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How is students' mental model in the post-pandemic era? Work and Energy Concept Analysis using the Wright Map

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Abstract: Students' mental models are important to be analyzed properly. Mental models are able to be described for students' knowledge and diagnosed students' learning difficulties. This study aims to analyze students' mental models on work and energy concept in the post-pandemic covid-19 era. Students' mental models were measured by four-tier test instrument and analyzed using the wright map. The research study utilizes descriptive-quantitative research method. The participant of this study are 31 K-10 students (13 boys and 18 girls) at high school in the West Java, Indonesia. The data analysis shows that the most student had category of in (51.52%), Sy-D (18.52%), furthermore caterogy Sy-C (13.52%), Sy-B (11.29%), and only less students that had category of Sy-A (2.95%) and Sc (2.2%). It could be concluded that physics learning in forming students' mental models needs to be improvised immediately.

Keywords: Mental Model; Post-pandemic Covid-19 era; Work and Energy; Wright Map.

Introduction

Mental model is a representation of a person's knowledge that acts as a knowledge structure in understanding or explaining a situation or process (Batlolona et al., 2020; Sari et al., 2019). Besides that, mental models also show the ability of students to describe their thoughts on the information observed or obtained so that they can predict and describe their characteristics (Nersessian, 1992). To analyze a person's mental model, it can be done by analyzing their conceptual understanding (Holtrop et al., 2021; McNeil, 2015; Kurnaz & Eksi, 2015). So, the classification of students' mental models in this study were classified into six types, as described in Figure 1.

Mental model can show the structure of knowledge and influence a person's scientific development (Dewi et al., 2021). Thus, information on students' mental models becomes very important to learn in learning process. Learning is an activity to form students' mental models (Graaf, 2020; Eshach et al., 2018). Therefore, the achievement of studends' mental model is influenced by the learning carried out. Learning in secondary schools that is currently happening has undergone many changes. In its development, high school learning in Indonesia takes place offline. However, the implementation of online learning is now becoming increasingly popular in the world of education, especially in the current Covid-19 pandemic situation (Stefanidou et al., 2022).

There are many challenges faced by education in the online learning period. Some of the challenges are lack of communication, difficulty in creating collaborative discussions and limited experience of interaction and collaboration with instructors and their colleagues (Gay & Betts, 2020; Indira & Sakshi, 2017). These conditions can affect student learning outcomes. So to overcome obstacles in learning, in its development, *blended learning* began to be applied, by combining the implementation of online and offline learning both

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synchronously and *asynchronously* (Utami, 2018). The implementation of learning through blended learning is an alternative solution that is currently being implemented in the current post-pandemic Covid-19 era. The occurrence of changes in learning patterns will certainly affect the learning outcomes achieved by students. So, this study aims to analyze students' mental models during blended learning carried out on one of the concepts of physics, namely work and energy.

