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ESTRUTURA CONCEITUAL DE HABILIDADES CRÍTICAS DE PENSAMENTO PARA TESTES DE TRABALHO E ENERGIA APLICADOS AO ENSINO DE FÍSICA

CONCEPTUAL FRAMEWORK OF CRITICAL THINKING SKILLS FOR WORK AND ENERGY TESTS APPLIED TO PHYSICS LEARNING

IMPLEMENTASI KERANGKA KONSEPTUAL TES KETERAMPILAN BERPIKIR KRITIS USAHA DAN ENERGI PADA PEMBELAJARAN FISIKA

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RESUMO

Trabalho e energia são conteúdos tradicionalmente abordados no estudo de física e engenharia. Isso se deve ao fato desse tópico fazer parte da vida cotidiana das pessoas, ou seja, são habilidades de pensamento crítico incluídas nas realizações de aprendizagem do século XXI que devem ser dominadas pelos alunos. Este estudo teve como objetivo fazer uma formulação de avaliação apropriada para medir as habilidades de pensamento crítico dos alunos a respeito do tópico de trabalho e energia. O método sistemático de revisão foi realizado em três etapas. O primeiro passo foi procurar fontes relevantes de literatura por meio de um banco de dados e livros. O banco de dados utilizado incluiu Revistas SAGE, Biblioteca Wiley Online, Science Direct e Google Scholar. Foram examinados 115 periódicos ou procedimentos e selecionados 50 artigos de acordo com os critérios estabelecidos. O segundo estágio determinou a formulação de indicadores de desempenho, e o terceiro estágio desenvolveu testes conceituais de habilidades de pensamento crítico. Com base nesse estudo sobre a estrutura conceitual do estudo para medir as habilidades de pensamento crítico dos alunos em materiais didáticos para trabalho e energia, pôde-se concluir que (1) indicadores de habilidades de pensamento crítico sobre trabalho e energia incluem interpretação, análise, avaliação, inferência, explicação; (2) os princípios básicos da fabricação de instrumentos de teste do pensamento crítico incluem a apresentação de fenômenos, testes abertos e o teste da racionalidade das respostas; e (3) houve exemplos da aplicação do desenvolvimento do instrumento de teste de habilidades de pensamento crítico para análise de indicadores.

Palavras-chave: *habilidades de pensamento crítico, energia do trabalho, avaliação.*

ABSTRACT

Work and energy are contents traditionally addressed in the study of physics and engineering. This is because this topic is part of people's daily lives; that is, they are critical thinking skills included in 21st-century learning achievements that must be mastered by students. This study aimed to make an appropriate assessment formulation to measure students' critical thinking skills in work and energy. The systematic method of review was carried out through three stages. The first step was to search for relevant literature sources through a database and books. The database used included SAGE Journals, Wiley Online Library, Science Direct, and Google Scholar. There were 115 journals or proceedings that have been examined and then selected 50 articles following established criteria. The second stage determined formulating achievement indicators, and the third stage developed conceptual tests of critical thinking skills. Based on this study on the conceptual framework of the study to measure students' critical thinking skills in teaching materials for work and energy, it was concluded that (1) indicators of critical thinking skills on work and energy include interpretation, analysis, evaluation, inference, explanation; (2) the basic principles of making critical thinking test instruments include presenting phenomena, open-ended tests, and testing the rationality of answers; and (3) there were examples of the application of the development of the critical thinking skills test instrument for indicator analysis.

