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MENTAL MODELS AND CREATIVE THINKING SKILLS IN STUDENTS' PHYSICS LEARNING

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Abstract. The study of mental models and creative thinking skills in students' physics learning with the problem-based learning model has been scarce. This study aimed to analyze the relationship between mental models and creative thinking skills in high school students. Many previous research findings explain a relationship between mental models and creative thinking skills among students at the university level and workers. This mixed-methods study was conducted on high school students in Malang, East Java, Indonesia, aged between 14 and 15 years. The instrument used is in the form of mental models and creative thinking skills test questions. This finding explains no relationship between mental models and creative thinking skills because learning has not fully empowered mental models and creative thinking skills. On the other hand, learning at the previous level, students' knowledge is still fragmented, so that is incomplete. Therefore, at the high school level, they need help to improve their mental models and creative thinking skills. This finding implies that teachers in developing learning materials, tools, and instruments must pay attention to the level of student knowledge so that learning can be more optimal.

Keywords: creative thinking skills, mental models, physics education, problem-based learning, solid elasticity.

Introduction

Students can use what is often called a model, or more specifically, a mental model, to understand the invisible (abstract) physical phenomenon that occurs on a microscopic scale. Educational psychologists explain that the mental model is an internal thought that acts as a structural analogy of a situation or process (Stains & Sevian, 2015). Its role is when one tries to understand, recount, and have a good predictor of the final state of a phenomenon (Moutinho et al., 2014). Understanding the mental model enables the development of more effective communication and decision-making (Bancong & Song, 2020).

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In principle, the mental model represents multiple domains that support understanding, reasoning, and prediction. The mental models represent a more complex form of conceptual knowledge with a causal relationship (de Guzman Corpuz & Rebello, 2019). The characteristics of the mental models are structures related to the human knowledge of the natural world. The phase of knowledge processing is a memory unit involving symbols reflecting the knowledge of knowledge itself, thus giving birth to a good learning process (Ahi, 2016).

The mental model is built by the individual's cognitive system. It represents simplification, illustration, analogy, and simulation of natural objects. In an attempt to understand a new knowledge or a particular phenomenon, the mental model is built to refer to prior knowledge. The information presented enabled it to be interpreted (Gregorcic & Haglund, 2021). Therefore, a beginner in building his mental model is different from someone already an expert in his field in content, structure, and semiotics. Therefore, modifying learning depends on a mental model that is called conceptual change (Greefrath et al., 2021). According to cognitive psychologists, the mental model represents an internal scale model of external reality or a person's mental representation of an idea or concept (Haglund et al., 2017). An individual who has difficulty building his mental model will have difficulty building his thinking skills, not performing the problem-solving process well (Canlas, 2021).

The mental modeling process can be used to investigate physics concepts. The teacher can access the information to assist in building students' conceptual understanding (Hurtado-Bermúdez & Romero-Abrio, 2023). Mental model research results are mostly done on a large scale, such as in groups, so the data are reduced in groups to develop students' mental models (Brookes & Etkina, 2015). The learning process to see the development of students' mental models for each meeting is not adequately considered. The teacher cannot map the students' mental model as the material for learning evaluation.

The mental model in physics learning indicates that there is a good reason to construct good knowledge in explicitly explaining the allegations of a phenomenon (López & Pintó, 2017). Students make a mental effort to understand the complex system and build the proper mental representation to model and explain the system. The students continually modify and reorganize their mental model in every new experience, especially after the learning process (Childers & Jones, 2015).

The new experience is not only oriented to the mental model but also the skill in thinking or the so-called creative thinking skill. It is an important skill to solve problems in the era of openness (Ceylan, 2022). Such skills are interpreted as the ability to offer new perspectives, generate novelty and meaningful ideas, raise new questions, and produce solutions (Tawarah, 2017).

These skills need to be utilized to help individuals find the solution to solve problems. Creative thinking skills are beneficial in dealing with various problems in the era of globalization (Ritter & Mostert, 2017). The mental model has a relationship with creative thinking skills (Pitts et al., 2018). The mental model influences creative thinking (Leggett, 2017). Teachers as learners can apply a mental model frame or conceptual framework to students. Thus students will progress in learning (Schut et al., 2022). The concepts that have been formed in the students can bring creativity in the form of new, meaningful perspectives, ideas, and ideas. The students also become self-regulated learners (Yildiz & Guler Yildiz, 2021).