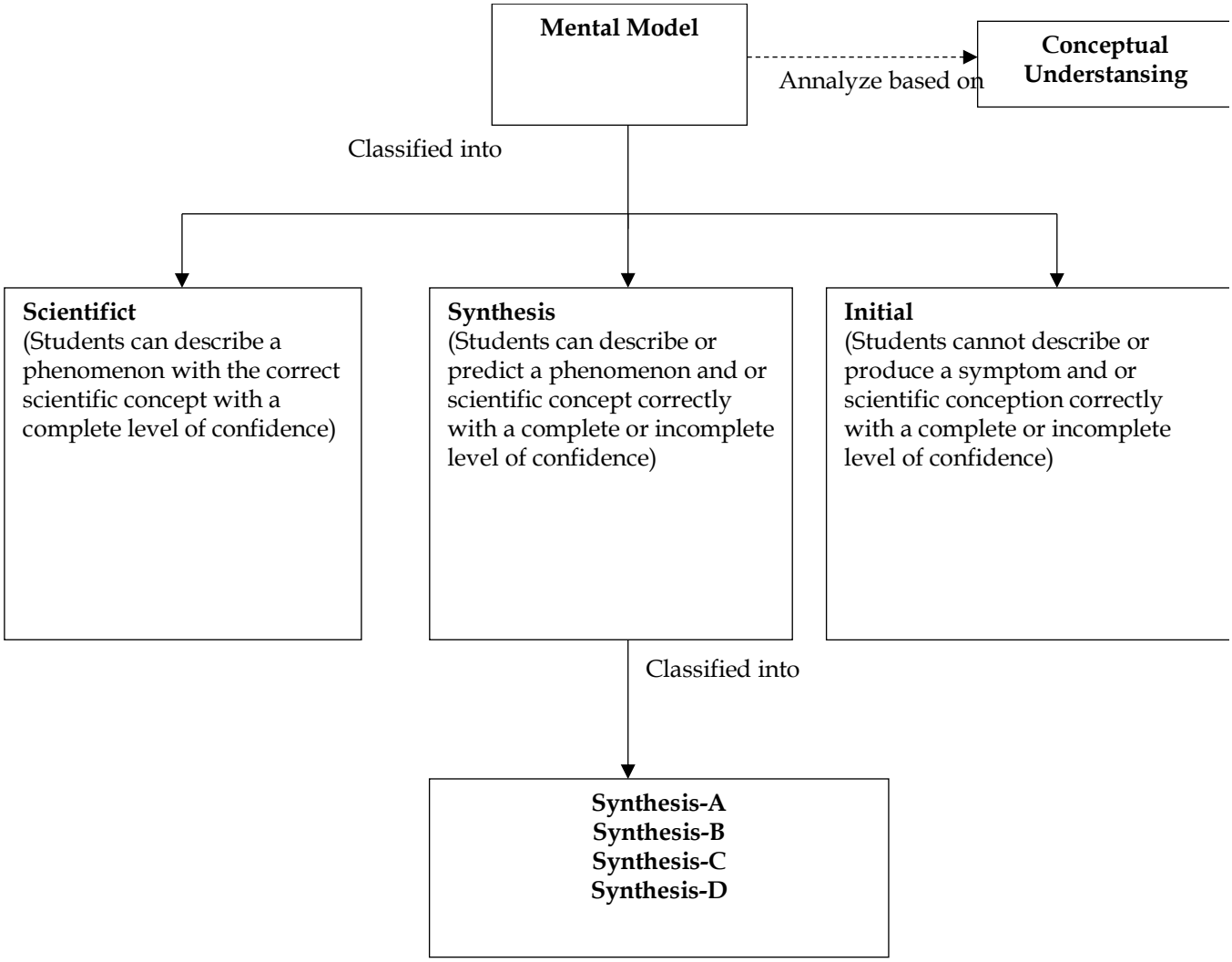
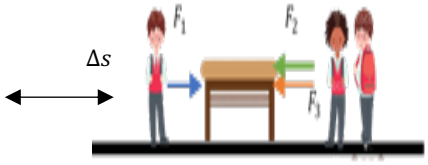
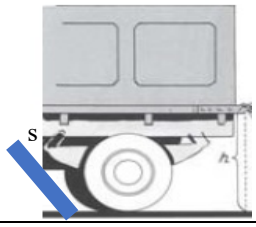


Figure 1. Clasificaion of Students' Mental Model

Work and energy is a fundamental physical concept and is related to daily life (Samsudin, Afif, et al., 2021; Singh & Rosengrant, 2003). The terms of work and energy are often found in daily life. But sometimes, it has a different meaning with the scientific conception. Thus allowing students' mental models to be partial. The existence of these different meanings makes it difficult for students to make associations between the concepts of work and energy and apply them to everyday life problems (Demircioğlu & Selçuk, 2016). There is an initial understanding of the terms work and energy brought by students before class learning is mentioned in several terms, namely pre-conception, naïve concept, material thinking and so on. (Demircioğlu & Selçuk, 2016; Eshach et al., 2018; Jiang et al., 2018). The existence of alternative conceptions can then trigger misconceptions in students. The following picture on Table 1 shows misconceptions on work-energy concept.

