Description students' conception and knowledge structure on electromagnetic concept

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Abstract. Electromagnetic concepts are abstract, difficult and complex concepts. There are diverse conceptions understood and knowledge structure by students in learning the electromagnetic concept. This study aims to explore, reveal, perform categorization and describe the students' conception and knowledge structure on electromagnetic concepts. The method used in this study was qualitative descriptive. The subjects of this research were 26 third-year physic education students at Jambi University. Data collection have been done by essay test and interview. Instruments essay test referred and adaptation to test models of Electromagnetism Concept Inventory (EMCI), those include sub-concepts of Electrostatic, Magnetism, Electromagnetic induction and Electromagnetic waves. The analysis of students' conceptions illustrates tend to be on the scale of '1' in electrostatic, electromagnetic induction and electromagnetic wave sub-concepts. In the sub-concepts of the magnetostatic, students' conception spread between the scale of '2' and '3'. Most of the students' knowledge structures situated in the category lack of local coherence and local coherence for every sub-concepts. There is also another knowledge structures in every sub-concepts which are the category of none structure.

1. Introduction

Several researches showed that electromagnetic was a concept which was had to be understood by the students in a various country. The biggest trouble for most university student in learning magnetic electricity was the same, before and after the learning [1]. This was caused by the abstract and complex concepts magnetic electricity had so lesson became less popular because the students needed the ability to think abstractly [2]. Common problem faced by students is mostly the abstract and complex concepts of magnetic electricity. The abstract concept in magnetic electricity was a concept that can be measured and observed, but the process in every indication was hard to observe [3]. The lecturing material for magnetic electricity emphasized more on the mastering the electric field and magnetic field through the introduction of vector analysis. Based on a few studies about magnetic electricity concept, there were four important points that made electric field was less popular and hard to be understood by students. They were; the various conception and knowledge about magnetic electricity concept the students had, the difficulty in understanding the concept particularly based on the mathematical formulation (quantitative), the difficulty in using mathematical operation and the difficulty which came from the magnetic electricity concept that students learn.

The observation done by the researcher showed that in magnetic electricity lecture, students tend to face problems if they were asked the basic and conceptual questions. Other problems faced by students were: 1) Difficulty in understanding magnetic electricity study material, 2) Do not know the right way

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to solve the problem, 3) Difficulty in analyzing the concept and 4) difficulty in solving problems with picture. Based on those difficulties, researcher assumed that students' problems in learning magnetic electricity concept were related to the students' conceptual knowledge. Conceptual knowledge was essential part for students to solve physics phenomena in daily life. Students' conceptual knowledge was really related to the conception that student had about one concept. Conception was the ability to understand the concept, either through interaction with the environment or concepts derived from formal education [4]. Conception was more about individual understanding which can be different from the experts' conception.

The conception developed by learners were result of several factors, such as: sense experience, language experience, cultural background, mass media and formal teaching [5]. The unique conception of natural phenomena was often resistant to the learning process, especially if the conception was obtained from the learning experiences and daily life of learners. Based on these views, it could be concluded that the conception of students tend to be obtained through formal learning that was integrated with the learning experience in everyday life. In the context of learning, the conception that students had in the learning process was generally vary. Those conceptions were generally derived from the previous formal education and also from students' interaction with the environment, either through direct observation, parents, or other various media. In the learning process, there were differences between the conception of the students and the scientific conception.

The results of research conducted [3] presented that the various conceptions were related to the students' knowledge in learning a concept. The students' knowledge in understanding a concept tended to have a certain pattern and structure of knowledge [6]. The term of knowledge structure was a scheme and a description of knowledge that the students had in facing certain problems. The student's knowledge structure generally depends on the signs or understandable information and how the information is interpreted. The structure of knowledge was like how to connect between the knowledge that has been owned by students and the new knowledge obtained by students during the learning process. The results of research done by [6] categorized knowledge structure into 4 categories which were: *lack of local coherence, local coherence*, *lack of global coherence* dan *global coherence*.

Lack of local coherence meant that the conception of students' answers was based on a single concept that was unrelated to other concepts. This meant that the conception was very simple, without merging with other concepts and inadequate [3]. *Local coherenc*e meant that the conception of students' answers was based on a single concept relating to other concepts. Students approached a particular problem in context, one of which used concepts in electricity and magnet consistently [3]. If the merging of concepts had not been consistent to produce an appropriate solution then it was categorized as *lack of global coherence* [3]. Furthermore, if students recognized some concepts that can be used consistently in solving problems correctly and were able to connect them, it was categorized as *global coherence* [3].