Keywords: *critical thinking skills, work, and energy, assessment.*

ABSTRAK

Usaha dan energi merupakan materi pokok yang dibahas dalam pelajaran fisika dan teknik. Materi ini berisi fakta dengan topik kehidupan sehari-hari yang dialami oleh masyarakat, dengan demikian, diperlukan keterampilan berpikir kritis sebagai bagian dari capaian pembelajaran abad ke-21 yang harus dikuasai oleh siswa. Penelitian ini bertujuan membuat formulasi penilaian yang tepat untuk mengukur keterampilan berpikir kritis siswa dalam materi usaha dan energi. Metode review sistematis dilakukan melalui tiga tahap. Tahap pertama adalah mencari sumber literatur yang relevan melalui basis data dan buku. Basis data yang digunakan meliputi SAGE Journals, Wiley Online Library, Science Direct, dan Google Scholar. Sejumlah 115 jurnal yang telah diperiksa kemudian dipilih 50 artikel sesuai dengan kriteria yang ditetapkan. Tahap kedua menentukan rumusan ketercapaian indikator, dan tahap ketiga mengembangkan tes konseptual keterampilan berpikir kritis. Berdasarkan penelitian ini kerangka kerja konseptual untuk mengukur keterampilan berpikir kritis siswa dalam materi usaha dan energi, disimpulkan bahwa (1) indikator keterampilan berpikir kritis pada usaha dan energi terdiri atas interpretasi, analisis, evaluasi, inferensi, penjelasan; (2) prinsip dasar pembuatan instrumen tes berpikir kritis meliputi penyajian fenomena, tes terbuka, menguji rasionalitas jawaban; dan (3) ada contoh penerapan pengembangan instrumen tes keterampilan berpikir kritis pada indikator analisis.

Kata kunci: *keterampilan berpikir kritis, usaha dan energi, penilaian.*

1. INTRODUCTION:

Mastery of physics is identical to Mastery of physical material, which is identical to systematic investigation and draws conclusions from applications based on theories and models developed in science. This is closely related to critical thinking skills (Holmes, Wieman, and Bonn, 2015; Arend, 2012). Work and energy Material became part of studying physics and engineering (Jeweet, 2010). The most crucial element in learning work and energy is the law of conservation of energy (Giancoli, 1997). This is because the work and energy are part of daily human life that cannot be separated by humans.

In science, energy is defined as the ability to do work. Even when you breathe, blink, or shift position in a chair, all the work requires energy. Energy can also be defined as the ability to cause change. Every change that occurs, big or small, involves energy (Hill, 2008). For example, when someone boils water, the initially cold water when it gets heat energy from the fire after 15 minutes turns the water into heat. Energy cannot be created and destroyed but can be changed from one form of energy to another form of energy known as the Law of Conservation of Energy. There are several examples of changes in the form of energy. A rock that falls at a certain height and a car that slides down on a hill are some. Both examples are a form of change in gravitational potential energy into kinetic energy (Giancoli, 1997).

Thus work, and energy materials become an essential part of the education curriculum in

Indonesia. Shiva must master the skills specified in the curriculum. One way to develop students' understanding of learning the material is to get students to think critically because critical thinking is the main asset in shaping one's intellect (Adey P, 1994). Critical thinking skills become an important recommendation in the 21st-century framework, which is parallel to the skills of creative thinking and innovation, problem-solving, collaboration, and communication (Trilling, n.d.). In survival skills, critical thinking skills are also included in an important part that must be considered (Wager, 2008). Critical thinking skills are essential in the context of student learning. Every decision students will consider rationality (Ennis, 1985; Facione, 2009; Mason, 2009; Wallace, 2001).

Besides, students will be more careful to provide stairs to any information that comes in (Dana S. Dunn, Jane S. Haionen, 2009; Mason, 2009). Every decision that is determined has a strong reason and can be justified (Crews-Anderson, 2007; Mason, 2009). So that someone will effectively achieve the desired goals (Halpern, 1999; Paul, Richard; Elder, 2014). Also, critical thinking skills are indicators of student success on an international level, such as TIMSS and PISA. This means that education in Indonesia must pay attention to critical thinking skills if you want to get good ranking results on an international scale. However, the fact the results of PISA in 2018 for Indonesian students is 396. This means that Indonesian students have not been able to solve complex problems or are only able to at a more superficial level. Solving complex problems requires students' thinking skills. The impact of the ability of our students who are still in the category

of simple problem solving is that Indonesian students are only ranked 70th out of 78 countries measured (OECD, 2019). In the context of educators, to know the development of critical thinking skills, an instrument that gives students to do argumentation is necessary. As Gutires's research results show, students' learning difficulties will be seen if the questions are given in essays, qualitative. So the instrument of thinking skills development becomes part of the research that is continuously being developed (Facione, N.C., Facione, P., Biohm, S. W., and Gittens, 2008)

The purpose of the paper was to make an appropriate assessment formulation to measure students' critical thinking skills on the work and energy subject.