Based on Table 1, it shows that students still have various alternative conceptions of the concept of work and energy after learning is done. These conditions cause the mental models obtained by students to be partial. These conditions can affect the achievement of students' mental models on other concepts, because the concept of energy work is a concept that is closely related to other physics concepts (Samsudin, Afif, et al., 2021; Demircioğlu & Selçuk, 2016; Singh & Rosengrant, 2003). So it will be very useful to analyze portraits of students' mental models before and after learning

Table 1. Students' misconceptions on the concept of Work and Energy

Concepts		Misconceptions	Scientific Conception
Positive, negative and zero value of Work		Total work on table system $W_t = W_1 - W_2 - W_3$ Work by a force directed to the left has a negative sign	Work in the direction of displacement is positive.
		The total work on an object of value $W_t = W_{AB} + W_{BC}$ Work on W_{AB} is not zero because there is a displacement.	The work done by a force perpendicular to the displacement is zero.
Work by conserfative force		The work done when lifting an object at a height h differs in value when pushing the object using a path s.	The work done by the conservative force (gravity) is not affected by the path it travels.

In this study, students' mental models were analyzed using the Wright map. Wright map is an analysis of the Rasch model that used to analyze the interaction between item test and respondent (Hikmah et al., 2021). The results on the Wright Map can provide information on the distribution of students' abilities, information on the difficulty of test items, as well as the interaction between students' abilities and the level of difficulty of the questions (Dewi et al., 2021; Hikmah et al., 2021). This study aims to obtain a picture of the mental model of students on the concept of work and energy which was analyzed using the Wright map.

Method

Design

The research method used is descriptive quantitative. Descriptive-quantitative is a research method that describes a phenomenon based on the results of data obtained quantitatively (Dewi et al., 2019). The following Figure 2 shows a sketch of the research method used to analyze students' mental models.

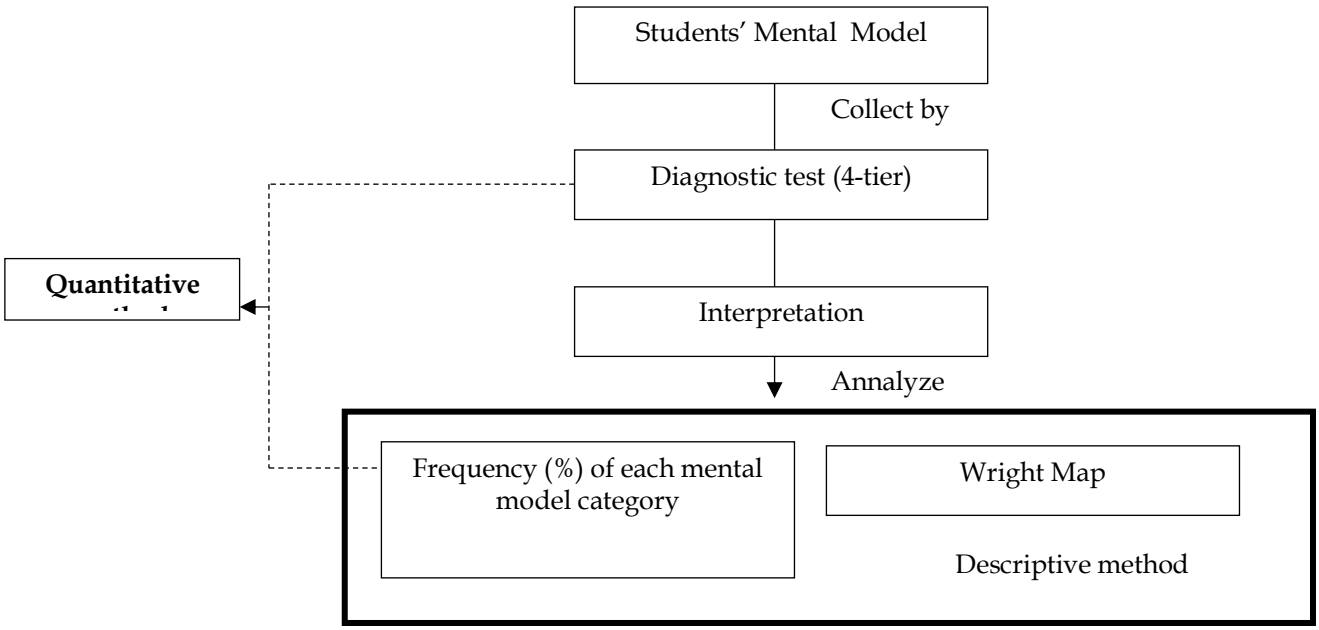


Figure 2. Descriptive-quantitaive Reseach method

Based on Figure 2, this study aims to obtain an overview of students' mental models during the post-pandemic Covid 19 learning period. Data on students' mental models were obtained using an instrument test, then obtained the percentage of each type of mental model. The results of the mental model were analyzed descriptively using analysis on the Wright Map. The method used is descriptive-quantitative.

