstration can develop students' analytical thinking. With the teaching props then the information becomes clear and concrete according to reality. The steps taken in the study are according to the statement of Montaku *et al* (2012). Montaku states that the model that trains analytical thinking consists of five steps, there are: 1) presentation of problems; 2) demonstrating; 3) guiding each step; 4) full step guidance; and 5) evaluation.

Students of 2$^{nd}$ semester, 4$^{th}$ semester, and 6$^{th}$ semester have different analytical thinking skills. Differences in mean value of analytical thinking skills among students were tested for significance using ANAVA One Way test. The ANAVA One Way test results data are presented in Table 2.

**Table 2.** The ANAVA One Way Test Results Pretest and Posttest Values

| Level of student | Pretest | | | Posttest | | |
|---|---|---|---|---|---|---|
| | mean | $F_{count}$ | $F_{table}$ | mean | $F_{count}$ | $F_{table}$ |
| 2nd semester | 39,72 | | | 66,59 | | |
| 4th semester | 42,67 | 11,19 | 3,09 | 66,54 | 5,61 | 3,09 |
| 6th semester | 51,60 | | | 71,96 | | |

with a significance level of 5%, $F_{count} > F_{table}$ is obtained. These data show significant value differences. In Table 2 the results $F_{count}$ the pretest > $F_{table}$, it can be concluded that there is a significant difference in the initial ability of each student level. The 6th semester students have the highest initial ability compared to students of 2nd semester and 4th semester. After getting treatment, students' analytical thinking skills are measured by posttest. Based on the data presented in Table 2, $F_{count}$ the posttest value > $F_{table}$. There is a significant difference in posttest value among students. Analytical thinking skill of 6th semester student is higher than student's analytical thinking skill in students of 2nd semester and 4th semester. However, the analytical thinking skill of student of 2nd semester is higher than student of 4th semester.

Achievement of analytical thinking skill acquired by student of 6th semester higher than student of 2nd semester and 4th semester is influenced by many factors. One of the factors is the 6th semester students have obtained more learning materials than students of 2nd semester and 4th semester. The 6th semester students have depth and width of good material. To analyze the physics phenomena caused by Mini tesla coil, it is necessary to master the concept of electromagnetic induction. Complete and detailed electromagnetic induction materials have been obtained in Electrical Magnetic lecture at 4th semester. While the 4th semester students currently attending Electrical Magnetic lectures acquire lower analytical thinking skills. The material of electromagnetic induction in Electrical Magnetic lecture is delivered in the final chapter of the lecture. The 4th semester students haven't received electromagnetic induction material when posttest was held, so to answer the question in posttest of student's analytical thinking skill, 4th semester students still use concept which they have got in basic physics courses. As with the 2nd semester students, they gain low analytical thinking skills as they answer with the concepts they have gained in basic physics courses. The depth and width of matter becomes the decisive factor in the attainment of students' analytical thinking skills. This is in accordance with the research results of Kao (2014) which states that there is a positive relationship between a person's cognitive ability with analytical thinking and creative thinking skills.

Based on the review of each indicator of analytical thinking skill, the data obtained as shown in Figure 3.

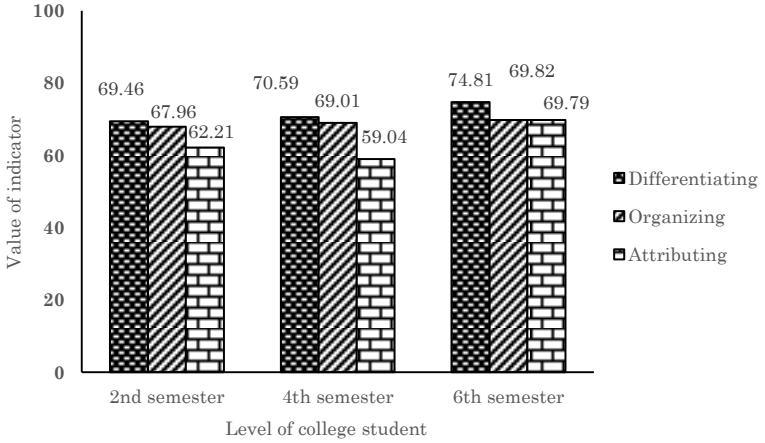


**Figure 4.** Graph Values of Analytical Thinking Skills Indicators

The student's analytical thinking skill consists of three indicators: differentiating, organizing, and attributing. All three indicators are arranged hierarchically as shown in Figure 5 where indicators differentiate into a foundation or foundation for other indicators.

