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TWO-TIER ITEM TEST IS TO EXAMINE THE CONCEPTUAL OF MECHANIC MOTION FOR CLUES ABOUT CRITICAL THINKING SKILLS

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Abstrak. Critical thinking skills is one way to be able to understand the scientific concepts that exist in physics content as a whole in this case represented by motion content. The aim of the research is to find critical thinking skills behind success and failure in understanding the motion concepts of prospective science teachers. The concept of mechanical motion is expressed in verbal, formal, graphical, and numerical representations. The concept of motion is the subject of the problem in the first tier of the test item. The second tier of the test item measures one of the four critical thinking skills that are relevant to the subject matter. The critical thinking skills studied are reasoning effectively, using systems of thinking, making judgments and decisions, and solving problem. The results of the study show coherence between the ability to understand concepts and critical thinking skills expressed by the correlation index. The magnitude of the correlation index shows the level of coherence between understanding the concept and the underlying critical thinking skills. Empirical data shows a high correlation value between verbal representation and reasoning effectively, formal representation with using system thinking, graph representation with making judgments and decision, and numerical representation with the solving problem skills.

***Kata Kunci**: Conceptual motion; Critical Thinking Skills.*

INTRODUCTION

Physical science learning is primarily how to teach physics concepts and their applications in everyday life for each learning material by involving critical thinking skills. Lack of attention in practicing critical thinking skills will result in a weak understanding of a concept. This statement is supported by the view that critical thinking skills are an ability to be able to analyze and evaluate information (Duron et al., 2006). The involvement of critical thinking skills in lectures will provide a more challenging lecture atmosphere, clarify and believe in the truth of the concepts that are owned and provide in-depth direction to mastery of lecture material.

Active lectures will occur if the atmosphere of class communication between lecturers and students is actively involved and uses critical thinking skills to deepen the concepts and applications. This is in line with (Piawa, 2010) opinion which states that critical thinking skills seen from the education side state that the process of critical thinking includes evaluating ideas, solutions, evidence and arguments. Evaluation of thinking skills is the highest level of the process of effective thinking and learning. Physical material exams are generally presented separately from one representation of concepts with representations of other concepts even though they are on one topic of discussion, this can be found almost on all items of physics tests in the form of ordinary multiple choice. This situation provides an opportunity for uncertainty to be able to trace the success or failure of the contents of the content tested on the item in question. This information does not provide clues as to what reasons underlie a concept can be understood or not comprehensively understood.

The discussion of a concept or material in a physics textbook is displayed in the form of a multi-representation that aims to provide an understanding of the concept of physics comprehensively. Understanding a concept will work well if it involves critical analysis from the textbook reader. The critical thinking skills needed include basic clarification abilities, decision-making abilities, advanced clarification skills, the ability to integrate and the ability to believe something right (Ennis, 2011). The items about a test are designed according to the purpose of the test and involve a very varied conceptual level. A two-level multiple choice test item is designed to find the ability to answer questions in the first part and measure the reasons underlying the choice of answers in the second part. Errors in determining the choice of answers in one part of the question shows the incoherence between knowledge and critical thinking that lies behind it.

(Partnership for 21st Century Skills, 2011) develops and unifies the mastery of core academic material ideas and four skills namely critical thinking and problem solving, collaboration, communication, creativity and innovation. Bring together a number of skills that can prepare students to be successful in education, career and life. These learning and four skills must be supported by relevant education standards and relevant assessment

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systems that meet the principles of instrument validity and reliability. 21st century critical thinking skills are important components that must be possessed in order to be able to analyze the understanding of physics material concepts, as well as relevant assessment standards that combine comprehensive mastery of concepts and critical thinking skills. How to measure conceptual understanding and background of relevant thinking skills is the focus of research problems. The research problem formulation is how to find critical thinking skills behind successes and failures in understanding the motion concepts of prospective science teacher and utilizing test results information to build effective learning processes. (Stobaugh, 2013) states several benefits from practicing and refining students' critical thinking skills. Embedding critical thinking skills in the curriculum helps sustain an educated citizenry; prepares students for college, future careers, and life situations; and primes students to meet the mandate of state and national tests and standards.

