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EDUSAINS,11 (2), 2019, 156-162

Research Artikel

THE DEVELOPMENT OF MENTAL MODELS TEST ON HEAT AND TEMPERATURE

PENGEMBANGAN INSTRUMEN MODEL MENTAL PADA TOPIK SUHU DAN KALOR

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Abstrak

Kami telah mengembangkan tes sebagai analisis model mental pada materi suhu dan kalor. Penelitian pengembangan ini didasarkan pada pentingnya mengetahui tingkatan model mental siswa. Model mental merupakan representasi internal siswa dalam memahami sebuah konsep. Penelitian ini menggunakan model pengembangan 4-D. Produk yang dihasilkan merupakan instrumen analisis model mental berupa soal terbuka. Selanjutnya, instrumen tes model mental diujicobakan kepada responden (N=90) untuk mengukur validitas dan reliabilitas. Tes yang telah dikembangkan terdiri dari 8 soal dengan reliabilitas sebesar 0,667. Berdasarkan analisis data, instrumen tes model mental pada materi suhu dan kalor layak digunakan sebagai instrumen penilaian.

Kata Kunci: *model mental; penilaian; suhu; kalor*

Abstract

We have developed test inventory as an analysis of mental models on heat and temperature topics. This development research based on the importance of knowing the level of students' mental models. The mental models are a student's internal representation of understanding a concept. This study uses a 4-D model. The product being produced is a mental model analysis consists of open-ended questions. Furthermore, mental models test were tested on respondents (N = 90) to measure the validity and reliability. The test that has been developed consists of 8 questions with a value of reliability is 0.667. Based on data analysis, the test of mental models on heat and temperature topics is feasible to use as an assessment instrument.

Keywords: mental models; assessment; heat; temperature

***Permalink/*DOI:** http://doi.org/10.15408/es.v11i2.10332

INTRODUCTION

Physics is one of the lessons in a secondary school which has many concepts. Physics concepts can be understood through two dimensions of knowledge that is macroscopic and microscopic dimensions (Kantarinata *et al*., 2017). The macroscopic dimension used to understand the physics concepts through daily experience and can be observed directly (Kurnaz & Emen, 2014; Priyadi *et al*., 2019). The microscopic dimension used to understand physics concepts based on smaller views, for example, interactions between molecules, energy flows, waves, and others (Amrizaldi *et al*., 2014; Jansoon *et al.*, 2009; Kurnaz & Emen, 2014).

Students' understanding of the microscopic dimension can assist them in understanding the concept of physics-based on the macroscopic dimension (Albaiti *et al.*, 2016; Priyadi *et al*., 2018). One topic of physics that requires understanding in the microscopic dimension is heat and temperature (Amrizaldi *et al.*, 2014; Kantarinata *et al.*, 2017). This is because heat and temperature topics can be studied through daily life phenomena (Amalia *et al*., 2017; Chu *et al.*, 2012), for example, expansion and heat transfer phenomenon. Through the microscopic dimension, students can understand the occurrence of this phenomenon through physics concepts.

Students' understanding of these two dimensions will affect the way students think about physics concepts, especially in heat and temperature. Students who can understand both dimensions will find it easy to solve physics problems related to phenomena that occur (Chermack *et al.*, 2012; Jansoon *et al.*, 2009; Priyadi *et al.*, 2018). The ability of students to solve any given problems determines the level of mental models they have.

The mental model is a unique internal representation that is owned by each student. Mental models are also used to construct their experiences to be more meaningful (Chermack *et al.*, 2012; Hendriani & Suhandi, 2017; Kara & Ertürk, 2015), and to understand their minds to construct new knowledge (Busselle, 2017; Fazio *et al.*, 2013; Garcia-Nunes *et al.*, 2017; Rook, 2013; Schmidtke & Cummings, 2017). Mental models become one of the cognitive abilities that must be trained in learning (Chiou, 2013; DeChurch & Mesmer-Magnus, 2010; Didiş *et al.*, 2014; Van den Bossche *et al.*, 2011).