Participant

The participants in this study were 31 K-10 students (13 boys, 18 girls) in the age range of 15-16 years, and came from several schools in West Java. Therefore students come from various environments, learning habits, regions, family and economic backgrounds. However, all students come from the Sundanese ethnic (Sundanese language and culture). The following Figure 3 shows the distribution of participants in this study.

Figure 3. The distribution of research participants

Instrument

The instrument utilized to obtain information on students' metal models in this study was the Work and Energy four-tier diagnostic test. The instruments used have been tested and validated by experts. The following Table 2 shows the results of the validation test on the instruments used.

Table 2. *Four-tier* Instrument Test Validation Value (*Rasch Model* Analysis)

Raw variance explained by measures	Interpretation	Unexplained variance 1st contrast		Interpretation	Summary
		Eigen	Observed		
32.9%	fulfilled	1.9836	14.2%	fulfilled	Valid

While the reliability of the instrument shows a cronbach alpha value of 0.75, has a "good" interpretation. The instrument consists of 14 test items presented in four-tier form. The following is Table 3 which shows the distribution of concepts on the instruments used.

Students do the test within 45 minutes (1 lesson hour) online on the google-form as shown in Figure 4. Each item consists of four levels (Samsudin et al., 2021, Afif, et al., 2021; Dewi et al., 2021; Dewi et al., 2019). Tier-1 is a problem, symptom or physical phenomenon developed from multiple choice of work and energy concepts (Singh & Rosengrant, 2003) and consists of five answer choices and has only one correct answer. While tier-2 is the level of confidence in students' answers to tier-1. Tier-3 is the choice of students' reasons for answering in tier-1, at this tier it can have several correct answers and some research also presents in the form of open-ended questions. The last tier is the level of student confidence in the reasons chosen in tier-3. The level of confidence is a statement about students' beliefs about the answers they have chosen and two answer choices are presented, namely "Sure" and "Not sure".

Table 3. The distribution of Concepts on four-tier Instruments

Concept	Sub Concept	Item Number
Work	Work definition	T01
	Zero value of Work	T10
	Positive and negative Work	T02
	Work by conserfative force	T06, T12
Energy	Potential Energy	T03
	Kinetic Energy	T08
	Mechanical energy conservation law	T04, T05, T11
Work-energy theorm	The relationship between work and potential energy	T09
	The relationship between work and kinetic energy	T07
Power Concept	Aplication of power concept	T13, T14