RESEARCH METHODS

Various studies relevant to this research have been conducted to examine the aspects of critical thinking skill as well as critical thinking skills related to other educational aspects shown in Table 1. The survey method was conducted to know descriptively about the teacher's critical thinking skills, data obtained by multiple choice tests with analysis t test statistics and ANOVA (Gedik, 2013). The research aims to determine the relationship between thinking models and critical thinking skills, using experimental models with data analysis using regression and correlation (Abdi, 2012). Assessing the ability of thinking systems of college graduates is one of the interdisciplinary skills that must be continuously improved to describe cognitive flexibility in working collaboratively in social communities in society, the method developed is an experiment with the form of developing scenario problems (Grohs et al., 2018). The mixed research method is used to evaluate the validity of the scientific argument test (Bao et al., 2018) .The Thiagarajan 4D development research model is used to improve critical thinking with a research-based learning model (Usmeldi et al., 2017).

Considering the purpose, validity and reliability of research, the study conducted aims to analyze qualitatively and quantitatively the information obtained from an item in the form of a two-level multiple choice question, thus the research method used is mixed methods applied in develop a test instrument that measures the ability to master concepts and find reasons for critical thinking skills behind understanding a concept of mechanical motion that appears in one representation.

Table 1. Critical Thinking Skills Methods

Critical Thinking Skills	Methods
measure critical thinking skills of students (Gedik, 2013)	Survey Model, means *t* test
the relationship of thinking styles and critical thinking skills (Abdi, 2012)	Experiment, regression and correlation
Assessing system thinking (Grohs et al., 2018).	Problem scenario development
Evaluation of test validity arguments (Bao et al., 2018)	Mixed methods
Improve critical thinking (Usmeldi et al., 2017)	Model 4D Thiagarajan

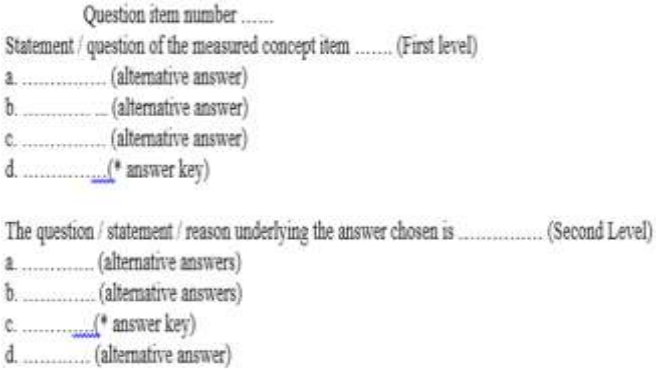
The steps of development and research are carried out by carrying out activities: (1) formulating the objective of developing test items to measure the mastery of the concept of motion by taking into account four concept representations, (2) formulating critical skills that will be tested which are integrated with the reasons for each item, (3) synchronizing concept content with critical thinking skills, (4) formulating test development grids, (5) assembling draft questions and tests, (6) conducting small scale trials, qualitative and quantitative analysis, (7) implementing research involves large groups, (8) qualitative and quantitative analysis of data obtained from tests by considering the purpose of the study, (9) making conclusions and evaluating the entire stages of the study.

Synchronization between critical thinking skills, concept representation and mechanical motion content is listed in Table 2. Synchronization is done by paying attention to the indicators of critical thinking skills and motion concepts obtained by the relationship between verbal representation and effective argument skills (explanations), formal representations with thinking systems use skills, representation graph with decision making skills, and numerical representation with problem solving skills.