The Programme for International Students Assessment (PISA) international survey (Organisation for Economic Co-Operation and Development, 2018) states that Indonesia is still at the bottom in mathematics and science. Indonesia is not able to reach the top ten levels. PISA results describe that of 70 countries, Indonesia is still ranked 62. Therefore it still needs many struggles to be at the best level. Similarly, the Trends in International Mathematics and Science Study results in the context of mathematics and science in Indonesia are still at the bottom of the rankings compared to Singapore in the first rank (Organisation for Economic Co-Operation and Development, Asian Development Bank, 2015).

The facts described above are not much different from physics learning in Malang. Students still less create independence in learning during the lesson, presentation of the material is still dominated by teachers. In contrast, students have not found a good way of learning. Students feel confused about developing their conceptual framework (Adbo & Taber, 2009). At the same time, students' creative thinking skills are essential for competence in the 21st century (Ritter & Mostert, 2017). Such a learning process affects students "saturation and impacts students" cognitive learning outcomes.

A physics study at several high school schools in Malang reported by Yogantari (2015) revealed that as many as 35% of students have difficulty with elasticity and Hooke's law, 30% optics, and 15% kinematics. The difficulty is caused by the lessons experienced by students more minor than the maximum in a hands-on activity. As many as 76% of students stated that teachers as a learning resource still dominate learning in the classroom. As many as 14.6% of students found difficulties understanding the physics presented in diagrams. 33% had difficulty understanding concepts, 38% had difficulty using mathematical representation, and the rest had difficulty making conclusions based on analysis.

Students' difficulties in studying physics affect low learning outcomes. They lack exploration and empowerment of mental models and creativity in learning. Learning activities are more oriented towards achieving mathematical knowledge elements than the mastery of physics concepts. They are accommodating in finding the most appropriate answer to the problems given based on existing information.

Material elasticity is an integral part of learning physics and everyday life. It can be seen when people use elastic material in most activities to protect the limbs such as the head, body, and feet. Mental models and creative thinking skills are perfect when collaborating with elasticity materials. The mental model explains the macroscopic and microscopic circumstances of material so that students will be accustomed to explaining how the state of a particle or molecule when given a force. Like creative thinking skills, students will be creatively trained by using elastic material to make a quality product to protect the limbs with the existing materials.

Physics emphasizes products, processes, applications, and attitudes. Physics learning is not only based on the results of cognitive learning as the final result, but the learning process should also prioritize and improve its quality. Creating learning conditions involving student learning experiences needs to be empowered to foster students' thinking to be scientific. Reasonable efforts have to be made by teachers and students to achieve student competence according to the critical demands in the curriculum, especially how to find more effective patterns or student learning models. The selected model can be used according to the situation and condition of the student. Therefore, good innovation is required by applying a constructivist-based learning model (Qarareh, 2016) in order to be able to empower the mental model and creative thinking skills of students (Barrett et al., 2013).

Problem-based learning (PBL) is a model that involves students' learning experiences through developing questions and thinking skills to solve physics problems. PBLs are the potential to facilitate the quality of a good mental model of an object/material that stimulates a change of thinking structure. Denizhan (2020) affirmed that group learning activities to solve problems or cases encourage students to think with their knowledge, identify necessary information, locate more relevant information, and analyze and evaluate to construct problem-solving flows. These activities have an impact on changing the mental model of the students. In addition, the involvement of real experience in learning is expected to stimulate students' mental models and improve students' creative thinking skills in physics. The findings of Salari et al. (2018) prove that PBL has the potential to change the mental model of students. Creating learning situations can further enhance the students' actual experiences in learning through students' mental models.

The potential of PBL in improving students' creative thinking skills can be accessed during learning. Creativity can generate ideas, novelty, new questions, or new and valuable solutions through preparation, incubation, evaluation, and elaboration. Preparation is done during the brainstorming of opinions about the issues/problems found, followed by an incubation phase in which issues are identified and discussed. The evaluation phase is concerned with deciding whether the ideas are relevant, and elaboration is the final phase. The ideas are applied/manifested in actual activity and then reevaluated (Seibert, 2021). The potential of PBL in fostering students' creativity can be started from individual activities, which are continued with group activities. Such activity will result in innovation in applying and transferring knowledge (McCrum, 2017).