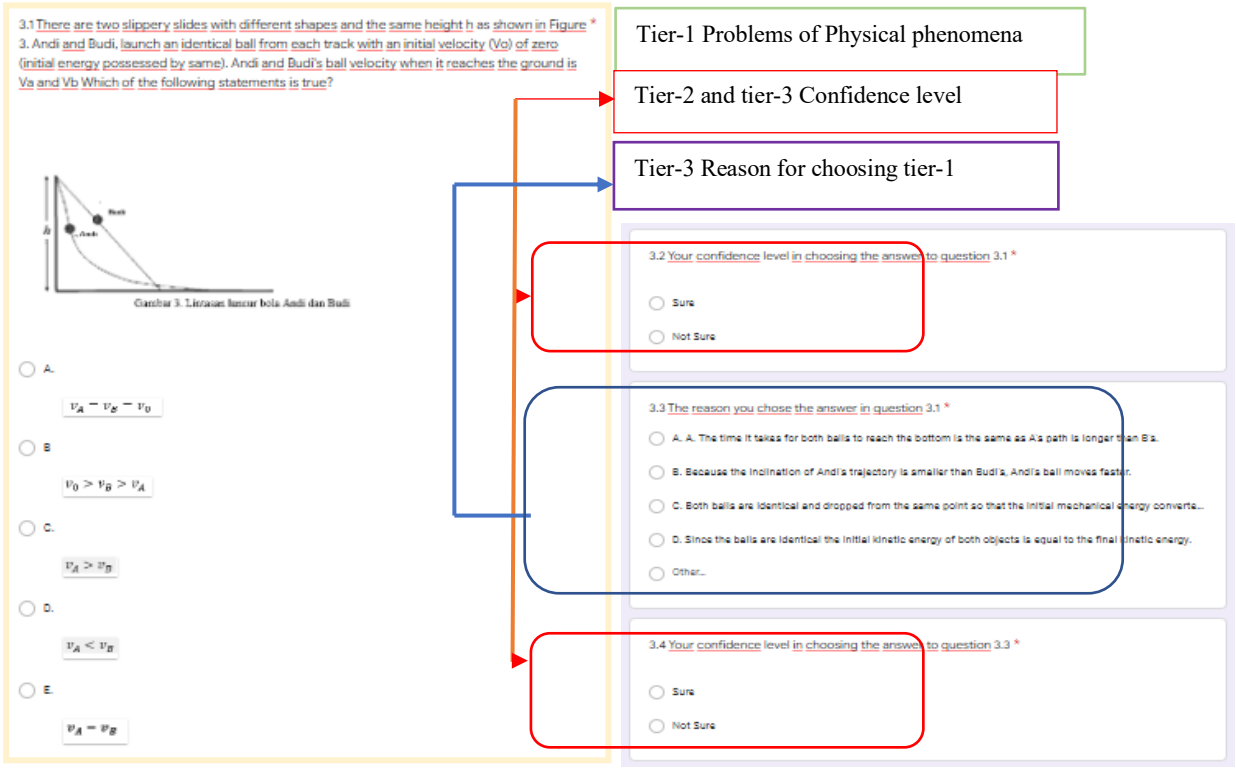


Figure 4. The Example Questions on Instruments Work and Energy Four-tier Diagnostic Test

Table 4. The combination of students' answer and classification of students' mental model

	Students' Answer														
Tier-1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Tier-2	Y	Y	TY	TY	Y	Y	TY	TY	Y	Y	TY	TY	Y	Y	TY
Tier-3	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0
Tier-4	Y	TY	Y	TY	Y	TY	Y	TY	Y	TY	Y	TY	Y	TY	Y
Model Mental	Sc			Sy-A				Sy-B				Sy-C	Sy-D		In

Explanation:
1: Correct Answer 0: Wrong Answer Y: Sure TY: Not Sure

Students' answers to the questions given are then analyzed to obtain the category of students' mental models with the following answer rubric (Dewi et al., 2021; Samsudin et al., 2021; Afif, et al., 2021).

Data Analysis

Students' mental model data were analyzed using a wight map to find out the distribution of students' abilities in general, namely students with high, medium and low mental model abilities (Dewi et al., 2021; Samsudin et al., 2021; Cahyani, et al., 2021). To get a description of students' abilities through the wright map, a scoring technique was used for each type of student mental model. The *scientifict* mental model has a score of 5, *synthesis-A* has a score of 3, *synthesis-B* and *synhesis-C* have a score of 1 while 0 for *synthesis-D* and *initial* types (Dewi et al., 2021). Furthermore, the scoring data of the students' mental models were analyzed using Winstep 4.8.0.0 software to obtain an overview of the Wright Map.

$$Students' mental\ model\ (\%) = \frac{Total\ number\ of\ students\ in\ one\ category}{(total\ students\ x\ number\ of\ questions)} x100 \quad (1)$$

The percentage of students' mental models were analyzed for each concept to obtain information on the distribution of concepts understood by students. Also analyzed as a whole to obtain general information on the condition of students' mental models on the concept of work and energy (Dewi et al., 2021).

Result and Discussion

In this study, a general analysis was conducted of students' mental models on the concept of work and energy. The results obtained based on data that have been processed using Winstep 4.8.0.0 are shown in Figure 5. Based on Figure 5, it shows that most of the students are in the "medium ability/mental model"

with a total of 22 students labeled *Cluster I*. Then 9 students who are in the "low ability" level are labeled *Cluster II*. Meanwhile, there are no students who have "high ability/mental model" and there is one S05L student with an *outlier position*. Outlier position indicates that students are outside the limit of two standard deviations (T). This indicates that the instrument used is too difficult for S05L students.