Initially, research on mental models was the research in the cognitive psychology field. This research was conducted to study how students learn, remember (Rook, 2013; Sternberg, 2009), think (Shute *et al.*, 2009), and to know systematic explanations (Pitt, 2017). Based on this description, Mental models can be applied to evaluate students' level of understanding of physics concepts (Corpuz & Rebello, 2011; Didiş *et al*., 2014; Rahayu & Purwanto, 2013).

Information about the level of students' mental models can be known through assessment. For example, assessment on how students' ability to explain the state of atoms when expansion occurs (Kurnaz & Emen, 2014). Assessment of mental models through interviews, linguistic analysis, or open-ended questions (Corpuz & Rebello, 2011; Johnson-Laird, 2013).

The students' answer becomes a reference to determine the level of mental models they have. There are many methods for determining the level of students mental models, i.e., ACSMM, MITOCAR, SMD, DEEP, SSI, and PDE (Al-Diban & Ifenthaler, 2011; Johnson et al., 2006; Langan-Fox, Code, & Langfield-Smith, 2000; Priyadi *et al*., 2018).

Nowadays, mental model research has progressed and is a major attraction for researchers to understand how students think. However, the availability of model mental tests is still difficult to find, if mental models test is available, it will help educators and other researchers to access students' mental models. Based on the problems, this study aims to produce mental model tests, especially on heat and temperature.

METHOD

This study is a development research that produces mental models test and used the 4-D

model (Tiagarajan *et al.*, 1974). The step carried out in each 4-D stage are presented in Table 1.

Table 1. Steps of 4D Models

4-D Model	Developmental Steps
Define	Preliminary studies to checked the availability of mental models test inventory.
Design	a. Analyze the Competencies and indicators of heat and temperature topics. b. Produce a draft question consisting of open-ended questions.
Develop	a. Conduct construct validity (by working on questions that have been designed for physics education students at State Universitas Negeri Malang as subject research). b. Analyze the validity of questions items using product-moment correlation. c. Analyze the reliability using Cronbach's alpha coefficient.
Disseminate	a. Implementation questions that have been developed to measure students' mental models. b. Use two classes at state senior high school 4 of Malang as subject research.

RESULT AND DISCUSSION

Define

Based on preliminary analysis, it is still difficult to find tests of mental models in physics, especially on heat and temperature. The limitations of mental model tests on the topic of physics are the main reason for developing mental model tests. The availability of many mental model tests will help educators and other researchers to explore mental models possessed by students.

Design

In this step, we analyze the competencies of heat and temperature in mathematics and science classes in senior high school. Furthermore, from the competency analysis, four indicators must be achieved during learning. Competencies and indicators are present in Table 2.

Table 2. Competencies and Indicators

Competencies	Indicators
Analyze the effects of heat transfer, including the thermal characteristics of a material, capacity, and heat conductivity in daily life	1. Analyze the temperature changes towards the expansion of the object. 2. Analyze the effect of heat on temperature and phase changes of an object. 3. Apply the Black Principle 4. Analyze the amount of heat received and released in mixing two objects with different temperatures. 5. Explain the heat transfer concept (conduction, convection, and radiation).

Develop

Based on the indicators in Table 2. Mental model tests were developed as open-ended questions. Each question consists of three items that are useful for classifying students' mental models. One example of a developed mental model test presented in Table 2.

Table 2. Examples of Mental Models Test

Problem Description	Questions
A carpenter is making a wooden window with the middle in the form of glass. The part between wood and glass gave a gap.	a. What is the use of making this separation gap? b. Explain how the event occurred! c. Visualization of the condition of glass molecules at night and day!

After the questions were developed, a trial was then conducted on 90 respondents to see the validity and reliability of the test. Based on data analysis, the results of the validity and reliability of the mental models' test are presented in Table 3.

Table 3. The Results of Validity and Reliability

No	Validity		Reliability	
	Correlation	Criteria	Value	Criteria
1	0.438	Valid	0.667	High
2	0.602	Valid		Criteria
3	0.359	Valid		
4	0.335	Valid		
5	0.313	Valid		
6	0.370	Valid		
7	0.457	Valid		
8	0.330	Valid		

Disseminate

The developed test is then implemented to determine the level of student's mental models. To determine the level of students' mental models, the method used is SSI. There are three levels of mental models, i.e., scientific, synthetic, and initial.