The study of mental models and creative thinking skills of physics is still limited, and collaboration with the PBL model until the present. Although there may be performed separately between the two variables done by (Hofgaard Lycke et al., 2006; Lin, 2017), mental models and creative thinking skills using PBL models on elasticity materials of material have not been studied. Therefore, a comprehensive and in-depth study of the process of change or the development of mental models and students' creative thinking skills by applying the PBL model in physics learning is needed.

1. Method

This study used a mixed-methods embedded experimental model to explore the research subject fully. This mixed-methods approach can better understand the research problem than quantitative and qualitative methods alone.

The steps in this study are described as follows. The first step was to carry out mental models and creative thinking skills pretests to determine the students' mental models and creative thinking skills before implementing learning physics with the PBL model. The second step was learning physics using the PBL model in the treatment group and learning with the lecture or conventional model in the control group. At this stage, qualitative data was also collected through interviews with several selected students to confirm their answers during learning related to mental models and creative thinking skills. During the learning process, the development of students' mental models and creative thinking skills was observed through worksheets on each topic. Observers conduct observation activities, and learning activities are documented through photos and videos as evaluation material. After all, the topics were taught, the third step was to post-test mental models and creative thinking skills. The fourth step was collecting qualitative data by filling out response questionnaires and interviews with students to determine student responses to learning with the PBL model. After the four steps are completed, the interpretation of the quantitative and qualitative data is carried out to make conclusions following the formulation of the research problem.

The participants in this study were 78 students consisting of 39 students in the PBL class and 39 in the conventional class. The research was conducted at Public High School 8 Malang. The research subjects were 10th-grade science students with the category level five semesters (medium level). The average student who studied was 16 years old. The experimental class consisted of 20 male students and 19 female students. There are 25 male students and 19 female students in the control class. Before conducting the PBL experiment, the mental models and creative thinking skills instruments were tested for 250 11th grade students at several high schools in Malang, namely High School 1, High School 2, High School 3, High School 4, High School 5, High School 6, Frateran Catholic Senior High School, Christian High School Kalam Kudus, Petra Christian Academy, Catholic High School Santa Maria, and St. Albertus High School.

The mental models test instrument refers to the rubric developed by (Ifenthaler, 2006) by having three types of mental models: surface, matching, and deep. The creative thinking skills instruments developed include fluency, flexibility, originality, and elaboration. The creative thinking skills instrument was compiled and developed by Torrance (1990). The level of creativity: very creative (high level) (68–100), moderate creative (moderate level) (34–67), less creative (low level) (0–33). The creativity domain consists of fluency, flexibility, and originality: 1) fluency can be characterized by (0) students cannot provide ideas/answers, (2) students can come up with one to two ideas/answers, and (4) students can come up with three or more ideas/answers; 2) flexibility can be characterized by (0) students are not able to provide ideas/methods, (2) students can come up with one to two ideas/methods, and (4) students can come up with three or more ideas/methods; 3) originality can be characterized by (0) students do not answer/general ideas/common ideas and no originality, (2) students come up with moderate unique ideas, and (4) students come up with unique ideas; 4) elaboration; (0) there is no addition of ideas from students, (2) a simple addition of ideas from students, (4) extraordinary ideas from students. The mental models and creative thinking skills questions developed were ten questions. Before the instrument was applied, expert validation was carried out in theoretical physics and physics learning by the two experts from the postgraduate physics education State University of Malang, Malang.

Qualitative data were analyzed descriptively, while quantitative data were analyzed by linear regression to determine the relationship between mental models and creative thinking skills in physics learning with PBL and conventional learning models. Data analysis was assisted with *SPSS* version 23.00 for *Microsoft Windows*. Before data analysis, normality and homogeneity tests were performed. The results of the prerequisite test for both classes showed normal and homogeneous.

2. Results and discussion

The results of the answers' mental models and creative thinking skills analysis indicate a high level of thinking, as shown in Table 1.