The limited research of conception related to the structure of knowledge, encouraged researcher to study the image of conceptions and the structure of knowledge of the students who had studied the concept of magnetic electricity. The purpose of the research was to explore, reveal, categorize and describe the conception and knowledge structure of physics education students on the concept of magnetic electricity.

2. Method

This research used descriptive qualitative research design. The subjects in this study were the students of Physics Education Study program third year who had taken the electromagnetic courses at one of the state university in Jambi city. The sample of this research was students from Physics B regular, there were 26 students. Sampling was done by using purposive sampling technique. The research instrument used an essay test and an interview guide. The essay test was about electromagnetic concept, which consisting of four major sub concepts of electrostatic, magnetostatic, electromagnetic induction, and electromagnetic waves. Essay test items used were the adaptation, modification and reference to the test of *electromagnetic concept inventory* (EMCI) developed by Notaros and Abdullah with the level of validity and reliability 0.68 and 0.72 in good category. Interview Guides was in-depth interviews, to support data obtained from essay test results. The data were collected through an essay test and an in-depth interview. The conception and knowledge structure data in this research was processed using rubric scale of response category. Conception data from essay test result was processed using rubric scale of response 0, 1, 2, and 3. Scale 0 indicated that the respondent did not answer question, wrote back what was known in the question and repeated what was asked. Scale 1 showed the wrong answer and also wrong reason. Scale 2 showed that the answer was correct, with wrong reason and wrong answer, with correct reason. Scale 3 indicated that the respondent's reason and answer were correct. Structure of knowledge data were processed based on respondents' answers and then categorized into 4 scales which were *lack of local coherence, local coherence, lack of global coherence and global coherence*. Data analysis was done by categorizing conceptions and knowledge structures based on rubric scale of answer supported by the in-depth interview process. Furthermore, the categorization was analyzed and described qualitatively.

3. Results and Discussion

3.1. Students Conception on the Electromagnetic Concept

The research involved 26 students of Physics Education Study program third year at one state university in Jambi City, particularly in class Regular B. Data collection was done by giving test and interview. The test was carried out in 100 minutes with a *close book* system. The essay test was used to describe the conception of students who had studied the concept of magnetic electricity in magnetic electrical lectures. The conception of students' answers based on the tests was categorized based on the rubric of response scale. The rubric was divided into four scales that were 0, 1, 2 and 3. Data conception of students' answers were then categorized and grouped in percentage form. Table 1 represented the percentage of student conceptions on each sub-concept based on the response scale.

Table 1. Percentage of student conceptions on each sub-concept based on the response scale

Sub Concepts	% Average of Response Scale Category			
	0	1	2	3
Electrostatic	11	50	32	7
Magnetostatic	3	34	42	21
Electromagnetic Induction	6	52	36	6
Electrtomagnetic Waves	6	55	33	5

The data in Table 1 showed the average percentage of student response scale category on each sub-concept. The data was represented by Figure 1 the percentage of category diagram of the student's conception scores on each sub-concept.

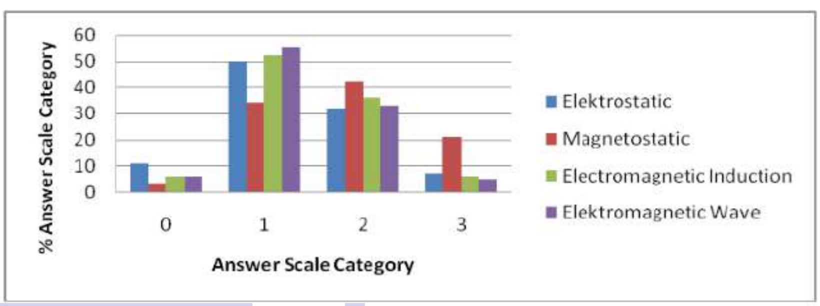


Figure 1. The percentage of category diagram of the student's conception scores on each sub-concept.

Based on Table 1 and Figure 1, it was shown that the distribution pattern of students' conception answers was generally dominant on the scale of '1' and '2' on each sub-concept. It showed the percentage of conception of answer on electromagnetic concept can be categorized "not good (poor)" because the percentage of student's conception across the academic level was low (below 50%) who responded wrong to each sub-concept.

