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ANALYSIS OF MENTAL MODEL OF STUDENTS USING ISOMORPHIC PROBLEMS IN DYNAMICS OF ROTATIONAL MOTION TOPIC

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ABSTRACT

The analysis of mental models is a part of the identification of students' thoughts on the concept. Mental models analysis is conducted by conditioning the complex problems such as the isomorphic issues. The research objective is to analyze the development of students' mental models on the topic rotational motion dynamics. The study was designed with the mixed method. The design phase of the research was conducted in both quantitative and qualitative approach. The quantitative phase was performed by providing pre-test, learning, and post-test containing isomorphic problems; while qualitative phase was implemented by interview and quiz. The data were analyzed quantitatively and qualitatively. The results of the study categorizes mental models into three types, i.e. Low Mental Model (LMM), Moderate Mental Model (MMM), and High Mental Model (HMM). Based on the pre-test results, it was proved that all students used Low mental model in resolving the isomorphic problems. Using the Low Mental Model, it was found that students have misconceptions on the moment of force and moment of inertia. Mental models developed gradually from Low mental model to Moderate Mental Model and then reached the High Mental Model Mental. It was observed from the results of pre-test, quizzes, and post-test. The quiz and post-test results showed the students who used Mental Model and High Mental Model.

Keywords: analysis, mental models, isomorphic problems, the dynamics of rotational motion.

INTRODUCTION

Diagnosis in learning is a form of assessment. One objective of the assessment is to determine the ability and learning difficulties experienced by students (Kusairi, 2012: 6). The ability and students' learning difficulties can be identified through a description of students' way of thinking. When a person is trying to solve a problem, the person will create a model in his mind about how is the way to conquer the problem. Model that describes a person's mind in solving the problems, a form of the response to the phenomenon and the situation can be defined as a mental model (Greca and Moreira, 2002, Coll & Treagust, 2003, Engelhandt et al, 2003, Ornek, 2008). Fazio et al (2013) defines more specifically about mental model of physics that includes the student's ability to determine a reason when constructing a knowledge and explicitly explain the allegations of knowledge. Mental models are not easy to identify a person's mental model which represents a different thought on everyone (Coll & Tragust, 2003). However, the students' mental models need to be known by educators as an initial diagnosis in learning (Chiou, 2013). Mental models are not easy because of the nature of mental models that are tend to be unstable, inconsistent, and always changing as more information is obtained or recalled (McClary & Talanquer, 2011). Mental model developments would gradually become better as the mental models of experts

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in a particular domain (Seel, 2006, Darabi et al, 2009). Therefore, mental models can evolve where to diagnose the development of mental models require eight principles that must be observed (Seelet al, 2008), namely: 1. It is embedded in complex problem situations; 2. It is applied in different subject domains; 3. It allows the construction, modification, and reorganization of mental models; 4. Data collection on mental models is in a longitudinal design; 5. Able to demonstrate the construction of mental models in a row until it was perfect from beginner to expert; 6. Referring to the expert model characteristics; 7. It provides the quantitative data which are valid and reliable; 8. It allows direct methodological analysis and interpretation of data collected.

Eight principles which were established by Seel et al (2008) form the basis for this study. Complex problem to diagnose mental models can be presented in the form of isomorphic problems and longitudinal research design to do several times diagnosis. The material in different situations or contexts that make researchers used varies categories of mental model type (Bao & Warnakulasooriya, 2001, Fazio et al, 2013).

In fact, isomorphic problems are the problem that have different features but use the same physics concepts to solve problems (De Cock, 2012). Isomorphic problems can be presented in several forms of matter. In research by Singh (2008), the isomorphic problems presented in the form of open-ended. The open-ended items have some advantages and disadvantages. The advantages of open-ended instrument can reveal the students' mental models without restricting the expression of the students' thinking way.

