Mapping of Students’ Learning Progression Based on Mental Model in Magnetic Induction Concepts

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Abstract. The progress of student learning in a learning process has not been fully optimally observed by the teacher. The concept being taught is judged only at the end of learning as a product of thinking, and does not assess the mental processes that occur in students' thinking. Facilitating students' thinking through new phenomena can reveal students' variation in thinking as a mental model of a concept, so that students who are assimilative and or accommodative can be identified in achieving their equilibrium of thought as well as an indicator of progressiveness in the students' thinking stages. This research data is obtained from the written documents and interviews of students who were learned about the concept of magnetic induction through Constructivist Teaching Sequences (CTS) models. The results of this study indicate that facilitating the students' thinking processes on the concept of magnetic induction contributes to increasing the number of students thinking within the "progressive change" category, and it can be said that the progress of student learning is more progressive after their mental models were facilitated through a new phenomena by teacher.

1. Introduction
Science as one of the important lesson materials in schools, especially in elementary schools that present contextual concepts that should appeal to students if teachers can relate it to the social context of each student, but the fact that there is so many misconceptions found in learning science [1], [2], [3], [4]. This is highly likely because teachers have not optimally incorporated prior student experience as the basis of new knowledge builders. Teachers also need to have the ability to catalyse [5] to trigger a process of developing a structured and growing understanding of concepts leading to a more scientific concept as well as having the ability to assess the progress of each student relating to the concepts taught, therefore conceptual changes at each stage of learning can be identified.

As a part of science learning, science-physics learning is closely related to nature that has various phenomena around students' lives, and this is a part that should not be separated from the set of learning when the teacher teaches the concept. The research results from [6] reveal that physics knowledge is a necessary condition for the development of creativity, which means that basic science teachers are not very impressed with the use of creative questions as part of classroom teaching practice, or teachers have not applied the creativity elements of the mainstream science curriculum effectively. In line with this, [7] emphasize the necessity to build relationships between theory and phenomena or objects. In understanding of science learning today's, consideration of students' prior knowledge is important to improve [8].

The fact that in studying complex material, like the concept learned in a science class, can occur at least three conditions different from the original knowledge. First, a student may not have the prior knowledge of the to be learned concepts, although they may have some related knowledge. In this
case, prior knowledge is missing, and learning is consist of adding new knowledge. Second, students may have some correct prior knowledge about the to be learned concepts, but that knowledge is incomplete. In this incompleteness knowledge case, learning can be conceived as a gap filling. In the both missing and incomplete knowledge condition, knowledge acquisition is of enriching kind. In the third condition, a student may have ideas that he has gained, either in school or from everyday experience, that are "in conflict with" the to be learned concepts [9].

This condition should be the basis for teachers to intervene for a science learning process that prepares sufficient space to facilitate and explore and assess the development of concepts that students have understood, ranging from what they think about the concept before learning, how the process of conceptual change at each level of a particular concept, by conducting a formative assessment of changes in the progress of students' conceptual understanding based on learning progression (LP).

LP gives some perspective in science learning, in addition can be used as a cognitive reflection, can also provide information for the emergence of various ways and patterns of development of students' knowledge in a learning process, whether the student's knowledge actually grows in a linear way or progressive or more random. LP on the other hand also provides a true and practical way to describe the students' cognitive pathways. This will certainly contribute to the development of curriculum, classroom learning and assessment [10]. Therefore, determining the appropriate action in a learning that allows students to more easily understand the concept, is closely related to the ability of teachers to know the variation of the characteristics of students' thinking on the concept. The pattern of student concept movement should be the basis for teachers in choosing approaches, methods or techniques in learning, so that learning can be more effective and efficient.

Referring to one of the principles of science education [11], which asserts that assessment has a key role in science education. Formative assessment of the learning done by the students and the summative assessment of its learning progress should be applied to all learning objectives. For an assessment of learning, there is another principle in science learning that the advancement of great ideas must result from studies on topics of interest to students and relevant in their lives. This is possible because students have basically had various alternative conceptions or natural (early) conceptions, which can negatively affect the results of their judgments and their ability to argue about natural phenomena [12]. Still related to the assessment, The National Research Council, 2001 [13], [14] asserts that each assessment is based on three interrelated elements or foundations: aspects of achievement to be assessed (cognition ), The tasks used to collect evidence of student achievement (observation), and the methods used to analyze the evidence resulting from the task (interpretation).