Table 1. Students answers and categorize questions for mental models and creative thinking skills (source: created by authors)

Questions	Students' answers	Category
In designing a window, carpenters usually give a slit in order to enter the glass. [1] Is glass an elastic object? [2] Why do carpenters create slits in the windows to be able to insert the glass? Please explain. [3] What is the condition of the glass particles in the morning and afternoon?	***S25*** [1] Yes, glass is an elastic object during the day. The glass will expand and return to its original shape in the afternoon with a high temperature. [2] The goal is to give space for the glass when it expands during the day. [3] In the morning, the substance particles vibrate weaker (releasing heat) so that they approach each other, and the object shrinks. Expansion occurs during the day when a substance or glass is exposed to sunlight (receiving heat). İt makes the substance particles vibrate faster so that they move away from each other.	Mental model type *deep*
The pole vault is one of the athletic sports in jumping numbers. The pole vault is performed with the aid of a pole to achieve the highest possible jump. Alfred made a jump using a pole and managed to get over the bar with a buffer height of 4.5 m. Explain things that allow Alfred to cross the bar.	***S45*** 1. The pole used by Alfred is made of elastic and strong material. 2. The force given by Alfred is quite large due to the influence of Alfred's mass and instantaneous velocity/impulse 3. The position of Alfred's grip at the end of the pole to provide a high jump 4. Alfred's running speed is set in such a way that it can help Alfred to jump.	*Very creative*

2.1. Students' mental models and creative thinking skills on problem-based learning

Based on the results of analysis of variance (ANOVA), as shown in Table 2, it is known that the P-value of 0.568 is more significant than alpha ($\alpha = 0.05$), which means that there is no significant correlation between students' mental models and students' creative thinking skills in the PBL model.

Mental models' contribution to creative thinking skills in PBL learning is shown in Table 3.

The R-value in the correlation between mental models and creative thinking skills in the PBL model is 0.096. The R^2 value is 0.009 or 0.9%. Thus, the mental models' aspect contributed 0.9% to students; creative thinking skills, and other factors contributed 99.1%. Table 4 can be determined the regression equation resulting from the relationship between mental models and creative thinking skills. The value of a = 93.221 and b = –0.190, so the regression equation $Y = 93.221 - 0.190\ X$.

Table 2. The summary of anova correlation between mental models and creative thinking skills in problem-based learning model (source: created by authors)

ANALYSIS OF VARIANCE[a]						
Model		Sum of squares	degree of freedom	Mean square	Fcount	P-value
1	Regression	36.981	1	36.981	.332	.568[b]
	Residual	4011.974	36	111.444		
	Total	4048.955	37			
a. Dependent variable: creative correlation problem-based learning (PBL).						
b. Predictors: (constant) mental correlation PBL.						

Table 3. The summary of linear regression between mental models and creative thinking skills in problem-based learning model (source: created by authors)

MODEL SUMMARY				
Model	Correlation coefficient (R)	Determination coefficient (R^2)	Adjusted R-squared	Standard error of the estimate
1	.096[a]	.009	−.018	10.55669
a. Predictors: (constant) mental correlation problem-based learning.				

Table 4. Regression coefficient value between mental models and creative thinking skills learning (source: created by authors)

COEFFICIENTS[a]						
Model		Unstandardized coefficients		Standardized coefficients	T-count	P-value
		Coefficient B	Standard error	Beta		
1	constant	93.221	25.217		3.697	.001
	mental correlation problem-based learning (PBL)	−.190	.329	−.096	−.576	.568
a. Dependent variable: creative correlation problem-based learning.						

2.2. Students' mental models and creative thinking skills on conventional model

Based on the results of ANOVA, as shown in Table 5, it is known that the significance value of 0.881 is more significant than alpha ($\alpha = 0.05$). There is no significant correlation between students' mental models and students' creative thinking skills in conventional learning.

Mental models' contribution to creative thinking skills in conventional learning is shown in Table 6.

Table 5. The summary of analysis of variance correlation between mental models and creative thinking skills in the conventional model (source: created by authors)

ANALYSIS OF VARIANCE[a]						
Model		Sum of squares	Degree of freedom	Mean square	F-count	P-value
1	Regression	.834	1	.834	.023	.881[b]
	Residual	1366.799	37	36.941		
	Total	1367.632	38			
a. Dependent variable: creative correlation conventional.						
b. Predictors: (constant) mental correlation conventional.						

Table 6. The summary of linear regression between mental models and creative thinking skills in conventional model (source: created by authors)

MODEL SUMMARY				
Model	Coreelation coefficient (R)	Determination coefficient (R2)	Adjusted R-quared	Standard error of the estimate
1	.025a	.001	–.026	6.07787
a. Predictors: (constant) mental correlation conventional.				