2. MATERIALS AND METHODS:

The design of this research was an integrative review in three stages, namely: (1) searching for relevant literature, (2) the formulation of indicators of critical thinking skills on work and energy, and (3) developed conceptual tests critical thinking skills.

The first step was to search for relevant literature sources through a database and books. The database used included (1) SAGE Journals, (2) Wiley Online Library, (3) Science Direct and (4) Google Scholar. The selection of papers was made based on the inclusion of criteria (1) Journals and proceedings published in 1990-2020 written in English, (2) implementation of critical thinking skills in the world of education, and (3) the critical study scientific article about the level of science. Keywords used to search literature included critical thinking skills, critical thinking in science, critical thinking skills in physics, assessment of critical thinking skills. A total of 115 have been examined, but only 50 articles were selected that fit the established criteria. Thirty books written by experts under critical thinking skills, work, energy, learning theory using English, and Indonesian were also used to build critical thinking skills test concepts on work and energy materials.

The second stage was the formulation of indicators of critical thinking skills on work and energy. This stage was carried out by examining several concepts of critical thinking skills that have been written by experts in the critical field of the environment, such as Ennis, Halpern, Crew Anderson, Facione, Paul, and Eider. This thinking is important to obtain an excellent concept to be set as an indicator of critical thinking skills on work and energy materials.

The third stage of developing conceptual tests was appropriate to measure these indicators by developing existing empirical questions and facts.

3. RESULTS AND DISCUSSIONS:

3.1. Literature review

3.1.1 Learning

The definition of learning, according to Mahmud, is a change in a person's behavior due to interactions with the environment (Mahmud, 2012). The environment in question in learning to start from learning resources, learning processes, and behaviors that support learning. If someone does the learning process to the maximum, this is the same as developing thinking skills (Jurfri, 2013). Thus people who are learning are practicing their thinking skills to be developed continuously. As a result, someone will have life skills. Learning is practicing one's cognitive skills, not just memorizing (Hamruni, 2011). This means that an educator must always evaluate whether during the learning process can facilitate students to train students' cognitive or just memorize information. As noted, learning is a complex student action and behavior (Dimiyati, 2011).

Learning is developed for the thought process and develops one's skills and attitudes (Nana Syaodih, 2011). The knowledge that has been possessed can also be applied in real life through good behavior. To achieve the ultimate goal in learning needed meaningful learning, which can master the concepts and linking science and analyzing other ideas to obtain optimal results (Suryabrata, 2008). Learning is a long process that has characteristics not only mastering the concept but also developing thinking skills, cognitive so that it can have a complete understanding that can link science and analyze concepts that enter a person's mind.

3.1.2 Critical Thinking skills

Critical thinking reflects one's understanding and reasoning with an element of creativity in making a decision. The decision type is based on formulating hypotheses, questions, alternatives, and activity plans (Ennis, 1996). Although the decision taken is still in one study of science, it does not involve analyzing other areas of science. The keyword in thinking about critical thinking skills is action based on the concept of rationality.

Critical thinking is the goal and directed

towards the goal (Halpern, 1999). This is a type of thinking with a specific purpose with a foundation of rationality. These goals include solving problems, formulating conclusions, calculating possibilities, and making decisions. This opinion also requires a person to have a rational decision base. Another view of critical thinking is thinking to process the knowledge possessed by someone in the form of analysis of understanding, existing synthesis, and ideas by considering aspects of a sense of accuracy and skills to provide solutions or anticipation of problems (Moon, 2007). Managing knowledge to become a synthesis also requires a process of rationality in thinking.