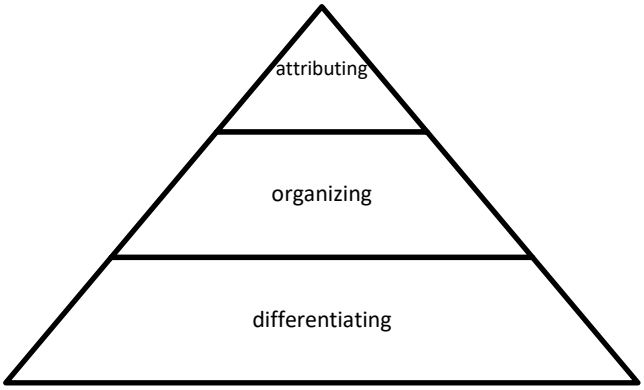


**Figure 5.** Analytical Thinking Skill Indicators

Differentiating is the ability of someone to sort out important or unimportant and relevant or irrelevant parts of an existing problem. Organizing is the process of establishing systematic and coherent relationships between pieces of information obtained from the differentiating stages. While the attributing is the process of determining the purpose or conclusion of the problem (Anderson, 2015).

Figure 4 shows the differentiating indicator is the highest score indicator in the 2nd, 4th, and 6th semester students. The differentiating indicator is the most basic indicator of analytical thinking, so that this ability is owned by all students. While the value of the indicator attributing is the lowest value among other analytical thinking indicators. This occurs in every level of students. Attributing is the indicator with the highest level in analytical thinking, so to achieve high attributing value is needed the good ability to differentiate and organize. Learners will not be able to move to a higher level if they do not master the aspects at the level below.

Mini Tesla Coil can improve students' analytical thinking skill because the using of Mini Tesla Coil appropriate to analytical thinking skills' indicators. Mini Tesla Coil can measure analytical thinking skill with the stage that shown in Figure 6.

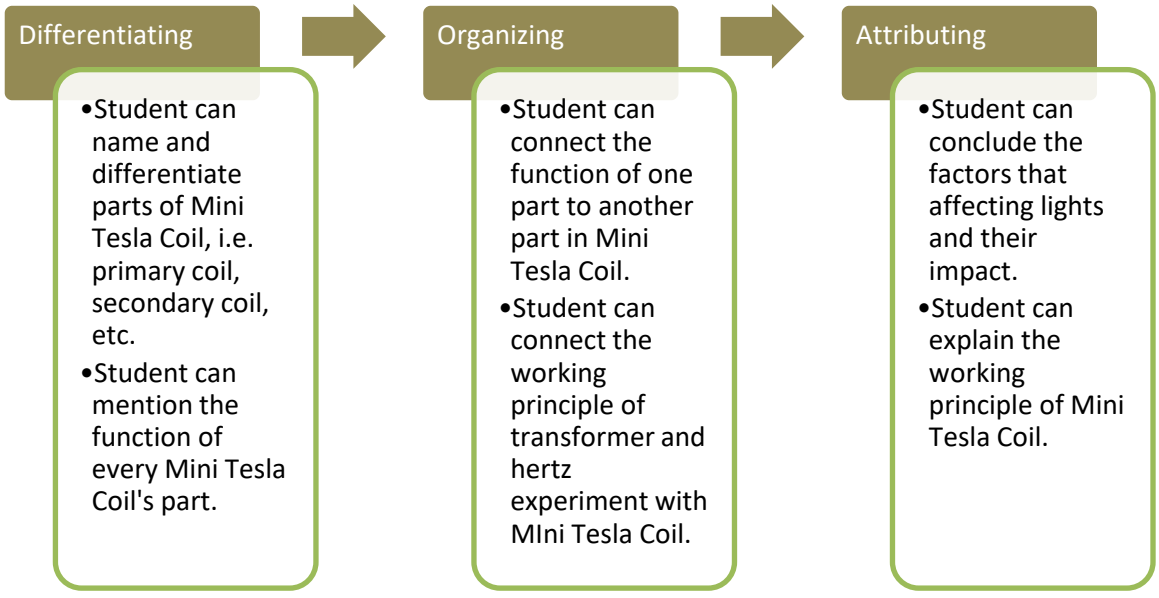


**Figure 6.** Stage of analytical thinking with Mini Tesla Coil

In the 6th semester students, it appears that the value of three indicators of analytical thinking is relatively constant. This shows that in the 6th semester students have good analytical thinking skills. All indicators are evenly controlled even though they have not reached their maximum value. The 6th semester students have more experience, width and depth of electromagnetic induction materials than students of 2nd semester and 4th semester, so they can get higher grades. The attributing in 4th