The isomorphic problems are given to students through physics learning. The physics subject covers the complex problems to diagnose the students' ability to solve the problem. One of mental models among the items that need to be overcome by the physics students is the concept of the dynamics of rotational motion. The research results suggest that there are some students of various classes with the same difficulties in understanding the concept of rotational motion and the rolling material (Rimoldini & Singh, 2005, Close et al, 2013) . The learning process given to students is oriented to the everyday life problems. There are some researches to identify the mental model using the various instruments (Didişet al, 2014). The methods and instruments are used to achieve the certain results. This study aims to diagnose the development of students' ability in the topic of dynamics of rotational motion using mental models.

METHOD

This study employed a mixed method research design (Cresswell, 2007). The study consisted of two phases which quantitative and qualitative. In the quantitative phase began with the provision of pre-test before learning, intervention with problem-based learning, and post-test after the lesson. Qualitative phase following each stage of the quantitative phase. Qualitative phase was conducted by interview after the pre-test and post-test, as well as the provision of a quiz question in each lesson. The results of the interview can clarify answers written by students. Results of interviews used to support a deeper analysis of the mental model of students' thinking way. Interviews were conducted because not all students could express the answer through written language. The subject of this research was 19 students of class XI IPA at SMAN Jenangan, Ponorogo. Questions used to diagnose mental models in the form of 10 questions with the open-ended isomorphic shaped.

The data analysis was performed by using qualitative and quantitative approaches. The quantitative analysis was performed by counting the percentage of students on each type of mental models in pre-test, quizzes and post-test. The qualitative data was obtained by coding the students' answer to categorize the students in three mental models, i.e High mental model (HMM), Moderate mental model (MMM), and Low Mental Model (LMM). The categorization of dominant mental model was performed by analysis of mental models which were used by students to answer 10 questions. If students used 40% type of mental model in answering 10 questions, then that models are dominating the student's mind. The classification of students in three types of mental models is adapted from the research of Wang & Barrow (2010). Students are categorized as LMM if they get 0-3 points on their mental model characteristics to answer the question. Next, if they get 4-6 point, that means they are classified as LMM. Finally, if the students obtain 7-10 points, they could be use the HMM. Those classifications are set according to the stage and it depends on the analysis of the characteristics of problems solving.

RESULT AND DISCUSSION

The results of the analysis is presented in the form of column-chart as shown in Figure 1. Figure 1 shows the percentage change in the number of students in pre-tests, quizzes, and post-test.

The pre-test result showed 100% students using Low Mental Model to answer questions. After students obtained complete information through learning, Moderate and High mental model were starting to be seen on their answers to the quiz and post-test.

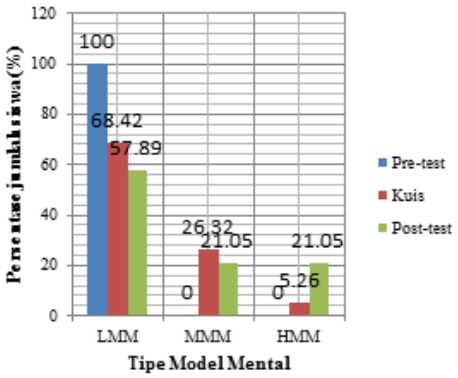
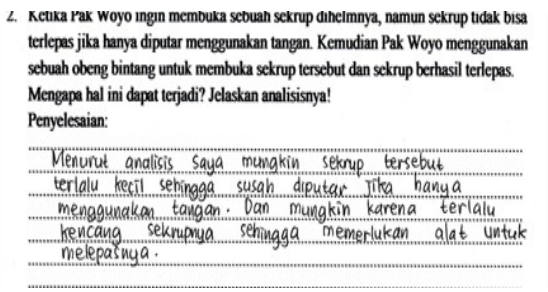


Figure 1. Percentage of Students in Each Type of Mental Model.

Students experienced a gradual development of mental models. This mental model changes were caused by the influence of the information obtained. The nature of mental models of the students tend to be unstable, inconsistent, and it is always changing as more information is obtained or recalled (McClary & Talanquer, 2011). Description of students' mental models is shown as follows.