In the electrostatic sub concept, students' answer conception was generally more distributed into the scale of '1', which was an average of 50%. The conception of students' answers on a scale of '1' illustrated the pattern of distribution of answers that were generally more diffuse. Conceptions of student answers were mostly using mathematical equations to answer the questions and prove the statements given. For example, the student used the equation $v = E.r$ to prove that if the electrical potential was zero, then the electric field was zero.

The conception of other answers showed that students generally only answer yes or no based on assumptions without the reason of the conception of student answers which was studied based on the influence of concept elements in the questions and statements given. For example, the student stated that the electrical potential would be zero if the electric field was zero, since the magnitude of the electric potential would be as big as the electric field and affect each other. Below was the Conception of dominant students in scale category "1" and "2" in electrostatic sub concept represented in Table 2

Table 2. Conception of dominant students in scale category "1" and "2" in electrostatic sub concept

Question	Student Conception
If the electric potential at one was zero, was the electric field equal to zero?	Based on the equation relation between the electric potential and electric field.
	Only answer no, means electric field was not zero.
	The magnitude of the electrical potential will affect the electric field and is of equal value
	Answer yes, with equation $V = \int E.dl,$ L = r
	Asnwer yes, with equation V = E . r
When the negative charge moves in the direction of the electric field, the field conducts a negative effort on the charge and the potential energy of charge becomes increased	Charge moves in the direction of electric field.
	Electrons moved in the opposite direction of electric field.
	Usaha is the representation of potential energy.
If the dimensions and the distance between the rectangular capacitor plates were changed into half, determine the value of the new state capacitance.	The new state capacitance was equal to the old state
	The new state capacitance was twice of the previous state.
	Value of new capacitance was: $C = \frac{2A}{d}$

Based on the example above it could be concluded that the conception of student answers was dominantly based on mathematical analysis. The influence of the concept elements on the question represented that the student's conception pattern was almost the same to the original student's conception pattern obtained from the previous level of learning. The results of this study were relevant to the results of previous study conducted by [7] which suggested that the pattern of conception of XII class high school students tended to use mathematical equations and concept definitions to solve problems and questions on electrostatic sub concept.

The conception of student answers on scale "2" scale had mostly correct answer and referred to the relationship between concepts which matched the questions. Students tended to answer using an appropriate equation to prove the answer. However, the reason for the answer was still less accurate and the degree of complexity is partial (not wholly complex). For example, the electric field was not equal to zero because the electrical potential only represented the electric field's resultant at one point.

Based on several findings related to the conception of students' answers on electrostatic sub concept, it could be assumed that the majority of students were mostly using mathematical equations in explaining the reason for the answer to the problem in the given question. Most of the conceptions of students' of academic level electrostatic sub concept answers were in the '1' scale category. It represented that the electrostatic sub concept was a concept that was hard for students to perceive across academic levels. The results of this study were relevant to the results of research conducted by [1] and [8] which stated that electrical potential, electrical potential energy was a learning material that was considered difficult for students from various countries in studying magnetic electricity. The description of the difficulty indicated that basic topics in magnetic electricity such as law of gauus, electric current and electrical potential needed more comprehension from the students [9] and [3].

In the Magnetostatic sub concept, students' conception was dominantly distributed on the scale "2" that was equal to 42%. The conception of students' answers in the '2' scale category generally used relationships and studies of other concepts related to magnetostatic sub concept. The relationship could be a factor, influence, cause of a concept to others related to the sub-concept of magnetostatic. For example, the students demonstrated that the magnetic field could not stop the movement of electrons because the nature of the magnetic field causes the movement of electrons to spread, obstruct and change the direction of movement of electrons. Below were the most dominant conception of students' answer in the scale category "2" on magnetostatic sub concept represented in Table 3.