The critical thinking skills developed in this study are from (Partnership for 21st Century Skills, 2011) which has identified four areas of critical thinking skills: (1) effective reasoning, (2) using systems thinking, (3) making judgments and decisions, and (4) solving problems. Klein at el (2017) states that five representations are needed to assess the concept of motion kinematics: (1) verbal representation, (2) formal representation in the form of mathematical formulas, (3) image or pictorial representation, (4) graph representation, (5) numerical representation. Image representation is not included in the study because of consideration of coherence with the critical thinking skills studied.

RESULT AND DISCUSSION

The test produced to find the critical thinking skills needed to understand the concept of mechanical motion material is a two-level multiple choice test totaling 20 items with 5 pairs of questions each. Test reliability was measured by Cronbach alpha indexed 0.84 and fulfilled expert validity, user validity, and construct validity. Expert validity is intended to fulfill the validity of question making based on the theory of classical test development. The user validity was found from the response of the test participants when the small group tried out. Construct validity is built on the parallels between critical thinking skills, content / concept representation measured in four types of representations for motion physics content as in Table 2. Outline form of items can be seen in Figure 1. Each item consists of two parts (two tier), the first part measures the concept of mechanical motion by using one representation and the second part measures the relevant reasons for answering the first part by considering relevant critical thinking skills.


Question item number .....
Statement / question of the measured concept item ..... (First level)
a. ..... (alternative answer)
b. ..... (alternative answer)
c. ..... (alternative answer)
d. .....(* answer key)

The question / statement / reason underlying the answer chosen is ..... (Second Level)
a. ..... (alternative answers)
b. ..... (alternative answers)
c. .....(* answer key)
d. ..... (alternative answer)

Figure 1. Outline item test

Based on the analysis of empirical data using the SPSS program, there was a correlation between the ability to understand mechanical motion concepts (4 representations) and (4 critical thinking skills), the Pearson correlation with each correlation index as shown in Table 3. The types of critical thinking skills do refutation effectively correlates strongly with mastery of the concept of mechanical motion (verbal representation) with an index of 0.70. This gives the meaning that critical thinking skills do effective objective can be found or contribute to mastery of the concept of verbal mechanical motion by 49% (determination = 0.72). (Kirmizi et al., 2015) stated that the same thing is there is a relationship between the skills of critical thinking (disposition) and perceptions of problem solving skills (r = 0.53).

Table 2. Parallels between Critical Thinking Skills, Multi Representations, and Mechanical Motion Concepts

Critical Thinking Skills	**Indicator**	**Representation**	**Concept of Mechanical Motion**
Reason effectively	Use various types of rebuttal (deductive and inductive) according to conditions	Qualitative statement (Verbal)	Motion along a straight line
Use systems thinking	Analysis of how parts interact with others to produce concepts in their entirety for complex systems	Express the relationship of concepts in the form of mathematical formulas	Motion in two dimension for trajectory
Make judgments and decisions	Conduct effective analysis and evaluate evidence. Synthesize and connect information and arguments. Interpret and make conclusions.	Use concepts to solve problems in a graphical representation	Force and Newton 1& 2
Solve problems	Solve problems conventionally and in innovative ways	Use concepts to solve problems in a numerical representation	Force and circular motion

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Table 3. Correlation Pearson index between Multi representation and critical thinking skills

Critical Thinking Skills	Representation	Concept of Mechanical Motion	Correlation
Reason effectively	Qualitative statement (Verbal)	Motion along a straight line	r = 0.70, p <0.01 (2 - tailed)
Use systems thinking	Express the relationship of concepts in the form of mathematical formulas	Motion in two dimension for trajectory	r = 0.72, p < 0.01 (2-tailed)
Make judgments and decisions	Use concepts to solve problems in a graphical representation	Force and Newton 1& 2	r = 0.66, p < 0.01 (2-tailed)
Solve problems	Use concepts to solve problems in a numerical representation	Force and circular motion	r = 0.73, p < 0.01 (2-tailed)

The use of critical thinking systems correlates with understanding the concept of two-dimensional motion for the bullet trajectory of 0.72 with mathematical representation. Problem solving questions for bullet motion dominated by the use of mathematical formulas can be solved with critical thinking ideas up to 52%. (Rakbamrung et al., 2015) stated that the use of a thinking system to teach the concepts of force and motion in nursing schools can be applied with a formative assessment with an achievement of between 20-60% for understanding concepts.