2. Experimental Method

This research uses mixed methods research with convergent parallel design that collect quantitative and qualitative data simultaneously and sequentially [15]. Based on the design of this study, the stages of the study include: (1) quantitative and qualitative data collection, (2) analyzing the two sets of data separately, (3) comparing the results of the analysis of the two data sets, and making interpretations, centering (converging) or more having a varied (divergent) spread. If there are any irregularities, more explanation of the data is required, re-analyzing its database, or checking the quality of the two data forms more carefully. The direct comparison of both sets of data is convergent. The subjects of this study were selected through non-probability sampling technique by purposive sampling. This method is based on the consideration of the researcher according to the particular characteristics being sought [16], namely the fourth grade of elementary school students as many as 25 people who learn about magnetic induction concept.

Learning progression is a series of changes in the students' frame of mind on a concepts learned whose development occurs gradually in the learning phases, through a facilitation process by the teacher. The mapping of the student's frame of mind refers to the category of mental model it has, and the opportunity for the movement / change of ideas has several alternatives: 1) consistent with intuition; 2) consistently analogous to everyday experience; 3) change randomly (ultimately not yet scientific); Or 4) change more progressively toward a scientific final concept.

The techniques used in data collection are: 1) Interviews with representatives of groups of mental model frameworks for students to know the basic or background of the mental model framework.
related to the concepts they have in interpreting the phenomena observed, 2) video-based observations in the classroom Documentation, especially on the implementation of CTS-based learning by teachers that allows valid data to be obtained in relation to aspects of application activity at each stage of learning. Interaction data between teacher and student and between student and fellow student, teacher facilitation process toward idea emergence from student group. This observation is a reflection for the next learning, and 3) Documentation of students' written responses or responses from observations of the observed phenomena and responses after facilitation and questions given by the teacher at the end of the learning stages to map learning progression and conceptual level patterns change that refers to the student's thinking construction over the time span during the lesson.

3. Result and Discussion
The study of the concept of magnetic induction is the last part of the magnetic concept. Prior knowledge of the magnetism of previously concepts learned will contribute in part to the formation of new knowledge of students about magnetic induction. One indicator of this is the emergence of more mental model group variations than other subspects. In addition, using activities with abstract phenomena, there is less time to facilitate students' thinking through appropriate experience. If an elementary school teacher wishes to succeed in assisting students with misconceptions, learning activities should be limited to observable concepts that can be effectively facilitated, and in accordance with the stages of development for students at the basic levels. This is done to help students understand the magnet in a more meaningful way [17].

When students observe a paper clip that is sticky to the magnet and then the paper clip is held close to one other paper clip, and it turns out to be interested, not a magnet, but a magnet. Against this phenomenon there are two major groups of ideas, the first being that "there is a magnetic flow of energy or magnetic energy" that is understood by 40% of students, and the second is that. "The strongest attraction in the first direct clamp on the magnet" by 44% of the students. In addition, there are students who consider that this phenomenon occurs because of the pressure factor as a link between magnet and paper clip and temperature similarity factor between one clip with another clamp, as their paperwork as seen in Figure 1.

![Figure 1. The student's mental model of magnetic induction](image)

Overall how the portrayal of student idea movement related to the concept of magnetic induction is shown in Figure 2.
Based on Figure 2 it is known that in addition to the two dominant ideas groups as described earlier, there are three variants of the intuition-based idea expressed by the students, although each comes from a student, but the idea is unexpected. For example, student 13 reveals that the phenomenon is due to "the presence of magnetic presses linking the iron brace", and the student 5 with a more intuitive comment that "there is a temperature equation in the clamp and is connected to the magnet." Nevertheless, the two students after having facilitated their thinking by the teacher, then both can change the idea and move in a scientific direction. Student 13 has a new idea that "power / magnet tensile strength has a limit" and student 5 turns his idea into "magnet has a temporary magnet.