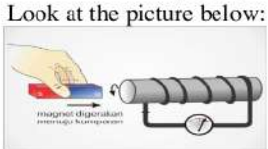
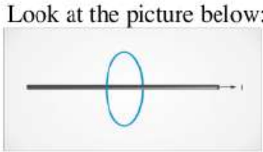
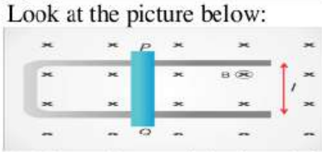
Table 3. The most dominant conception of students' answer in the scale category "2" on magnetostatic sub concept

Question	Student Conception
In your opinion, if a permanent magnet was divided into two, did each part remain as a magnet?	It was remain as a magnet and had natures of magnet
	Remain as magnet and has new magnetic pole which ere U and S
Did you think that a magnetic field can stop a moving electron?	No, it cannot, Magnetic field caused the electron to spread, inhibit and alter the movement.
	No, it cannot, because electron would move if there was a change of magnetic field
	Electron would not stop because of Lorentz force
Two iron bars always pull each other, no matter the two ends are brought together. were the two iron rods magnets?	yes, because iron could be a magnet if it always put together
	No, only one rod was a magnet because of induction process.

Based on several findings related to the conception of students' answers on the sub-concept of magnetostatic, it could be concluded that most of the conceptions of students' answers used relationships and studies of other concepts related to the sub-concept of magnetostatic. The distribution pattern of students' answers was more dispersed in the '2' scale category. This indicated that within the sub-concept of magnetostatic, there were still part of concepts and considered difficult by students in understanding the sub concept. The results of this study were in line to the results of research carried out by [3] which proved that the image of student difficulties was more caused by the pieces of the concept which were not wholly intact.

In the sub-concept of electromagnetic induction, conception of students' answers was generally more distributed on a scale of '1' and '2' with the average of 52% and 36%. The conception of the student's answer on the sub concept of electromagnetic induction studied more on the relationship of influence and direction caused by a concept to another in the concept of electric magnet. For example, the direction of the earth's magnetic field from north to south caused the junction of the galvanometer needle to move in the right direction. Below were the most dominant conception of students' answers in the category of scale "1" and "2" on sub concept Electromagnetic Induction represented in Table 4.

Table 4. The most dominant conception of students' answers in the category of scale "1" and "2" on sub concept Electromagnetic Induction

Question	Student Conception
Look at the picture below:  If the magnetic rod was moved toward the coil, why did the galvanometer needle deviate? Explain	Galvanometer needle deviated because of the electric current made from magnetic induction.
	Galvanometer needle deviated because of the outside field effects.
	Galvanometer needle deviated because of electric current
Look at the picture below:  The picture showed a straight wire flowing in stream I. A ring was placed coaxially around the wire. If the current changes over time, determine how much ggl generated on the coaxial ring	Only write the ggl equation based on flux change toward the time.
	Counting the ggl induction based on Biosavart magnetic field equation.
	Write down ggl induction equation based on the current strength changes to the time
Look at the picture below:  A PQ conductor with a length *l* was sliding with velocity *v* to the right on U-shaped conducting rails. The magnetic field with a magnetic induction leads into the paper field. Prove that the ggl induction at the end of PQ can be expressed by $\varepsilon = -BLV$?	Only used and wrote down ggl equation
	The magnetic field currents lead inward causing the direction of velocity against the motion of the conductor.

Based on several findings related to the conception of students' answers on the sub-concept of electromagnetic induction, it could be concluded that most of the student's conception answers tend to be on the "1" and "2" scale. This was due to the lack of students' basic understanding of electrostatic which could support the understanding of the sub-concept of electromagnetic induction. The results of this study was applicable to the results of research conducted by [10] which stated that the difficulty in studying electromagnetic induction was more caused by students' understanding of basic concepts such as electric fields, magnetic fields, flux and electromagnetic forces.

In the sub-concept of electromagnetic waves, the conception of students' answers was mostly placed on a scale of '1' with an average of 55%. The conception of student responses on the scale of '1' illustrated the distribution pattern of answers that were more diverse. The pattern of conception of students' answers to the sub concept of electromagnetic waves generally referred and connected with one other concept. For example, students revealed that electromagnetic waves occurred when an electric field and magnetic field were both moving perpendicular to each other. Below was the most dominant conception of students' answer in the category of scale "1" on sub concept of electromagnetic waves represented in Table 5.

