Excavating the Quality of Vocational Students’ Mental Models and Prediction on Heat Conduction

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Abstract. This study aimed to depict of vocational students mental models and the relationship of mental models with predictive on heat conduction. Participants in this study are 20 vocational students in eleventh grade. The descriptive method was used in this study. The data were taken using a semi-structured interview with the interview protocol was adopted and adapted from Chiou and Anderson (2010). The data gathered was analysed by using constant comparison method. The results showed that there were 11 mental models emerged in heat conduction (Interaction, Friction, Gear-like interaction, Substance, Heat as Substance, Energy, Medium, Position, Absorption based Conduction, Numbers of particles and Sample Based Conduction). More than 90% of students have unscientific mental models. Moreover there is a complex relationship between mental model with prediction as it showed by Chiou. Investigating the students mental models on heat conduction of vocational students have a wide implication in improving the Physics learning in Vocational School.

1. Introduction
Science is observing the world, asking question and making discoveries [1]. Through science learning, students are expected to observe the phenomena which they find in daily life and continue to analyze the pattern, and in the end of the process they are able to predict other phenomena’s behavior.

The study of students’ mental models is become an area of considerable interest of research in cognitive psychology and science education [2]. Excavating students’ mental model in certain topics, provide a constructive feedback to stakeholders of physics education particularly to probe students’ reason behind misconception [3]. The main goal of physics education is helping students to construct a compatible scientifically mental model [4, 5]. Mental model refer to people’s internal representations which share analogous structures with the external physical phenomena or systems [4]. Although there is not agreement about the exact definition of the mental model, the common term of mental model is internal representations that people form of the environment through their interaction with it [6]. Mental models represent ideas in individual’s thinking are used to describe and explain the phenomenon [7].

The profile of students’ mental model leads teacher to improve the quality of learning, to design the learning become clear based on the need analyze through initial students’ mental model. There are several studies that have been done in the investigation of mental models. First, Chiou reveals complex relationship between mental model and prediction of a phenomena [4]. Moreover, the finding from Sari expressed the complex relationship between mental models and prediction [3].
Fazio, etc. investigated the relationship between the quality of mental models with manufacture explanation and suggested for do research qualitative and quantitative in design environment of learning that focus on comprehension of aspects in daily life at level causation and mechanism [8].

Based on the National Curriculum of 2013, Physics is one of the fundamental lessons in Vocational School especially in expertise of Light Vehicle Engineering [9]. Heat and heat conduction become one of the most important topics that students should master that concept and apply it to the lesson of burning system in light vehicle.

Therefore, this study is important to evaluate the students’ understanding obtained by students’ mental model. In addition there are two reasons that examined mental models affect cognitive function and is able to provide valuable education regarding the conceptual framework owned by the participants [10]. The aims of this study are identify mental models and the relationship between students’ mental model with predictions on the concept of heat conduction.

2. Research Methodology

2.1 Method
The method used in this research is the constant comparison method of students’ response which adapted and adopted from Chiou [11]. There are three rounds of data analysis. The first round of analysis was focused on the level of individual models, the second phase aimed to identify patterns among 20 individual mental models acquired in the first phase. The third phase aimed to test the reliability of the results of coding using measurement of interater reliability between the coders.

Two science educators are invited to use the encoding scheme recode mental models of each participant. The second phase transform code into new categories or delete existing categories. Intercoder reliability was calculated as kappa coefficient. The results of kappa coefficient was 0.76 and one with a very good category stating an agreement which is very good between the two science educators.

2.2 Participants
Participants in this study were 20 students of class XI in SMK TKR (Light Vehicle Engineering-Vocational School).