The R-value in the correlation between mental models and creative thinking skills in the conventional model is 0.025, and the R^2 value is 0.001 or 0.1%. Thus, the mental model's aspect contributes 0.1% to students' creative thinking skills. Other factors contribute as much as 99.9%. From Table 1, it can be determined the regression equation resulting from the relationship between mental models and creative thinking skills. The value of a = 59.257 and b = 0.24, so the regression equation Y = 59.257 – 0.24X. The regression coefficient value between mental models and creative thinking skills is shown in Table 7.

The study results prove no linear relationship between students' mental models and creative thinking skills in physics learning with PBL and conventional models. The student's

Table 7. The regression coefficient value between mental models and creative thinking skills in the conventional model (source: created by authors)

COEFFICIENTS[a]						
Model		Unstandardized coefficients		Standardized coefficients	T-count	P-value
		Coefficient B	Standard error	Beta		
1	constant	59.257	10.114		5.859	.000
	Mental correlation conventional	.024	.163	.025	.150	.881
a. Dependent variable: creative correlation conventional.						

mental models do not determine their creative thinking skills. The relationship between creative thinking skills in students, exceptionally high school students, in learning physics from this study is an anomaly. High school students are in the formal operational stage and need the help of others. The environment inside and outside the home, including the school environment, significantly affects creative thinking skills. This information is in stark contrast to the findings of Mumford et al. (2012) in their research on many students in the university. Their findings confirm that there is a relationship between mental models and creativity. The knowledge or expertise possessed by the student contributes to creative problem-solving. It means that the relationship between mental models and problem-solving could increase creativity. A student should be able to solve problems. In this case, creative thinking skills are needed.

According to Hester et al. (2012), before solving a problem, the mental models used by students to understand problems in this domain are assessed from two characteristics or attributes, namely subjective and objective. It was found that the objective and subjective features of mental models students were related to quality and originality. The assessment of subjective mental models attributes is based on a presentation mental models concept map in front of the assessment team after being involved in the training. The assessment team was asked to rate the student's mental models based on evidence of subjective and objective attributes. Objective attributes are assessed based on eleven criteria, while subjective attributes are assessed based on nine criteria. Assessment of objective attributes continues subjective attributes in concrete or tangible terms. For example, how many concepts are included in the mental models and the number of links provided between the concepts? The subjective and objective attributes of mental models can produce high-quality thinking that results in creativity. Encouraging creativity takes several presentations of essential concepts and can encourage students to formulate coherent things related to existing concepts.

Toader and Kessler (2018) describe a creativity test conducted on several mental models teams. The teams are dissimilar, similar, and complementary. The results showed that the different mental model's team had higher creativity than the similar and complementary mental models team because of the potential for knowledge recombination when each team member reached a balance between exploration and exploitation. Another study was conducted by Curşeu and ten Brink (2016) on two different ethnicities, namely the Dutch and the Chinese. The results showed that group members who received divergent thinking manipulation had a less negative evaluation of minority opinion conceptualization than group members who did not receive divergent thinking manipulation. Divergent thinking can trigger group members to conceptualize minority differences of this opinion only in individualistic groups and not in collective groups. It will ultimately lead to less creative performance in groups operating collectively in a cultural context. This study also contributes to extrapolating cultural differences in creative performance from individual to group-level analysis. It shows that groups operating in a collective culture have lower creativity in divergent thinking tasks than groups operating in an individualistic culture. Another study by Marques Santos et al. (2015) was conducted on 161 teams of 735 people who investigated the mediating mechanisms of intragroup conflict and creativity in the relationship between shared mental models and team effectiveness (team performance and satisfaction). The results show that high shared mental models are associated with low intra-group conflict levels, encourage creativity, and improve team performance and satisfaction. These findings contribute to the relationship between shared mental models and creativity and emphasize the importance of shared understanding for creativity and effectiveness team, not the individual.

Another study examining mental models and creative thinking skills was conducted by Lucas and Mai (2022) but on workers, not on the students. There were two types of mental models: insight and production, which encourage workers to work more creatively so that their performance is the best. Mental models insight directs workers to focus more on preparation, such as information seeking, but mental models production help workers to behave more productively at work, such as by creating ideas and validating ideas. A worker with mental models insight is more likely to frame tasks and think about problems from a different perspective to produce a more creative approach to completing their tasks. In contrast, workers with mental models of production will prioritize production behavior rather than preparation. They will spend more time on activities such as examining creative ideas and using them creatively in their work.