The mental model level is categorized using rubrics, which are divided into two rubrics, i.e., descriptions analyze rubric and visuals analyze rubric. The descriptions analyze rubric is present in

Table 4, and the visuals analyze rubric is present in Table 5.

Tabel 4. Descriptions Analyze Rubric

Levels	Criteria
Sound Understanding (SU)	The answer contains all scientific response components.
Partial Understanding (PU)	The answer contains half the response component.
Partial Understanding with Alternative Conception (PU-AC)	Answers like to PU level, but other concepts are not appropriate.
Alternative Conception (AC)	The answer is scientifically wrong and contains incorrect.
No Understanding (NU)	Not answer.

Source: Kurnaz & Eksi (2015)

Table 5. Visuals Answer Evaluation Rubric

Levels	Criteria
Correct Depicting (CD)	Answers reflect all components of scientific description.
Partial Correct Depicting (PCD)	Answers reflect half the components of scientific description.
Correct Drawing also reflecting Non-scientific Depicting (CD-ND)	Answers like to the PCD level, but some descriptions are not appropriate or not scientifically accepted.
Incorrect Depicting (ID)	The answer reflects a description that is not scientific.
No Depicting (ND)	Not answer.

Source: Kurnaz & Eksi (2015)

After analyzing students' answers, they are classified according to the level of mental models (scientific, synthetic, or initial) presented in Table 6.

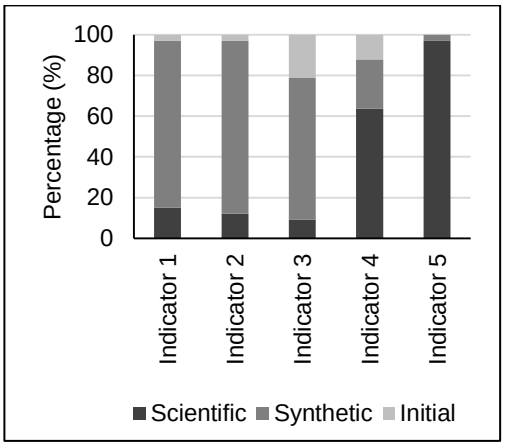
Tabel 6. Levels of Mental Models

Levels	Criteria
Scientific	The perception that coincides with PU or PCD / SU or CD.
Synthetic	The perception which is partially located or not by knowledge
Initial	The perception that is not by knowledge. Answers are at NU or ND / AC or ID / PU-AC or CD-ND.

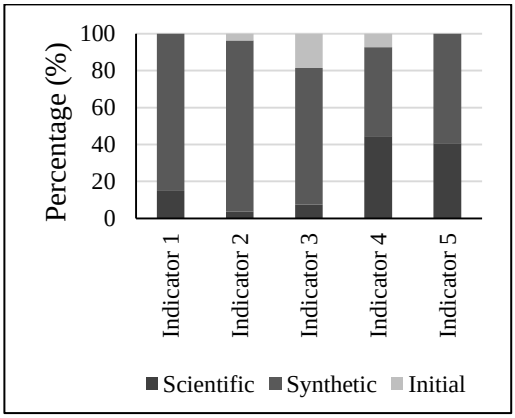
Source: Kurnaz & Eksi (2015)

The scientific level that describes students thinking scientifically on each concept is that they can relate the phenomenon to an appropriate concept. The synthetic level describes that students are not consistent in using concepts. Sometimes, they use concepts that are not relevant when solving problems. The initial level that describes students unable to connect phenomena that arise with an actual concept (Abraham *et al*., 1994; Kurnaz & Eksi, 2015).

The research subjects in this step are 11th-grade students of mathematics and science in-state senior high school 4 of Malang, consisting of two classes. The use of two classes aims to assess the accuracy of developed mental model tests. The accuracy of mental models test in each class based on indicators is present in Figure 2.



(Class A)



(Class B)

Figure 2. Accuracy of Mental Models Test Based on Indicators in Class A and Class B

Figure 2 explains that dominant students have mental models at the synthetic level on indicators 1, 2, and 3 in each class. Whereas indicators numbers 4 and 5 show different results, the majority of students in class A are at a scientific level and class B is at a synthetic level. Therefore, the test instruments that have been produced can distinguish the level of students' mental models.