Opinions about critical thinking also relate to incoming information, namely, the ability of a person to give detailed responses to the strengths and weaknesses (Crews-Anderson, 2007). The opinion is analyzed in principle with a general view of truth, by arranging arguments in a structured way to facilitate information interpretation. Even though the opinions expressed must also be based on the ratio of our reason, namely general truth, meaning truth that is following common sense. Likewise, Mason thinks critically is the ability of someone based not only rooted in the dogma of reality at a particular perspective but also integrates various perspectives, information that has a reasonable rationale (Mason, 2009). Whatever knowledge comes in and can still be justified logically can be the basis in critical thinking skills. Reason and evidence are also important in critical thinking skills; critical thinking is not a set of skills that can be used at any time, in any context (Willingham, 2008). Critical thinking lies in the domain of knowledge mastery owned by someone and has an open attitude towards new ideas that have reasoned with evidence.

Other opinions concerned with critical thinking skills include the ability to recognize events with specific patterns (Dana S. Dunn, Jane S. Halonen, 2009). The ability to solve problems through scientific and practical ways to be used, involving reasoning and adapting different sense, is new. Critical reasoning includes (a) asking questions and being willing to ask questions, (b) defining the problem clearly, (c) examining evidence, (d) analyzing assumptions (e) avoiding emotional reasons, (f) avoiding oversimplification, (g) consider alternative interpretations, and (h) tolerate uncertainty.

In the critical perspective in testing one's thinking, it also puts forward rational thinking and the reflective thinking of evaluating thinking independently to get better results (Paul, Richard; Elder, 2014). The meditative process of thought

includes (1) asking essential questions and problems, (2) formulating them clearly and precisely, (3) collecting and assessing relevant information, (4) using abstract ideas to be interpreted effectively, (5) arriving at conclusions and reasonable solutions, (6) testing the relevant criteria and standards, (7) thinking openly in alternative thought systems, (8) recognizing and assessing, as needed, their assumptions, implications, and practical consequences; and (9) communicating effectively with others in finding solutions to complex problems.

Judge, Jones, and McCreery (2009) discussed the ability to think about how to evaluate the students' thoughts so that they will find strengths and weaknesses in their skills or knowledge. Based on these results, they will have a perspective on themselves as consideration for taking action to improve their abilities by not closing themselves to one's opinion or being open to the views of others. There are also opinions to respond to arguments (Wallace, 2001). His opinion is the skill used to identify, analyze, and evaluate statements and truth claims; to find and overcome personal problems of bias and bias; to formulate and present convincing reasons in support of conclusions, and to make sensible and intelligent decisions about what to believe and what to do.

Representations of critical thinking skills have self-thinking and respond to a phenomenon or object (Facione, 2009). Described in detail as a person's cognitive skills, including interpretation, analysis, evaluation, inference, explanations, and self-regulation, which have good, exact, logical, wise thinking properties, pay attention to facts, are open to alternatives. Based on some of these opinions, it can be concluded that critical thinking skills are students' skills in rational decision-making with facts learned through experience or experimental activities.

3.1.3 Thought Requiring Instrument Critical Thinking Skills

In the scenario of education, critical thinking skills are a part that is, actually, not an option that must be chosen but is a unity that cannot be released by the purpose of education itself (Norris, 1985). With critical thinking skills, this will help in the problem-solving process based on valid and relevant information (Paul, 1991; Gagne, 1988; Niu, Behar-Horenstein, and Garvan, 2013).

Critical thinking skills are important thinking skills and are needed by students to carry out learning activities ranging from assignments,

interpreting work, and engaging in creative assignments given by the teacher (Bailin, 2002).

Students who are not accustomed to thinking critically, if they get a different concept, feel themselves a failure, and cannot withstand feelings of sadness. The inculcation of critical thinking skills needs to start from elementary school to college to have an open habit of problems or criticism of differences (Sarigoz, 2012).

3.1.4 Existing instruments

Mastery of learning in science, including Physics, Biology, and chemistry, this in every material requires critical thinking skills. Each material must be reviewed in depth to prepare students' critical thinking skills (Holmes *et al.*, 2015; Arend, 2012).