Low Mental Model (LMM)

The number of students who use the LMM in pre-test was 100%, quizzes was 64.42%, and the post-test was 57.89%. In pre-test, students answered question number 2, 4, 5, 10 using LMM as much as 100%. The response of students in problem solving using LMM is shown in Figure 2.


2. Ketika Pak Woyo ingin membuka sebuah sekrup dinelmnya, namun sekrup tidak bisa terlepas jika hanya diputar menggunakan tangan. Kemudian Pak Woyo menggunakan sebuah obeng bintang untuk membuka sekrup tersebut dan sekrup berhasil terlepas. Mengapa hal ini dapat terjadi? Jelaskan analisisnya!

Penyelesaian:

Menurut analisis saya mungkin sekrup tersebut terlalu kecil sehingga susah diputar jika hanya menggunakan tangan. Dan mungkin karena terlalu kencang sekrupnya sehingga memerlukan alat untuk melepasnya.

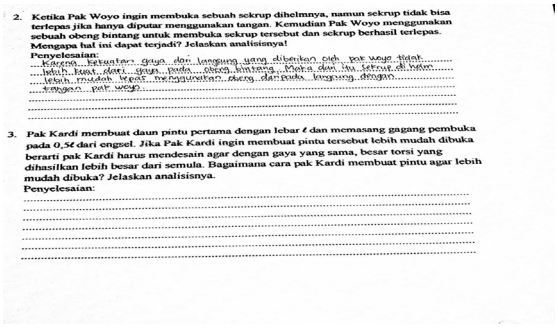
Figure 2. An example of student's answer in the pre-test which is categorized as LMM

Students who used the LMM tend to respond by providing an explanation. However, their explanation was not based on the concept of physics. The explanation given to answer the question were based on the observations or experiences encountered by students everyday. Based on Figure 2, further interview was conducted and the results of interviews with students showed that the student's assumption was based on their experience that has ever happened. When using a screwdriver that fits to the place, it will be easier to detach/attach the screws. The question states that the screwdriver shape is paired. For example, star screwdriver is used to unscrew a hollow star, whereas strip screwdrive is applied to unscrew the strip. The LMM mental models have similar characteristics to the practical mental model of research Fazio et al (2013).

Number of students with LMM on the quiz and post-test were reduced, it was because of students were able to process the information obtained when learning. At LMM stage, it was found that some students had the misconceptions. Misconceptions experienced tend to be resistant because of the student's answers did not change from pre-test to post-test. Misconceptions are resistant in accordance with the finding of Wang (2007) which stated that individual misconceptions and understanding lead to the development of mental models with features that are not true, making the mental models produced will provide feedback erroneous and reinforce misconceptions. Answer of students who have misconceptions can be seen in Figure 3. The misconception experienced by students in line with the results of research Rimoldini & Singh (2005).

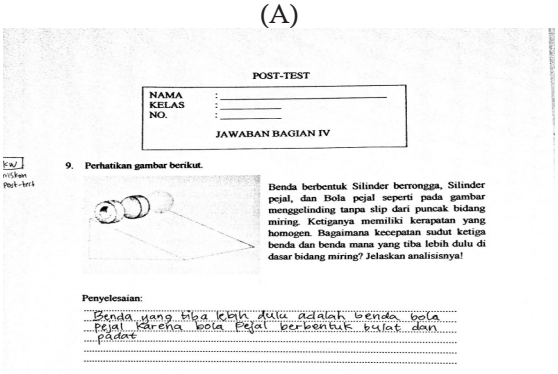
The students' answer as shown in Figure 3 shows that they have not used the moment of force concept to explain the screw rotation. They thought that the force influences the difference on power to open the screw with screwdriver and with hands. They did not know that the screwdriver can form the torque; therefore it influences the moment of force value that can rotate the screw.

The student's answer in Figure 3 indicates that students have misconceptions. The students assumed that the objects can roll faster because of the mass, weight, and shape of the surface of objects. Twelve students in pre-test and two students in post-test showed their assumption that solid ball have the higher mass; therefore, it can roll faster. Moreover, the solid texture influences the ball movement.