CONCLUSION

Test instruments have been developed as an analysis of students' mental models on heat and temperature topic. The test consisted of 8 items of mental models that were valid and had a value of reliability is 0.667. Based on the results, it was concluded that mental model tests on heat and temperature were suitable for use as analyzes of students' mental models. Future studies are expected to develop a mental model tests on other physics concepts.

REFERENCES

Abraham, M. R., Williamson, V. M., & Westbrook, S. L. 1994. A Cross-Age Study of The Understanding of Five Chemistry Concepts. *Journal of Research in Science Teaching*, *31*(2), 147–165.

Al-Diban, S., & Ifenthaler, D. 2011. Comparison of Two Analysis Approaches for Measuring Externalized Mental Models. *International Forum of Educational Technology & Society*, *14*(2), 16–30.

Albaiti, Liliasari, & Sumarna, O. 2016. The Study of Mental Model on N-Hexane-Methanol Binary System (The Validation of Physical Chemistry Practicum Procedure). *Jurnal Pendidikan IPA Indonesia*, *5*(1), 6–13.

Amalia, R., Sari, I. M., & Sinaga, P. 2017. Students' Mental Model on Heat Convection Concept and its Relation With Students Conception on Heat and Temperature. In *Journal of Physics: Conference Series* (Vol. 812, p. 012092).

Amrizaldi, Diantoro, M., & Wartono. 2014 Pengembangan Tes Diagnosis Untuk Memetakan Model Mental Siswa Kelas X SMA/MAN Materi Suhu dan Kalor. In *Prosiding Seminar Nasional Fisika* (pp. 27–31). Jakarta: Universitas Negeri Jakarta.

Busselle, R. 2017. Schema Theory and Mental Models. In *The International Encyclopedia of Media Effects* (pp. 1–8). Hoboken, NJ, USA: John Wiley & Sons, Inc.

Chermack, T. J., Song, J. H., Nimon, K., Choi, M., & Korte, R. F. 2012. The Development and Assessment of an Instrument for Measuring Mental Model Styles in Korea. *Learning and Performance Quarterly*, *1*(1), 1–20.

Chiou, G.-L. 2013. Reappraising the Relationships Between Physics Students' Mental Models and Predictions: An Example of Heat Convection. *Physical Review Special Topics - Physics Education Research*, *9*(1), 010119.

Chu, H.-E., Treagust, D. F., Yeo, S., & Zadnik, M. 2012. Evaluation of Students' Understanding of Thermal Concepts in Everyday Contexts. *International Journal of Science Education*, *34*(10), 1509–1534.

Corpuz, E. D., & Rebello, N. S. 2011. Investigating Students' Mental Models and Knowledge Construction of Microscopic Friction. II. Implications for Curriculum Design and Development. *Physical Review Special Topics - Physics Education Research*, *7*, 020103.

DeChurch, L. A., & Mesmer-Magnus, J. R. 2010. Measuring Shared Team Mental Models: A Meta-Analysis. *Group Dynamics: Theory, Research, and Practice*, *14*(1), 1–14.

Didiş, N., Eryılmaz, A., & Erkoç, Ş. 2014. Investigating Students' Mental Models About The Quantization of Light, Energy, and Angular Momentum. *Physical Review Special Topics - Physics Education Research*, *10*(2), 020127.

Fazio, C., Battaglia, O. R., & Di Paola, B. 2013. Investigating The Quality of Mental Models Deployed by Undergraduate Engineering Students in Creating Explanations: The Case of Thermally Activated Phenomena. *Physical Review Special Topics - Physics Education Research*, *9*(020101), 1–21.

Garcia-Nunes, P. I., Souza, R. M., & da Silva, A. E. A. 2017. Mental Models Analysis and Comparison Based on Fuzzy Rules: A Case Study of the Protests of June and July 2013 in Brazil. *IEEE Transactions on Systems,*

Man, and Cybernetics: Systems, *47*(8), 2021–2033.