2.3 Instrument
A semi-structured interview was used to determine the mental models and mental models with predictive relationship to the concept of heat conduction. This interview protocol has been adopted and adapted from Chiou [11]. Interview protocol consists of three phases. The first phase was understanding the concept of heat, heat conduction, heat conduction phenomena in everyday life and heat conduction mechanism. In the second phase: interview about events which students were asked to predict and explain the condition of two different rods after have been heated. The third phase was the reflection, ask the participants whether they want to change the answer. Moreover in the end of interview, participants were asked the certainty of their answer. This interview was recorded with recording equipment or handycam.

3. Result and Discussion

3.1 Mental Model of the Students.
The vocational students’ mental model in heat conduction was described in Table 1. There are eleven mental models of heat conduction emerged from 20-vocational students. The spread of the number of students in each model was almost evenly but there are mental models with the largest number of students e.g. friction. Each model has its own special characteristics. Scientifically acceptable model is
the mental model of interaction (Mental model of number 1 in Table 1). But in this study only found one person who included in this model.

Table 1. Vocational Students’ Heat Conduction Mental Model

| No. | Mental Model             | Mental Model Description                                                                 | Number of Students |
|-----|--------------------------|------------------------------------------------------------------------------------------|--------------------|
| 1   | Interaction              | Conduction of heat as a result of the particles mutually vibrate; The particles are close to the heat source, the faster the vibration, thus affecting temperature | 1                  |
| 2   | Friction                 | Conduction of heat as a result of particles rubbing together; Friction particles depend on the distance to the heat source, thus affecting temperature | 5                  |
| 3   | Like Gear - Interaction  | Conduction of heat as a result of particles that hand in hand with movements such as wheel | 1                  |
| 4   | Substance                | Conduction of heat as a result of a particle moving from a higher temperature to a lower temperature | 1                  |
| 5   | Heat as Substance        | Conduction of heat as a result of pengahantaran heat but not the same as the intermediary substance | 2                  |
| 6   | Energy                   | Conduction of heat as a result of the heat that flows from high temperature to low temperature | 2                  |
| 7   | Medium                   | Conduction heat as an intermediary / conductor to propagate heat                          | 3                  |
| 8   | position                 | Conduction of heat as a result of the heat that moves objects into other objects         | 1                  |
| 9   | Based Absorp Conduction  | Conduction of heat as a result of the heat transfer through the object to another by absorbing or removing heat | 1                  |
| 10  | Number of particles      | Conduction of heat as a result of the particles without reduction of an object when it sends out heat | 1                  |
| 11  | Sample Based Conduction  | Heat conduction is exemplified with two objects of different temperatures and then affixed to objects that initially cold becomes hot after pasted | 2                  |

There are several factors that influence the mental model that the teacher's explanation, language and word - a word, the experience of everyday life, social environment and cause-effect relationships and intuition [12].
3.2 Category Predictions Students

The results of the students' prediction are presented in Table 2.

| Category Predictions                  | Amount |
|---------------------------------------|--------|
| Overall equilibrium                    | A = B = C = D = E = F | 0 |
| Differentiated equilibrium             | A = B = C > D = E = F | 0 |
| Metal-only equilibrium                 | A = B = C > D > E > F | 0 |
| Continuous Increase in temperature    | A > B > C > D > E > F | 11 |
| Wood – only equilibrium                | A > B > C > D = E = F | 5 |
| Category 1                            | A > D > B > E > C > F | 2 |
| Category 2                            | A > D > B > C > E > F | 2 |

* A-B-C: Iron rod
* D-E-F: Wood rod

Based on Table 2 that the order of the temperature on both rods are grouped into seven categories: overall equilibrium, differentiated equilibrium, metal - only equilibrium, continuous Increase in temperature, wood - only equilibrium, category 1 and category 2. For the four initial categories are the result of research [11]. As for the final three categories are the findings of this study.

