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Investigating Students' Logical Thinking Abilities on Chemistry Learning

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Abstract

The purpose of this study is to map students' logical thinking abilities for learning chemistry. A total of 39 eleventh grade students of SMK-SPP Negeri Samarinda in Agribusiness and Horticulture Program participated in the study. Test of Logical Thinking (TOLT) was administered to determine students' reasoning abilities. Quantitative descriptive method was used to analyse the data. The result shows that 84,62 % students were found in the concrete level. It consists of 58,97 % male students and 25,64 % female students. Further, 7,69 % male students were found in the transition level and 7,69 % students were found in the formal level, each 2,56 % male and 5,13 % female. From the data, it can be concluded that the majority of students have the concrete level of logical thinking.

Keywords: logical thinking abilities, Piaget, students' logical thinking

Introduction

The success of learning process is influenced by the fit between the subject matter and the students' level of thinking ability. Students' thinking ability greatly affects the success of achieving learning objectives. According to Piaget in Simatwa (2010), every individual has different cognitive development levels. Piaget stresses that as children mature mentally, they pass through four major stages of cognitive development sequentially, with each stage having several sub stages. The major stages of cognitive growth are: sensory motor stage (0 - 2 years), preoperational or intuitive stage (2 - 7 years), concrete operations stage (7 - 11 years), and formal operations stage (11 - 15 years) (Simatwa, 2010). Formal reasoning is characterized by the ability to think about abstract ideas, organise ideas, think logically, and reason about what will happen later.

The relationship between prior knowledge, reasoning ability, achievement, and gender has received special attention in science education research for many years (Yenilmez et al., 2006). Throughout the courses taught in elementary and middle school, 'science' is the one requiring intellectual skills to collect and analyse data to solve problems. In fact, science process skills taught in elementary grades such as observing, classifying, and collecting data act as prerequisites for integrating the processes usually taught in middle school grades like hypothesising, controlling variables, and defining operations (Yenilmez et al., 2005).

Chemistry is one of the most important parts of science that makes the students understand what is happening around them. Chemistry relates generally to the structure of matter. Chemistry combines many abstract concepts, which is the basic knowledge to learn more about chemistry and other sciences (Taber, 2009). The chemistry curriculum commonly incorporates many abstract concepts, which are the central focus of more advanced learning in both chemistry and other sciences (Taber, 2009; Sirhan, 2007). Abstract concepts are important because further chemical science concepts or subsequent theories could not be understood easily if the abstract concepts are not well understood by the students (Sirhan, 2007). Empirical studies (e.g., Ben-Zvi, Eylon, and Silberstein, 1986, 1987) have shown that learning microscopic and symbolic representations are especially difficult for students because these representations are invisible and abstract while students' understanding of chemistry relies heavily on sensory information (Wu et al., 2000).

The concept still aligned with the level of students' thinking which has entered formal thinking according Piaget's level that the ages of 11-15 years and over are able to think abstractly. Ben-Zvi, Eylon, dan Silberstein in Wu, Krajcik & Soloway (2000) find many senior high school students who has not reached that level of thinking having difficulties in understanding chemical concepts. As a result, students who studied chemistry just memorize chemistry concepts without understanding the concepts.

Throughout the courses taught in elementary and middle school, 'science' is the one requiring intellectual skills to collect and analyse data to solve problems. Flavell mentions that Jean Piaget's theory of intellectual development in Simatwa (2010) is considered a leading theory on cognitive development.

Piaget viewed constructivism as a way of explaining how people come to know about their world. He buttressed this explanation with extensive documentation of behaviours he witnessed, and with well supported inferences about the functions of the mind. Piaget (1952) viewed the human mind as a dynamic set of cognitive structures that helps us make sense of what we perceive (Brooks, J. G., & Brooks, M. G, 1999).

Piaget (1952) also states that children are considered ready to develop a concept or special material when they obtain the necessary schemata. This means that children cannot learn if they do not have the cognitive skills. This also means that the learning process becomes blocked when students do not have the required formal reasoning.

SMK-SPP Negeri Samarinda have their own mapping in recruiting their students based on the farming region spread in East Kalimantan, so they have students with very diverse backgrounds. The teachers' ignorance of the cognitive development theory will result in having to solve problems with experiential learning and following the teacher's intuition.

As a result, it is necessary to conduct research on cognitive development according to Piaget's levels. This is due to the fact that according to their age, they should have been in the thinking stage of formal operations (Simatwa, 2010). The teachers' knowledge of the students' cognitive development made the teachers able to plan the exact method that can be used in the learning process that happens in the classroom.

Methodology

Sample

A total of 39 eleventh grade students (27 male and 12 female) of SMK-SPP Negeri Samarinda in Agribusiness and Horticulture Program participated in the study.