Mental models can describe and represent thinking processes in solving problems, which can help predict and offer about how individuals will perform and behave in certain situations and obtain and process new information. A team's mental model relies heavily on input from team members and directs the team on how to proceed in terms of process and content. The main characteristic of mental models is that they can help coordinate and adapt as required by the tasks assigned to team members. Therefore, there is interaction with each other to exchange opinions and ideas that are creative and innovative. Mental models can be modified, adapted, and finally divided into teams. This construction also directs that team members can be independent in designing things. The mental model consists of several stages, among others, a mental model based on tasks, processes, and teams. It follows the findings of architectural engineering students (Casakin & Badke-Schaub, 2015). Mental models generate creative ideas, knowledge creation, thinking concept formation, and decision making and evaluation (Toader & Kessler, 2018). Similar studies were also conducted on online games and social media such as *Facebook* and *Twitter*. A person's mental model dramatically determines the outcome of the game because it requires good creative thinking, insight, concepts, techniques, and strategies (Wasserman & Koban, 2019).

Several research findings have been presented above that there is a correlation between mental models and creative thinking skills. However, this study did not find a relationship between mental models and creative thinking skills. Therefore, it will be explained in more detail. As stated in several previous studies, this research was conducted on 10th-grade high school students, not on university-level students. In this case, emotional students required much assistance, direction, and instructions in learning since they were junior high school students who had just moved to the high school level. They were at the stage of formal operational development. The new school environment dramatically affects the intelligence of students. Moreover, junior high school students who have just moved to high school still have a powerful teenage personality. They are shy in adjusting to school and learning, exceptionally high school physics which requires high reasoning and analysis. Children need the help of others during the development period, especially in the development of intelligence. As age and psychological maturity develop, the child's dependence on others decreases (Chopik et al., 2018). Junior high school students are highly dependent on others and teachers when they are in the school environment (Wanders et al., 2020). Students may develop continuously and can also develop the potential within themselves. However, there must be something else felt by the child. The nature of humanity encourages children to need the help of others in their emotional development. Parents and teachers are the closest individuals who can encourage children's emotional development (Xiao et al., 2022).

The relationship between emotional intelligence significantly affects mental models and creative thinking skills. Students with good emotional intelligence can acquire good skills and vice versa. One factor that affects a person's intelligence is personality (Petrides et al., 2004). Students with good personalities must have good mental models and creative thinking skills. On the other hand, students with bad personalities must display poor intelligence (Chen & Guo, 2020). Bad personality can be seen through the following indicators: lack/no motivation, loss of self-confidence, low self-esteem, loss of self-control, and high anxiety (Crocker & Park, 2004). If a student shows these characteristics, this shows that his emotional intelligence is low, and it has a fatal impact on his learning skills.

Conclusions

A comprehensive study and analysis carried out on students' mental models and creative thinking skills physics through the PBL model found no linear correlation between students' mental models and creative thinking skills in PBL and conventional models. Therefore, it can be interpreted that the student's mental models factor does not determine creative thinking skills. The relationship between mental models and creative thinking skills in students, exceptionally high school students in physics learning, is an anomaly. It is due to various factors: 1) High school students, especially those who move from junior high school, still have incomplete knowledge with the understanding that they have not had much experience and have not mastered many concepts. It is because elementary and junior high school science is still in the introduction stage, and identification is not yet at a deeper level of analysis. Therefore, it is necessary to have reasonable teacher assistance to make the interaction between students and the learning environment more optimal; 2) the learning pattern of high school teachers is faster with a high enough level of material delivery so that students still need suitable adjustments and training; 3) giving physics questions with higher level, *i.e.*, mental models and creative thinking skills, and students are still not familiar with higher-order thinking skills questions and fast learning patterns. It can be traumatic, fearful, and anxious for students. This finding can also explain why the previous findings stated a relationship between mental models and creative thinking skills. It was carried out at a high level, namely undergraduate, postgraduate students, and even in the world of work. Adults have better knowledge levels, have good experiences, and are more emotionally stable. From elementary school to high school, students still need reasonable assistance from the teacher. The provision of materials can be adjusted to the child's abilities. This finding implies that teachers in developing learning instruments must pay attention to student knowledge so that they are not forced and are required to master what the teacher will teach optimally. Some suggestions for further research are measuring students' mental models and creative thinking skills in physics in learning science in elementary, junior high, and higher education with studies between cultures, ethnicities, or island regions with unique characteristics. In addition, it is necessary to study the relationship between mental models and creative thinking skills with other learning variables that have the potential to increase students' physics learning.

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