Overall equilibrium is the rod will reach thermal equilibrium entirely regardless of the region and the material of the two rods; Differentiated equilibrium is the claim that although aluminum and wooden sticks separately will reach thermal equilibrium, their last state of thermal equilibrium will be achieved at different temperatures; Metal-only equilibrium is the equilibrium only in metal, predicts that aluminum rod will only reach thermal equilibrium while the temperature on a log continues to increase; and Continuous Increase in temperature is the temperature in different areas of the two rods will continue to rise at different levels during the warming continues. The different levels of increase in temperature in various areas related to the gradient analogy. That is, the temperature decreases proportionally to the distance between a particular region with heat source. As for the three predictions of the findings of this study are: Wood-only equilibrium is the state of wood rod that will only reach thermal equilibrium, while the temperature in the aluminum rod continues to rise; Category 1 is the distance to the source point affect the temperature; and Category 2 is the distance point to the source of heat affect the temperature, but the type of material is also influent in changing the temperature of an object when given the heat. As can be seen in Table 3, 11 of 20 participants predicted that the temperature of the two rods will continue to rise (continuous Increase in temperature).
4. Mental model relationship with Category Prediction

Relations with the mental model predictions categories presented in Table 3.

Table 3. Relationship Mental Models with Category Predictions

| Mental Model                  | Overall equilibrium | Differentiated equilibrium | Metal-only equilibrium | Continuous Increase in temperature | Wood - only equilibrium | Category 1 | Category 2 | Total |
|-------------------------------|---------------------|----------------------------|------------------------|------------------------------------|------------------------|------------|------------|-------|
| Interaction                   | 0                   | 0                          | 1                      | 0                                  | 0                      | 0          | 0          | 1     |
| friction                      | 0                   | 0                          | 4                      | 1                                  | 0                      | 0          | 0          | 5     |
| Like Gear - Interaction       | 0                   | 0                          | 1                      | 0                                  | 0                      | 0          | 0          | 1     |
| Substance                     | 0                   | 0                          | 1                      | 0                                  | 0                      | 0          | 0          | 1     |
| Heat as Substance             | 0                   | 0                          | 1                      | 1                                  | 0                      | 0          | 0          | 2     |
| Energy                        | 0                   | 0                          | 0                      | 0                                  | 1                      | 0          | 1          | 2     |
| Medium                        | 0                   | 0                          | 2                      | 1                                  | 0                      | 0          | 0          | 3     |
| position                      | 0                   | 0                          | 1                      | 0                                  | 0                      | 0          | 0          | 1     |
| Based Absorp Conduction       | 0                   | 0                          | 0                      | 0                                  | 1                      | 0          | 0          | 1     |
| number of particles           | 0                   | 0                          | 0                      | 0                                  | 0                      | 1          | 1          | 1     |
| Sample Based Conduction       | 0                   | 0                          | 0                      | 1                                  | 1                      | 0          | 0          | 2     |
| Total                         | 0                   | 0                          | 11                     | 5                                  | 2                      | 2          | 2          | 20    |
Based on Table 4 shows that the continuous increase of the category prediction in temperatures is most prevalent with the mental model that is a total of 11 people. The results showed that participants do not seem to use a combination of mental models - a category prediction to predict the final state of the system. The participants tend to take their learning rules or interpretations of solid experience to make predictions, these findings are consistent with [4]. There is a complex relationship between mental model with prediction.

5. Conclusion and Implication

Based on the analysis and discussion that decomposes it can be concluded that there are eleven students’ mental models with 90% of students do not have scientifically accepted mental model and there is still a complex relationship between mental model with prediction.

These findings lead us to investigate a treatment that enhance students’ scientific mental model in heat concept in Vocational School. One of the best suitable treatments offered to enhance students’ scientifically mental model in vocational school is practicum. Practicum offer context rich learning experience, improve conceptual understanding, develop practical skills and is the best way to reflect on the nature of science [13]. Another solution is implementation of learning reconstruction. Based on finding of Karim et.al implementation of learning reconstruction gives a positive impact on the student’s conceptual understanding achievements [14]. These solutions offer the method to enhance the students’ conceptual understanding and it lead to the construction of students’ scientifically mental model.

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