Instrument

The Test of Logical Thinking (TOLT) developed by Tobin and Capie (1981), was used to determine the formal reasoning ability of students. The test consists of ten items designed to measure proportional variables (1-2), controlling variables (3-4), probabilistic variables (5-6), correlational variables (7-8), and combinational reasoning (9-10). Students select a response from among five possibilities and then they are provided with five justifications to choose from (Yenilmez et al., 2006). In the first 8 questions, the student is asked to provide the correct answer and the reason why this answer is correct. Both the answer and the reason must be correct for the student to be awarded a credit. The last 2 questions involve combinational reasoning and require the student to enumerate the possibilities. The score on the TOLT is an integer value between 0 and 10. For each question correctly answered, the student receives 1 point, and for each question with a wrong answer, the student receives 0 point (Etzler and Madden, 2014).

Procedure

In each class, students are informed about the purpose of the questionnaire and the procedure for completion. After this short explanation, the answer sheets were distributed, and students were required to complete their personal background information and think about each question and answer it as how it applies to them. Then, the TOLT tests were distributed and students were asked to complete the questions on their own. It took about 40 minutes for students to complete the test.

Data Analysis

This research was a descriptive quantitative study. The research described the mapping of formal thinking skills in the eleventh graders of Agribusiness and Horticulture Program of SMK-SPPN Samarinda.

Results

The TOLT scores of the 39 students ranged from 0 to 5. The age of the students taking the test was 15-18 years. Nevertheless, age of the students was not a significant factor relating to the TOLT score. Sixty-nine percent of the students taking the TOLT were male. There was no significant difference between TOLT score and gender and the average TOLT scores of each gender were nearly the same.

Descriptive statistics are used to see the distribution of student's TOLT results as shown in Figure 1, Figure 2 and Figure 3. In this study, the performance of students at TOLT was also used to categorise the stages of cognitive development by Piaget, divided by stages such as concrete level, transition, and formal. Formal stage was also divided into two parts: the formal stages and the final formal stages (Valanides, 1997). The results are presented in Figure 1.

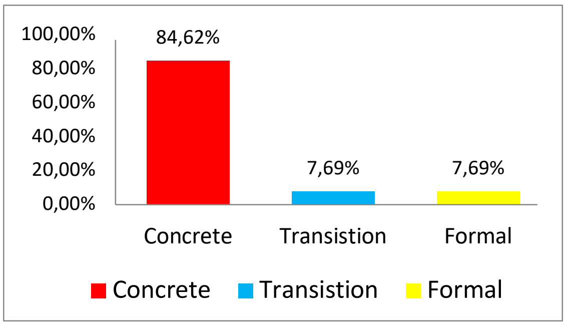

Figure 1. Students Mapping Cognitive Development

Students 'cognitive development, mapped by gender differences were presented in Figure 2. As shown in Figure 2, there is not a lot of students that have reached the formal operational stage. Of the total study sample of 39 people, as many as 33 students were at the level of concrete thinking (84,62%), three students were at the transition level of thinking (7,69%) and 3 students were at the early formal level of thinking (7,69%). The percentages of the male students in the concrete and transition level of thinking are higher than the female students. Even though the highest percentage in the formal level were the male students.

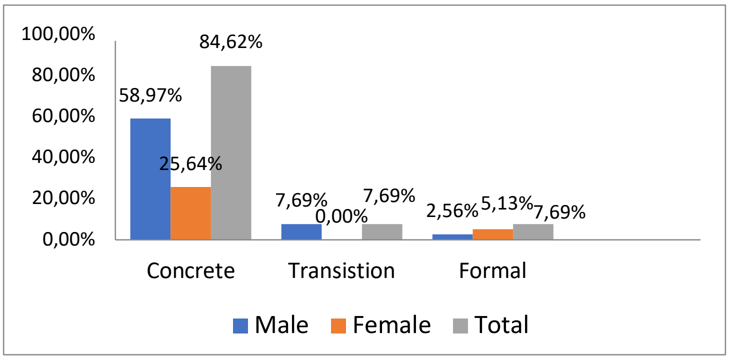

Figure 2. Students Cognitive Development Mapped by gender

The mapping of students' four stages of cognitive development by gender were presented in figure 3.

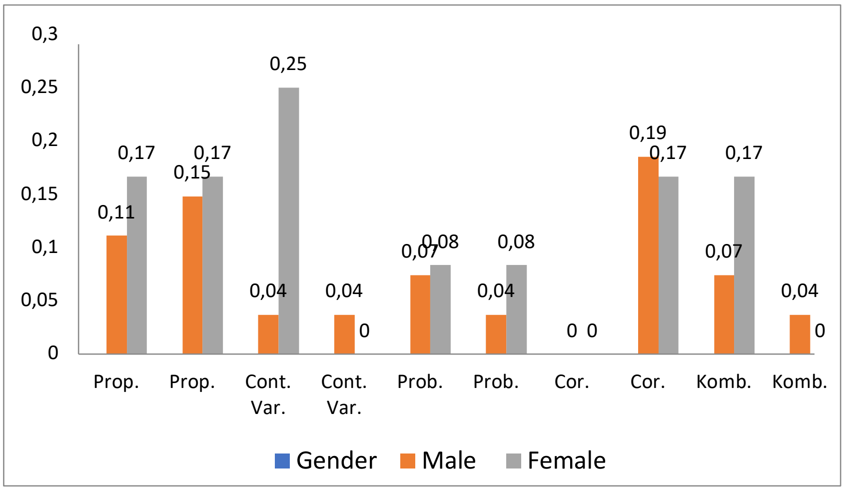

Figure 3. Students Mapping Cognitive Development Male and Female

Based on figure 3, female students scored higher than male students in the proportional logic level, controlling, probabilistic, and combinational reasoning. However, in the correlational level, male students scored higher than female students.