Students who have the same logit value position as the test item have a 1:1 chance of answering the question correctly (24). Thus, it can be ascertained that most students already have an understanding of the definition of zero work and the concept of power in questions T10 and T14. As for other concepts (T01-T05, T07-T09, and T11-T13) some students have the possibility of having a partial mental model type. However, in the concept of effort by conservative style (T06), no student can answer the questions correctly in full.

In general students' understanding can be partial or complete. Students' mental model will be analyzed more with the percentage of students' mental models for each concept in Table 5. Based on Table 5, it shows that most students in *Cluster I* have a complete mental model (*Sc* and *Sy-A*) on the concept of power with a percentage of 15.91%, while in the concept of the work-energy theorem most have a partial mental model *(Sy-B* and *Sy-C)* with a percentage of 52.28%. Then for the category of *initial* mental model and *Sy-D* has a total percentage of 69.09% on the concept of energy. Overall, these conditions are in accordance with the analysis on the Wright Map that most students already have a complete or partial understanding of the concept of power (T14). The information in Table 5 also shows that the mental models that dominate in all students are *Sy-D* and *in* types. However, it can also be compared that students in *cluster I* have the lowest percentage of mental model types *Sy-D, In* and partial (*Sy-B, Sy-C*) compared to *cluster II* and *outlier position*. This is consistent with the analysis on the Wright Map that students in *cluster I* have a higher mental model.