The application of questions for the concepts of Force and Newton's Law 1 and 2 involving graph representation correlates with index 0.66 with decision making and judgment skills, the lowest value compared to other correlation values. Difficulties arise from the graphical analysis capabilities needed which require critical thinking skills to make decisions and considerations based on the level of graph presented in the problem. (Sezen et al., 2012) and (Kilic et al., 2012) state that graph interpretation and reading charts are a type of thinking skills that are difficult to do in making decisions and considerations based on the type or type of graph faced. Critical thinking skills make decisions and considerations have an impact on the success of solving the concepts of style and Newton law 1 and 2 reaching 44%.

The relationship between critical thinking skills solving problems (solve problems) for items about force and circular motion with the type of numerical representation correlated 0.73, said that this thinking skill contributes ideas in solving the problem of the concept of numerical representation of 53%. Rodzalan and Saat (2015) state that critical thinking models and solve problem models are closely related in the application of classroom learning, problem solve relationship models and relevant thinking skills as triggered by Haller et al 2007. (Batlolona et al., 2018) states that problem solving abilities and understanding of physics concepts for temperature and heat material can be increased simultaneously by using the HPIL learning model by using multiple choice and essay test instruments. Increasing problem solving skills from 40.68% to 74.77% and concept mastery from 0.48% to 0.72%.

Figure 2 shows one of the questions that relates the understanding of motion concepts in graphical representation and the critical thinking skills of making decisions and considerations that are included in the form of verbal expressions of motion concepts which are included in the reason level. In the first part of the problem, the test participant is asked to determine the average speed owned by a car that passes through the BAD track. In Figure 2 can be seen the position of the car function toward time, and can also be determined instantaneous speed along the BAD path. If the test participant can determine the difference between the concept of average speed and instantaneous speed, this will be able to determine the average speed based on the graph of the position with time. At the second level, checking whether the answer is given is based on a correct analysis or just guessed. If the test participant can determine the reason correctly, it is said that the test participant can master the concept of average speed based on the graphical function of the position toward time. Reasons are built based on the skills of critical thinking to make decisions and considerations.

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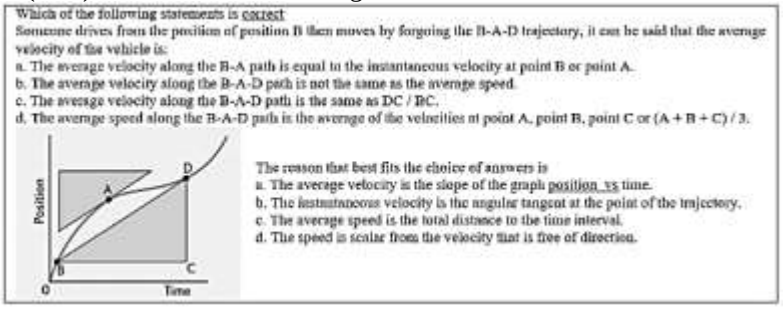

Figure 2. One of the graph representation test items and critical thinking skills in making decisions and considerations

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CONCLUSION

The first level of the two tiers multiple choice test item is designed to measure conceptual knowledge of mechanical motion by involving the use of one component of the concept of multi representation (verbal, formal, graphical, numerical) as an indicator of achievement of cognitive mastery of learning outcomes. The second level of multiple choice test items is used to find critical thinking skills which are the basis for determining the most appropriate reason based on concepts relevant to scientific physics that are in accordance with the concept of mechanical motion. The coherence between critical thinking skills in finding the right answers and reasons is expressed in the form of a Pearson correlation coefficient, with varying index values in the medium to high category (r = 0.66 - 0.73) for mastering the concept of mechanical motion with four representations measured.

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