Discussion

If categorised in stages of cognitive development, only few students have entered the formal stage. Most of students are at the concrete stage meaning that they are still unable to predict the final answers therefore any data and information are geared to achieve that goal.

The thinking ability of students who have not entered the stage of formal thinking would make them difficult to understand chemistry. Because chemistry generally combines many abstract concepts, which are the basis of knowledge to learn more about chemistry and other sciences (Taber, 2009).

Individual differences in cognitive development refers to the difference in capacity and speed of learning chemistry. Individual differences of learners will be reflected on the nature or characteristics of their abilities, skills, attitudes and habits of learning, as well as the quality of the learning process and results, either in terms of cognitive, affective and psychomotor.

The teaching methodology and materials with learning activities should be appropriate to each of the learners' cognitive developmental stages. It is stated in the theory that there is a mutual interaction between the learner and the environment, thus teaching materials should come from the learner's environment (Simatwa, 2010). The learning model that we can use is contextual learning model or could be combined with other learning model that is essentially rooted in the daily lives of the students.

Teachers as instructional managers should use the hierarchy to understand why children think and reason as they do and to help the pupils' master intellectual processes at the appropriate age (Simatwa, 2010). Each student has different intellectual capacity, in the same way children at various ages have different capacities for attention and comprehensive.

Piaget opined that teachers as learning managers need to ensure that the learning environment should be rich in physical experiences since intellectual development stage depends on student activity which is the key to intellectual development. How teachers manage the class will be visible from students' independency and creativity in classroom (Brooks & Brooks, 1999). Curriculum, learning and task developers must bring out exceptional effort to understand the world of children. They shall not assume that what they find good for children is certainly good for the child. They can design an educational experience based on the needs and readiness of children (Simatwa, 2010).

Chemistry teachers' understanding of students' logical ability thinking can improve teachers plan learning chemistry and stimulate students' ability to think logically. For instance, teacher can use multimedia to explain abstract concepts in chemistry learning.

Here are some practices that can boost students cognitive functioning in memorising, understanding, and applying knowledge of chemistry or other science.

1. Create a relevant learning and recall the prior knowledge.

Use the early teaching method (analogy, elaboration) with students to help stimulate their previous knowledge. Teacher can use image or animation to present the microscopic level in chemistry matter. The cognitive processes involved in comprehending a visual image can be described on various levels. At minimum level, they include: (a) identifying the important features of a visual display, which is referred to as a surface-level processing or external identification; (b) relating the visual features to their meaning, i.e., semantic processing; and (c) constructing the communicated message, i.e., pragmatic processing (Plass, Homer and Hayward, 2009).

2. Organise information.

Teacher should be well informed on how the students interpret ideas occurred during the class by encouraging a free discussion. They should also watch for the tendency of the adolescent to indulge in unrestrained and unrealistic political theorising where teachers must handle such immature forms of thinking by helping students to recognise that they have overlooked certain boundaries. Another example is teachers are required to classify specific issues under a more general problem.

3. Utilise questioning techniques.

4. Questions appearance prior to the introduction of teaching materials is necessary in helping students to learn the learning material. Teachers are demanded to encourage student curiosity by asking questions, open discussions, and encourage students to apply for a review question one to another. Teachers needs to always engage students through experiences which could create different viewpoint between each student, therefore there will be a discussion of various hypotheses and perspectives. On one side, teachers are not able to know what will be perceived as a disagreement for the students for itis an internal process. On the

other side, teachers are able and should challenge students' conceptions considering that the challenge only take place if the student form different ideas among them. Teachers directs the student's perspective to help them understand what the idea of another student and enable them to accept or to reject the conflicting views (Brooks & Brooks, 1999).

5. The further analysis revealed that dynamic visualisations are more effective than static visualizations only when they are of a representational rather than decorative nature, therefore it is suggested to use interactive multimedia to introduce abstract concepts. The analysis also showed a larger benefit of dynamic over static visualizations when the target knowledge was procedural motor knowledge rather than procedural or declarative knowledge (Plass, Homer, and Hayward, 2009).

Some of the practices above can be applied by teachers to help the cognitive functioning of students in chemistry and learning in general. As for the effects of these practices, students will find it easier to process information and knowledge which will bring advantage on their learning outcomes as well.

Conclusions

The study concludes that within the total study sample of39 people as many as 33 students are at the level of concrete thinking (84,61%), three students at the level of thinking transition (7,69%) and three students are at the level of formal thinking (7,69%).

Chemistry teacher plays an important role in helping and facilitating their students to learn chemistry in accordance to their ability and cognitive development. Teachers, as the manager of chemistry learning in class, should ensure that the learning environment is rich in physical experiences for growth in one stage depending on the many activities.

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