Table 5. The most dominant conception of students' answer in the category of scale "1" on sub concept of electromagnetic wave

Question	Student Conception
Explain with the electric and magnetic concept, how did the electromagnetic waves occur?	When an electric field and a magnetic field are equally moving perpendicular to each other.
	It occurred when the electromagneticwave moved along with a certain frequency
	Occurs when a nuclear reaction occurred (fission) when the atom broke down into smaller atoms, so there were change of energy.
	The occurance of electron's change and velocity balance with levels (spectrum) and move perpendicular to each other
In your opinion, in what condition an electric current will radiate electromagnetic waves?	If there were a really high energy.
	When moving in a high speed and in a magnetic field.
	When electric field and magnetic field moved to all direction without medium.
With your opinion, prove that in electromagnetic waves, the direction of electric field vibration and magnetic field was perpendicular?	Only stated and used Maxwell equation.
	Based on the transversal wave approach.
	By using oscilloscope.

Based on some descriptions about students' conceptions on electromagnetic waves sub concept, it could be concluded that students had difficulty in explaining every process of the symptoms that occur in electromagnetic waves. Students tended to use the definitions and natures of electromagnetic waves in explaining each question related to electromagnetic waves. The results of this study were relevant to [3] which revealed that students' difficulties in the concept of electromagnetic waves are due to a lack of understanding of the basic concepts of electrostatic and magnetism which underlying the concept of electromagnetic waves.

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3.2. Students' Knowledge Structure on Electromagnetic Concept

26 students of Physics Education Study program third year were involved in the analysis of knowledge structure as the part of the research study. The knowledge structure was analyzed based on the students' knowledge after the electromagneticlearning obtained from lectures. The collection of students' knowledge structure data was done based on the essay test and interview. The data were analyzed by examining conceptions of student's answer on each scale and then categorized in to knowledge structure categories based on [6]. The categories were; *lack of local coherence, local coherence, lack of global coherence* dan *global coherence*. Table 6 showed the percentage of each students' knowledge structure category for each sub concept.

Table 6. The percentage of each students' knowledge structure category for each sub concept..

Sub-concept	% Knowlege Structure Category			
	Lack of Local Coherence	*Local Coherence*	*Lack of Global Coherence*	*Global Coherence*
Elektrostatic	53	42	5	-
Magnetostatic	42	34	21	3
Electromagnetic Induction	52	36	6	6
Electromagnetic Wave	55	35	7	3

The data in table 6 showed the average percentage of students' knowledge structure category in each sub concept. The data were represented by Figure 2, the percentage of students' knowledge structure category in each sub concept.

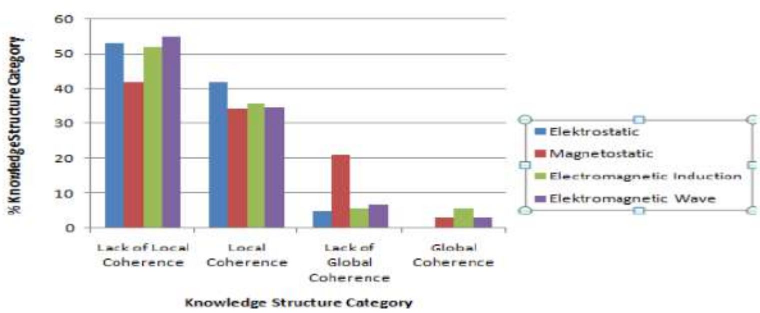

Figure 2. The percentage of students' knowledge structure category in each sub concept.

The data in Table 6 and Figure 2 showed the distribution pattern of students' knowledge structure on the concept of magnetic electricity. Sabella and Redish (2007) revealed that the structure of knowledge was perceived as a scheme or image of knowledge owned by students when dealing with certain problems. Scheme in this case was interpreted as a way or sequence of students' conception in solving a problem. In the electrostatic sub concept, most students were in the category of *lack of local coherence* with percentage of 52%. The category of knowledge structure could be seen from the pattern of conception of student's answers in answering questions on the electrostatic sub concept. The pattern of answers indicated that the students from the both level explained electrostatic problems using a single concept unrelated to other concepts. For example, a student used a mathematical equation to prove that an electric field was equal to zero, then the electric potential was zero. The following Table 7 illustrated the knowledge structure of students in the *Lack of local coherence* category.

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Table 7. Knowledge structure of students in the *Lack of local coherence* category in electrostatic sub concept

Knowledge Structure Category	Student conception
Local Coherence.	Answer not zero, with the equation $$V = \int E.dl,$$ L = r
	Because there was no charge that caused a charge current.
	Answer yes, because electric field was caused by a change in electric potential in each time produced by two or more charge interaction.