2. Ketika Pak Woyo ingin membuka sebuah sekrup dihelmnya, namun sekrup tidak bisa terlepas jika hanya diputar menggunakan tangan. Kemudian Pak Woyo menggunakan sebuah obeng bintang untuk membuka sekrup tersebut dan sekrup berhasil terlepas. Mengapa hal ini dapat terjadi? Jelaskan analisisnya!
Penyelesaian:
Karena kekuatan gaya dan lengan yang diberikan oleh pak woyo tidak lebih besar dari gaya pada obeng karena pada ini terjadi momen lebih mudah untuk menggunakan obeng dari pada langsung dengan tangan pak woyo

3. Pak Kardi membuat daun pintu pertama dengan lebar ℓ dan memasang gagang pembuka pada $0{,}5\ell$ dari engsel. Jika Pak Kardi ingin membuat pintu tersebut lebih mudah dibuka berarti pak Kardi harus mendesain agar dengan gaya yang sama, besar torsi yang dihasilkan lebih besar dari semula. Bagaimana cara pak Kardi membuat pintu agar lebih mudah dibuka? Jelaskan analisisnya.
Penyelesaian:

(A)


POST-TEST

NAMA :
KELAS :
NO. :

JAWABAN BAGIAN IV

9. Perhatikan gambar berikut.

Benda berbentuk Silinder berrongga, Silinder pejal, dan Bola pejal seperti pada gambar menggelinding tanpa slip dari puncak bidang miring. Ketiganya memiliki kerapatan yang homogen. Bagaimana kecepatan sudut ketiga benda dan benda mana yang tiba lebih dulu di dasar bidang miring? Jelaskan analisisnya!

Penyelesaian:
Benda yang tiba lebih dulu adalah benda bola pejal karena bola pejal berbentuk bulat dan padat

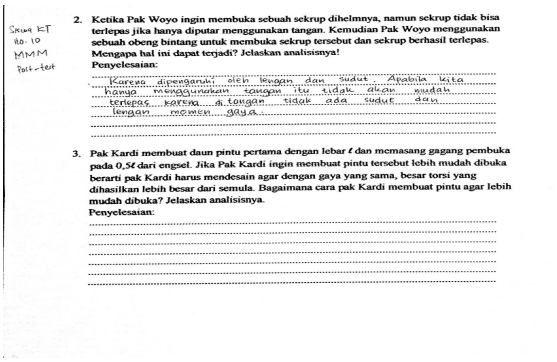
(B)

Figure 3. (a) The student's answers in the misconception on moment of force (b) The student's answer in the misconception on inertia moment.

Moderate mental model (MMM)

The number of students using the type of MMM was 37% in solving the quizzes, and 21.05% when they worked on the problems of post-test. In pre-test, there were no students who predominantly used the MMM to solve problems. The answer of students who used MMM can be seen in Figure 4.

Students who used MMM could analyze the concept, although their analysis on concepts were less precisely. Moreover, other students could use the concept in solving equations. MMM has characteristics that similar to the type of mental models in the descriptive research by Fazio et al (2013).


2. Ketika Pak Woyo ingin membuka sebuah sekrup dihelmnya, namun sekrup tidak bisa terlepas jika hanya diputar menggunakan tangan. Kemudian Pak Woyo menggunakan sebuah obeng bintang untuk membuka sekrup tersebut dan sekrup berhasil terlepas. Mengapa hal ini dapat terjadi? Jelaskan analisisnya!
Penyelesaian:
Karena dipengaruhi oleh lengan dan sudut. Apabila kita hanya menggunakan tangan itu tidak akan mudah terlepas karena a tangan tidak ada sudut dan lengan momen gaya.

3. Pak Kardi membuat daun pintu pertama dengan lebar ℓ dan memasang gagang pembuka pada $0{,}5\ell$ dari engsel. Jika Pak Kardi ingin membuat pintu tersebut lebih mudah dibuka berarti pak Kardi harus mendesain agar dengan gaya yang sama, besar torsi yang dihasilkan lebih besar dari semula. Bagaimana cara pak Kardi membuat pintu agar lebih mudah dibuka? Jelaskan analisisnya.
Penyelesaian:

Figure 4. The students' answers in the post-test with the type of MMM.