The facilitation process is done in a similar way to the initial exploration of knowledge, only in the facilitation stage one by one the paper clip is clamped onto a paper clamp that has been sticky before until it is no longer sticky bias. Based on the facilitation, a new framework of ideas emerged: "magnetic attraction only for conductor objects" embraced by one student and "more magnetism more and more appeal" is a new idea of 40% of students who generally derive from the idea that more scientific.

The path of student idea movement on learning of the magnetic induction concept is very dynamic and tends to be random, although at the end of learning there are 80% of students have a more scientific concept, 16% of students are still arguing with an anaolgi basis on their experiences, and 4% With an intuitive idea stating that there is a flow of electricity to the clamp, whereas the student is at the beginning of the lesson and in the facilitation phase has a more scientific idea. This fact indicates that the level of students' confidence in their understanding is still low and volatile, regardless of the mental model it has.
An analysis of the student's idea movement profile during magnetic induction learning to determine the distribution of students based on the learning progress categories they have shown in Figure 3 below.

![Figure 3. Distribution of the percentage of students based on learning progress on the concept of magnetic induction](image)

The student profile is based on the learning progress of the concept of magnetic induction as shown in Figure 2, that type II (more progressive change) is a category with the highest proportion of students, and from all the concepts of electric and magnetism learned, the concept of magnetic induction is also the highest on (76% of students). This fact can be seen from the point of view of the student's travel process in constructing his knowledge during the study of electrical and magnetic concepts, and indirectly a part that perfects the student's understanding.

The data in Figure 3 also shows something important in the analysis of student learning progress on the concept of magnetic induction, where only 4% of students are consistent with more scientific ideas, while the number of students who have a more scientific mental model is quite large, ie 40%. This also indicates that the movement of student ideas in a learning is very dynamic. The phenomenon is reinforced by several research results that show that there are variations of student ideas on a science phenomenon that observed [18], [19], [20], [21].

The varied pattern of student movements in the learning of the concept of magnetic induction represented by each student from the learning progress category in each type is shown in Table 1.

**Table 1.** The progress of students' thinking on the concept of magnetic induction from the type of progress based on the learning stages.

| Students' argument at the stage | Early | Intermediate | Final | Type/Students' code |
|--------------------------------|-------|--------------|-------|---------------------|
| There is a magnetic flow of energy or magnetism | Power/power/magnet energy has a limit | Magnetic forces can flow on other magnetic objects | Consistent with more scientific concepts (3) |
| There is a similar temperature to the clamp and is connected to the magnet | Magnets have temporary magnetic properties | The existence of a magnetic field, and clamps attached to the magnet is a temporary magnet | Changed more progressively (5) |
| The strongest magnetic attraction is in objects that are directly in contact with magnets | Power/power/magnet energy has a limit | Magnetic forces can flow on other magnetic objects | Changed more progressively (8) |
| The strongest | Magnets can attract | The existence of a | Changed more |


Table 1 above shows that the movement of students’ ideas at each stage of learning as a sample for the categories of student learning progress on the concept of magnetic induction has a more diverse path or pattern toward a more scientific understanding. Suppose that students 5, 7 and 8 have a Type II advancement category (changed more progressively), but the pattern of idea change varies from one to the other.

The results of interviews on students 5 say that the phenomenon of a sticky paper clip on the magnet can attract another clamp when a paper clip is not a magnet because the magnet attaches the same appeal to another paper clip, and if the appeal is not enough then the clamp is not interested anymore. Different things expressed by students 24 with the type of learning progress "change more randomly" saying that "there is a difference between the flow of magnets with electricity, if the electricity is energy flowing with the conductor, while the magnet does not need a carrier (conductor)"

4. Conclusion
Facilitating the gradual thinking of the students on the concept of magnetic induction through the corresponding new phenomena can increase the number of students who have a change of thinking in the more progressive categories that observed from the mental model changes it has. In addition, through facilitation also obtained data show that not all students have a consistent and progressive thinking, but there are also students who think more randomly.

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