In the magnetostatic sub concept, it could be seen that the most percentage of students' knowledge structure were in the Local coherence and lack of global coherence category. Students' answers had used the relation between basic concepts and others in the magnetostatic sub concept, but it was likely to be inconsistent. The following table 8 showed the students' knowledge structure description in the magnetostatic sub concept.

Table 8. Students' knowledge structure in *Local coherence* dan Lack of global coherence category in magnetostatic sub concept

Knowledge Structure Category	Student conception
Local Coherence.	The magnitude of the magnetic field is strong enough against the potential energy and kinetic energy of the moving electrons.
	No, it cannot, because electrons will move when there is magnetic field changes.
	No, it cannot, because magnetic field occurred because of the current caused by the move of electrons.
Lack of Global Coherence	Remain as a magnet and had the nature of magnets.
	Remain as magnet and has new magnetic pole which ere U and S
	Electron would not stop because of Lorentz force

In electromagnetic induction sub concept, most students' knowledge structures were in the category of *lack of local coherence* (52%) and *local coherence* (36%). This indicated that most of third year undergraduate students were using a single concept and related inconsistently to other concepts in explaining the question on the sub-concept of electromagnetic induction. For example the students revealed that the deviation of the galvanometer needle to the right caused by the direction of the earth's magnetic field from north to south (south pole to the north pole). Table 9 showed the structure of student knowledge in *Lack of Local coherence* and *Local coherence* on electromagnetic induction sub concept.

Table 9. Students' knowledge structure in *Lack of Local coherence* and *Local coherence* on electromagnetic induction sub concept.

Knowledge Structure Category	Student conception
Lack of Local Coherence.	The direction of the earth's magnetic field from north to south (south pole to the north pole of the earth) made the galvanometer deviated to the right.
	GGL would be equal to zero
Local Coherence.	Galvanometer needles deviate due to the influence of magnetic field increases.
	Galvanometer needles deviate due to changes in magnetic flux.

In the electromagnetic sub concept, most of the students' knowledge structures were consistently placed in the category of *lack of local coherence* and *local coherence*. The pattern of students' knowledge structure could be seen from the pattern of conception of answers on the electromagnetic waves sub concept. This indicated that students tended to use a single concept and began to relate it to other concepts within the electromagnetic waves sub concept. For example, students tended to use the definition of electromagnetic waves in explaining the process of electromagnetic waves. Table 10 showed the structure of student knowledge in *Lack of Local coherence* and *Local coherence* on the sub-concept of electromagnetic waves.

Table 10. Students' knowledge structure in *Lack of Local coherence* and *Local coherence* category on the electromagnetic waves sub concept.

Knowledge Structure Category	Student conception
Lack of Local Coherence.	Occurs when a nuclear reaction occurred (fission) when the atom broke down into smaller atoms, so there will be change of energy.
	Occurred because the magnetic field and electric field keep moving.
	Occurred when the electromagnetic waves moves together in a certain frequency.
Local Coherence.	Electromagnetic waves occur because electric field and magnetic fields are equally moving perpendicular to each other.
	Electromagnetic waves occur due to the processes that produced waves of magnetic field and electric field and move perpendicularly on each other.
	Electromagnetic waves occur when electric field changes into magnetic field and vice versa

Based on the knowledge structure data analysis, it could be concluded that the Lack of Local Coherence and Local Coherence category were the most dominant knowledge structure owned students who learnt magnetic electricity concept. The results can be perceived from the conception of students' answers which tended to use one single concept. The use of single concept could represent the conceptual ability of the students was likely poor. The results were also in line with research done by [6], as well as [3] study that stated that the low level of students' basic comprehension was seen from the pattern students' knowledge structure which were still in Lack of *Local coherence* category.

4. Conclusion

1. Most of the distribution pattern of students' answer conceptions in each sub concept of magnetic electricity were in the scale of '1' and '2'. The results showed that students tended to have either a inappropriate answer or wrong reason for the answer. Students' answer pattern was mostly using quantitative aspect (through equation) in explaining a concept that was qualitative (conceptual)
2. The students' knowledge structure on the concept of electromagnetic tended to be in the category of *lack of local coherence* and *local coherence*. These results showed that students were less able to connect the supporting concepts in answering a problem or question that were conceptual in the concept of magnetic electricity

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