The pattern of responses as in Figure 4 illustrates that the student is able to analyze the moment of force but has not been able to connect the influence of moment arm force against force. Students have not been able to link the relationships between concepts, the concept used less precisely.

High Mental Model (HMM)

There was small number of students who were included in this type of HMM in this study. The number of students answered the problem in quiz using HMM was 5.26% and in the post-test was 21.05%. Students who used the HMM to answer the problems in question by providing the correct analysis of the concept, although it has not perfect yet.

The characteristics of HMM type are similar to the type of mental models in expliciative research by Fazio et al (2013). Students who used HMM provided information through interviews where they answered that they can understand the material studied which ranged from 75% -85%. The student's level of understanding on the material affects the mental models built. Seel (2006) stated that the relationship with the conception of mental models such as cause and effect is because of students build a mental model of the concepts, rules, and associations of potential students. The example of the student's answer with high mental model can be seen in Figure 5.

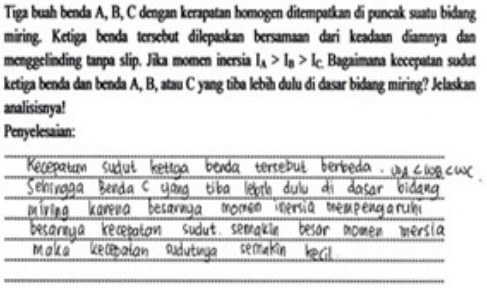

7. Tiga buah benda A, B, C dengan kerapatan homogen ditempatkan di puncak suatu bidang miring. Ketiga benda tersebut dilepaskan bersamaan dari keadaan diamnya dan menggelinding tanpa slip. Jika momen inersia $I_A > I_B > I_C$. Bagaimana kecepatan sudut ketiga benda dan benda A, B, atau C yang tiba lebih dulu di dasar bidang miring? Jelaskan analisisnya!
Penyelesaian:
Kecepatan sudut ketiga benda tersebut berbeda. Sehingga Benda C yang tiba lebih dulu di dasar bidang miring karena besarnya momen inersia mempengaruhi besarnya kecepatan sudut. semakin besar momen inersia maka kecepatan sudutnya semakin kecil

Figure 5. The students' answers in the post-test with HMM.

The pattern of responses as in Figure 5 shows that students can analyze the problem properly, without knowing the value of the moment of inertia of solid ball. The results of the interviews showed that the students said that they can predict that the moment of inertia of the small solid ball. It is because they can memorize the learning material about the moment of inertia of cooked eggs which are smaller than the moment of inertia of raw eggs and also the movement of two different eggs. Students with HMM were able

to connect the observations and the underlying concept.

Mental models of students is experiencing a gradual shift by phase. At the beginning before the learning, students only have Low Mental Model, but after learning there are some students who experience changes in mental models become Moderate or High Mental Models Mental Model. Changes in such mental models is not uncommon. Students' mental models can be developed near the mental model of an expert when it obtained the full information (Seel, 2006, Darabiet al, 2009). Isomorphic to the problem presented can affect students' mental model changes because a student can use different mental models in response to a set of circumstances or issues deemed equivalent by an expert (Fazio et al, 2013).

CONCLUSION

The conclusion of this study is based on the results and discussion as much as two points. First, there are misconceptions in students with mental model of the type Low Mental Model. The student with misconceptions has a Low Mental Model which is a thing that needs to be known by educators in the learning plan. Misconceptions can be reduced by providing learning that focuses on the concept. Second, mental models can evolve gradually into such an experts mental model. Mental model of a person may change because of the nature of mental models are unstable, inconsistent, which is caused by the development of the information obtained. The development of mental models starts from Low to High Mental Models. The development of the low mental model in pre-test can be reduced when resolving the existing problems in the quiz and post-test.

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