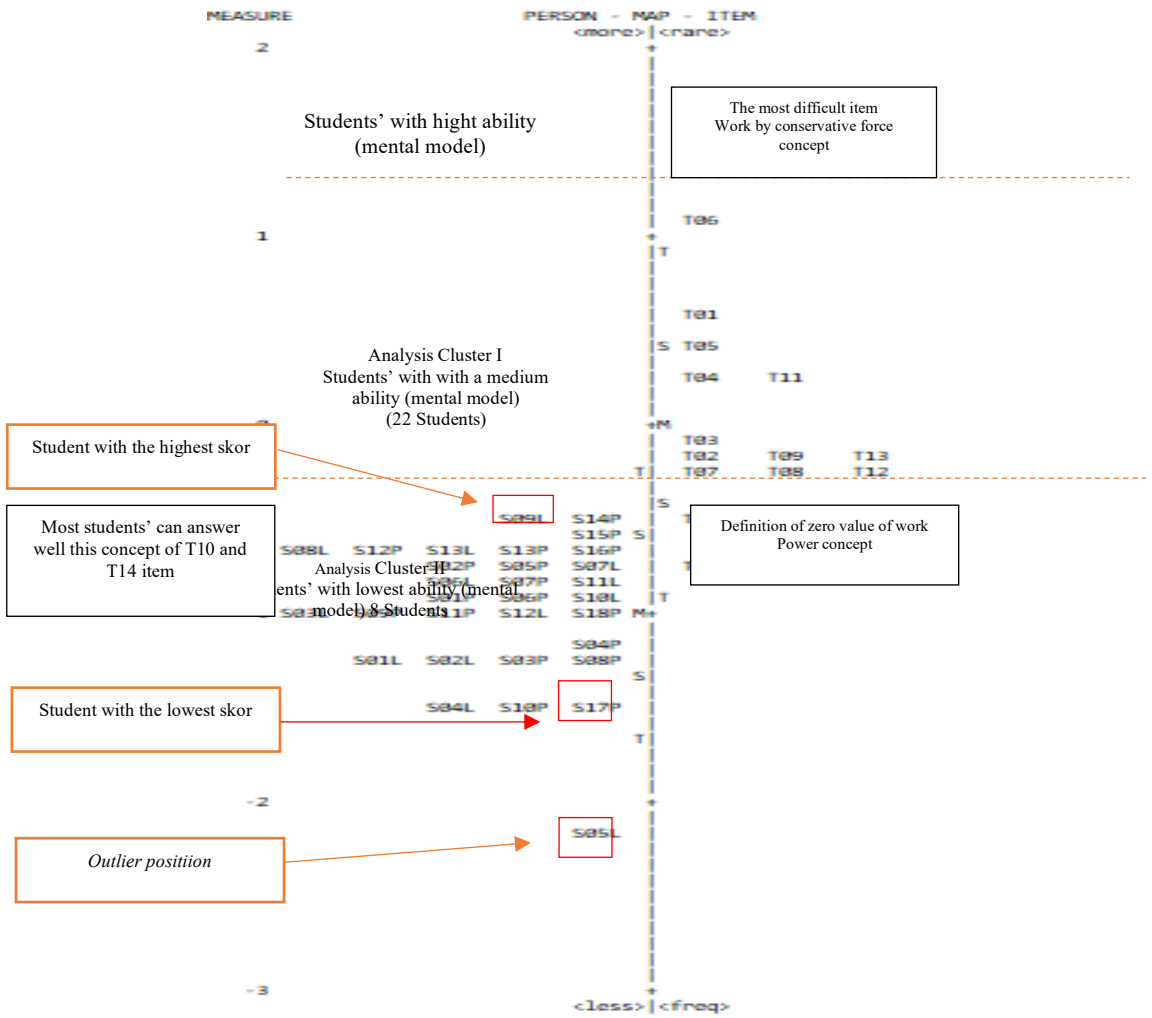


Figure 5. Wirght Map (Item-person) analysis

Table 5. Percentage of Mental Model Category in Each Concept in each Cluster

Cluster analysis	Mental Model	Work	Energy	Work-Energy Theorm	Power Concept	Summary (%)
Cluster I	In	25.45	29.09	13.64	25.00	23.30
	Sy-D	36.36	40.00	27.27	13.64	29.32
	Sy-C	7.27	11.82	38.64	29.55	21.82
	Sy-B	2.82	9.09	13.64	15.91	15.11
	Sy-A	4.55	6.36	2.27	2.27	3.86
	Sc	4.55	3.64	4.55	13.64	6.59
Cluster II	In	35	50	30	50	41.25
	Sy-D	30	32.5	30	12.5	26.25
	Sy-C	7.5	2.5	20	25	13.75
	Sy-B	27.5	12.5	15	0	13.75
	Sy-A	0	2.5	5	12.5	5.00
	Sc	0	0	0	0	0.00
Outlier position	In	80	80	100	100	85.71
	Sy-D	0	0	0	0	0.00
	Sy-C	0	20	0	0	7.14
	Sy-B	20	0	0	0	7.14
	Sy-A	0	0	0	0	0.00
	Sc	0	0	0	0	0.00

From the Table 5 also we can analyze that students have the most dominant difficulty in understanding the concept of energy as indicated by the total percentage of *In* and *Sy-D* that shown on the red line on the Table 5. As shown in previous research, the level of students' misconceptions about energy concepts and the law of energy conservation is still high (Samsudin, Cahyani, et al., 2021). While the types of partial mental models *(Sy-C* and *Sy-B)* most dominate the concept of the work-energy theorem. And the type of mental model *Sc* and *Sy-A* mostly on the concept of power as shown with blue line on the Table 5. Meanwhile, overall it can be concluded that in average students' mental models are still dominated by *In* type (51.52%), *Sy-D* (18.52%), *Sy-C* (13.52%), *Sy-B* (11.29 %), *Sy-A* (2.95%) and *Sc* (2.2%). This is in accordance with research by Pramesti et al. (2020) that students still cannot fully understand the concept of work and energy and their application in physical phenomena or phenomena that occur in the surrounding environment. Based on the results obtained, physics learning can be carried out both offline, online, or blended, so that it can be designed to support conceptual change so as to support the formation of mental models. As with previous research, presenting active, factual learning and activities that can compare prior knowledge with scientific conceptions can support the formation of a more optimal mental model (Hermita, 2017; Jiang et al., 2018; Syuhendri, 2017; Graaf, 2020).

Conclusion

This study aims to obtain an overview of students' mental models on the concept of work-energy in the post-pandemic Covid-19 era. The concept of work-energy is a fundamental concept and is related to daily life. This causes students to have different *prior knowledge* when learning begins and will affect the process of absorbing new information through learning. So it is important to analyze students' mental models on the concept of work-energy. Based on the information obtained, it shows that most of the students' mental models are still dominated by the *In* type (51.52%), *Sy-D* (18.52%), some are partial, indicated by the *Sy-C* (13.52%), *Sy -B* (11.29%), and only a small proportion have *Sy-A* (2.95%) and *Sc* (2.2%). Based on these results, it shows that learning in the post-pandemic Covid-19 period still needs attention and innovation, especially in conveying concepts to students.

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