The importance of thinking skills encourages experts to develop instruments to get valid results. The tools of thinking skills are still limited (Bassett, 2016; Sustekova, Kubiak, and Usak, 2019; Istiyono, Dwandaru, Ledo, Rahayu, and Nadapdap, 2019). Examples include Watson-Glaser Critical Appraisal Appraisal (WGCTA) (Watson, 1980). This instrument continues to develop and undergo improvements (Watson, G., Glaser, E. M., and Rust, 2002). The Ennis-Weir Critical Thinking Essay Test (EWCTET) (Ennis, Robert H, 1985), Cornell Critical Thinking Test (CCTT) (Ennis, R.H., Millman, J., Tomko, 1985; Tomko, 1985), the California Critical Thinking Disposition (CCTDI) (Banning, 2006), the International Critical Thinking Essay Test (Paul, R., and Elder, 2007) the California Critical Thinking Skills test (CCTST) (Facione, N.C., Facione, P., Blohm, S.W., and Gittens, 2008), and Assessment Critical Thinking Halpern (Halpern, 2010).

The measurement of critical thinking skills will be maximized to be applied to a particular subject matter, so this impacts teachers to practice critical thinking skills in each subject (Nitco, 2011). The measurement results will also be more valid if critical thinking skills are developed to certain specifications (Tironeh, De Cock, Weldeslassie, Elen, and Janssen, 2017; Kuhn and Kuhn, 1999). Research that measures critical thinking skills uses The California Critical Thinking Disposition Inventory (CCTDI-R), which Facione has developed (Özsoy-Güneş, Güneş, Derelioğlu, and Kirbaşlar, 2015). It uses the basic principle of Halpern in the form of a Multi Response Format Test on heat material (Mahbubah, Rusdiana, Juanda, Hermita, and Hakim, 2018; Sya'Bandari,

Firman, and Rusyati, 2018). The material on momentum has been developed using essay tests (Negoro, Rusilowati, Aji, and Jaafar, 2020), electrical matter (April and Kuswanto, 2017), fluid matter (Wartono, Hudha, and Batiolona, 2018; Maknun, 2020; Rosidin, W Distrik, and Herlina, 2018; Yulianti, Wiyanto, Rusilowati, Nugroho, and Pangesti, 2019), photoelectric effect (Sutarno, Setiawan, Suhandi, Kaniawati, and Malik, 2019) and Hooke's law (Asmawati, Rosidin, and a, 2018).

The development of measurement of critical thinking skills allows continuing on any physics material due to the nature of the material (Holmes *et al.*, 2015). One of the materials used to measure students' critical thinking skills is work and energy. Energy material is still found basic mistakes in everyday life (Dega and Govender, 2016).

3.1.5 Work and Energy

The energy takes various forms. In general, all physical processes that occur in the universe require energy (Jeweet, 2010). Everyone cannot be avoided in the concept of energy. For example, the sun, needed by the leaves for photosynthesis, and there is a long process of the food chain, which also requires energy. The definition of the concept of energy is still considered a source that has the potential to drive an object (Bächtold, 2018). Students assume that energy is something needed to move, heat, or ignite. Or, the teacher can express the definition of energy by giving examples. Lights require energy to illuminate. When discussing energy that needs to be conveyed is the most important concept in energy, namely the law of energy (Jeweet, 2010). The law of conservation of energy and momentum is fundamental when dealing with the systems of every object. The concept of energy is not only useful in the study of motion but all fields in physics and science (Giancoli, 1997).

The subject of the study discussed energy, including gravitational potential energy, kinetic energy, and work, which is usually difficult to separate so that it is included in the law of conservation of mechanical energy. However, this energy conservation statement remains limited to the ideal system without mentioning energy degradation. In the classroom learning process, a teacher must be able to relate the energy context to the experience of students at the school level. Besides, in teaching scientific work, teachers must consider a language easily understood by students (Warren and Richmond, 2018). One of the difficulties of the students in learning energy is

building the relationship between work and energy. That an educator finds valid results in learning work and energy in the future can apply essay questions, so it will be easy to analyze the difficulty of what parts of the learning process. (Gutiérrez-Berraondo, Guisasola, and Zuza, 2019).