semester student is lower than the 2nd semester student because the 4th semester student tried to solve the problem according to the expert (the real concept) with insufficient skill. They don't have sufficient skill because the material hasn't been gotten fully in Electrical Magnet lecture. While the 2nd semester students have a higher attributing because the 2nd semester students can solve and conclude the problem correctly even though using the alternative conception that they learned during high school or during basic physics. to simplify the concepts learned by experts.

Analytical thinking can be classified into four levels, there are 1) pre-analytical; 2) partial analytical; 3) semi analytical, and 4) analytical. Pre-analytical thinking is if someone can only explain the basic properties of a problem and tend to use standard procedures to solve the problem. Partial analytical thinking is that if someone has been able to decipher the problem but the parts of problem solving are not logically connected. Semi analytical thinking is characterized by the existence of intruding elements which resulted in the breaking of the logical structure in problem solving. While analytical thinking is a flexible thinking that can adjust the problem solved. It is said to think analytically if someone can differentiate, organize, and attribute parts in the problem appropriately.

Based on the results of interviews on several respondents, the level of students' analytical thinking in the 2nd semester tends to be at the pre-analytical level. The 2nd semester students tend to solve problems in a simple and low scientific way. They use an alternative conception to solve the problem. Alternative conception is a conception that is inconsistent with a scientifically accepted expert understanding. Problem solving isn't done in a coherent and detailed manner, they eliminate some steps despite getting the correct end result. The existence of this alternative conception inhibits the entry of new knowledge (Ipek & Calik, 2008). In the learning using Mini Tesla Coil, new knowledge doesn't erase old knowledge. Learning by using the Mini Tesla Coil isn't to eliminate alternative conceptions, but to create situations where new knowledge is more easily recalled from memory than the alternative conceptions of students (Shulman, 1986).

The 4th semester students tend to be at partial analytical level. They can differentitate between concepts on the Mini Tesla Coil phenomenon, most can differentiate and detail the important parts (differntiating) but not yet able to connect the parts properly and appropriately. This is influenced by the factor that the acquisition of Electrical Magnetic lecture material isn't full yet, so they can only convey some concepts correctly according to the concept of experts. The same thing is also experienced by 6th semester students. They tend to be at partial analytical level. Students of 4th semester and 6th semester are both at partial analytical level, the difference lies in the factors that influence the students can't connect parts of the concepts well. The 6th semester students have got all the Electrical Magnetic lecture materials, the students should be able to connect the concepts correctly, but since the Electrical Magnetic material was obtained one year ago, most 6th semester students have forgotten the material, so they can't explain the phenomenon of Mini Tesla Coil perfectly. According to Reber (2005), forget is a disturbance of conflict between information or material that is in human memory system. In this case the disturbance that occurs is a retroactive disorder. Retroactive disorders occur when new subject matter bring conflicts over the recall of subject matter that has been previously stored in the memory system. Meanwhile, according to law of disuse (Hilgard & Bower, 1981), forgot can be caused because the subject matter that has been obtained has never been used. Such treated material will in itself enter the subconscious or mix with the new material.

The theory is proved and clarified by interview in the research. The 6th semester students feel that Electrical Magnetic lecture material is an elusive material because it is abstract and mathematical. This is in line with the research result of Hau *et al* (2018) which states that the ability of mathematical representation in solving physics problems on Electrical Magnetic lecture at the medium category. Mathematical ability factor is what makes the change of interest and attitudes of students to the learning process Electrical Magnetic. Inadequacy of the material obtained causes the material to be easily forgotten.

## CONCLUSION

Mini Tesla Coil can be used to improve college students' analytical thinking skills effectively. It can visualize abstract concepts into concrete concepts that stimulate students to think analytically. Differentiating are indicators with the highest achievement, while attributing is the indicator with the lowest achievement in the indicator of analytical thinking skills. The level of analytical thinking

of low-level students tends to be at a pre-analytical thinking, whereas the level of analytical thinking of students at higher levels tends to be at partial analytical thinking.

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