Hendriani, S., & Suhandi, A. 2017. An Identification of Students ' Mental Model On Heat Convection Associated with the Implemented of Learning Model. In *4th ICRIEMS Proceedings* (pp. 77–82). Yogyakarta: Yogyakarta State University.

Jansoon, N., Coll, R. K., & Somsook, E. 2009. Understanding Mental Models of Dilution in Thai Students. *International Journal of Environmental and Science Education*, *4*(2), 147–168.

Johnson-Laird, P. N. 2013. Mental Models and Cognitive Change. *Journal of Cognitive Psychology*, *25*(2), 131–138.

Johnson, T. E., O'Connor, D. L., Pirnay-Dummer, P. N., Ifenthaler, D., Spector, J. M., & Seel, N. M. 2006. Comparative Study of Mental Model Research Methods: Relationships Among ACSMM, SMD, MITOCAR & DEEP Methodologies. In *Proc. of the Second Int. Conference on Concept Mapping.* (Vol. 1, pp. 87–94). San José, Costa Rica.

Kantarinata, D., Yuliati, L., & Mufti, N. 2017. Identifikasi Model Mental Siswa pada Materi Suhu dan Kalor. In *Pros. Seminar Pend. IPA Pascasarjana UM* (Vol. 2, pp. 161–165). Malang: Universitas Negeri Malang.

Kara, S. B. K., & Ertürk, A. 2015. Mental Models of the School Principals on Leadership. *Procedia - Social and Behavioral Sciences*, *174*, 2145–2152.

Kurnaz, M. A., & Eksi, C. 2015. An Analysis of High School Students' Mental Models of Solid Friction in Physics. *Educational Sciences: Theory & Practice*, *15*(3), 787–795.

Kurnaz, M. A., & Emen, A. Y. 2014. Student Mental Models Related to Expansion and Contraction. *Acta Didactica Napocensia*, *7*(1), 59–67.

Langan-Fox, J., Code, S., & Langfield-Smith, K. 2000. Team Mental Models: Techniques, Methods, and Analytic Approaches. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *42*(2), 242–271.

Pitt, D. 2017. Mental Representation. In *Stanford Encyclopedia of Philosophy* (Spring 201). Stanford University: Metaphysics Research Lab.

Priyadi, R., Diantoro, M., & Parno. 2018. Kajian Literatur: Model Mental dan Metode Evaluasinya. *Jurnal Pendidikan Sains*, *06*(02), 70–75.

Priyadi, R., Suryanti, K., & Varela, L. 2019. Profil Model Pemahaman Peserta Didik pada Topik Suhu dan Kalor: Studi Lintas Pendidikan. *Jurnal Penelitian Pembelajaran Fisika*, *10*(1).

Rahayu, S., & Purwanto, J. 2013. Identifikasi Model Mental Siswa SMA Kelas X pada Materi Hukum Newton tentang Gerak. *Kaunia: Integration and Interconnection Islam and Science*, *IX*(2), 12–20.

Rook, L. 2013. Mental Models: A Robust Definition. *The Learning Organization*, *20* (1), 38–47.

Schmidtke, J. M., & Cummings, A. 2017. The Effects of Virtualness on Teamwork Behavioral Components: The Role of Shared Mental Models. *Human Resource Management Review*, *27*(4), 660–677.

Shute, V. J., Jeong, A. C., Spector, J. M., Seel, N. M., & Johnson, T. E. 2009. Model-Based Methods for Assessment, Learning, and Instruction: Innovative Educational Technology at Florida State University. In M. Orey, V. J. McClendon, & R. M. Branch (Eds.), *Educational Media and Technology Yearbook* (Vol. 34, pp. 61–79). Boston, MA: Springer US.

Sternberg, R. J. 2009. *Psikologi Kognitif*. (T. Santoso, Ed.) (4th ed.). Yogyakarta: Pustaka Pelajar.

Tiagarajan, S., Sammel, D. S., & Semmel, M. I. 1974. *Instructional Development for Training Teacher of Exceptional Children: A Sourcebook*. Minneapolis, Minnesota: University of Minnesota.

Van den Bossche, P., Gijselaers, W., Segers, M., Woltjer, G., & Kirschner, P. 2011. Team Learning: Building Shared Mental Models. *Instructional Science*, *39*(3), 283–301.