Energy learning becomes more meaningful when students are asked to analyze concepts whose themes are still mastered with mapping concepts. For example, when studying the material work and energy, there is a relation to existing ideas in Newton's laws related to motion (Giancoli, 1997). It is even more interesting when the phenomenon is confronted with the events experienced. When learning energy, it is important to make students make predictions, so they can carry out scientific activities through experiments, further strengthened by linking it in daily life. By making predictions, students will find out the level of truth or concept errors predicted through scientific experimentation activities (Papadouris, Hadjigeorgiou, and Constantinou, 2014).

During this time, evaluating student understanding is placed mainly on the quantitative application of conservation (mechanical) energy in simple systems. This approach refrains from explicitly answering the fundamental question of what energy is, why is it needed in science, and how is it used? Although it might be enough to help students solve standard quantitative problems, it is certainly not enough to help them interpret the epistemology knowledge gained in learning. (Papadouris *et al.*, 2014). Therefore, it is necessary to develop tests that allow students to interpret the understanding obtained in work and energy learning.

3.2. Determination of Critical Thinking Skills Indicators on and Energy material

The number of studies related to critical thinking skills impacts the many different indicators of achievement of each expert thinker (Halpern, 2014a). This can cause no standard reference for the development of measuring instruments. Some use Facione (Özsoy-Güneş *et al.*, 2015), Helpem concept (Mahbubah *et al.*, 2018; Sutarno *et al.*, 2019), Ennis concept (Nisa, Jatmiko, and Koestari, 2018; Wartono *et al.*, 2018), Watson concept (Folly Eldy and Sulaiman, 2013), Facione concept (Ilfiandra Nurhudaya, 2019; Walsh, Quinn, Wieman, and Holmes, 2019; Aizikovitsh-Udi and Amit, 2011). Another form of determining indicators of critical thinking is one that summarizes the opinions of experts (Negoro *et al.*, 2020; April and Kuswanto, 2017;

Damayanti, Suyatna, Warsono, and Rosidin, 2017; Istiyono *et al.*, 2019; Suastra, Ristiati, Adnyana, and Kanca, 2019).

Therefore, it becomes crucial to analyze and determine critical thinking skills in business materials and energy. The determination of these indicators is based on the research conclusions conducted by one competent expert in education. Peter Facione was appointed by the *American Philosophical Association (APA)* to develop benchmarks for critical thinking skills with 46 experts from the fields of education, nursing philosophy, social science, and physics. This development research results concluded that the core cognitive skills of critical thinking are interpretation, analysis, evaluation, inference, explanations, and self-regulation (Nair and Stammer, 2013). The latest research-based on Facione's review is developing critical thinking skills assessment for secondary school students (Aizikovitsh-Udi and Amit, 2011). Employing the six indicators of conclusions of the Facione research results (Facione, 2009) above, it is possible to adjust to the characteristics of learning outcomes in the material work and energy.

The achievement of work and energy learning for the Physics learning curriculum in Indonesia includes (a) analyzing the concepts of energy, work, work relations (work) and energy changes, energy conservation laws, and their application in everyday events; and (b) propose ideas for solving motion problems in daily life by applying scientific methods, energy concepts, work, and energy conservation laws. Based on operational verbs as outlined in the learning curriculum at the high school level, namely analyzing and proposing problem-solving, the development of indicators of critical thinking skills chosen in the cognitive realm in work and energy material are interpretation, analysis, evaluation, inference, and explanations (Table 1). The self-regulation indicators are included in the affective domain (Paul, R., and Elder, 2007). It does not become a part that is measured for the achievement of critical thinking skills on the material work and energy.

Table 1 can be described as the process of determining indicators for work energy material by looking for a list of indicators that are often used as a benchmark that the indicators have in common with the opinions of other experts. The five indicators have a relationship with learning achievement in work and energy materials. So an operational definition needs to be made to facilitate the measurement standards.

The first indicator is related to the interpretation. It has the same thought in determining the interpretation indicators in critical thinking skills (Dana S. Dunn, Jane S. Halonen, 2009) and (Facione, 2009), which is relevant to learning achievement in point a. Interpretation in work and energy learners is a process of understanding and expressing meaning or a broad meaning, various experiences, situations, data, events related to work and energy phenomena into language that is easily understood by others (Maknun, 2020; Yulianti *et al.*, 2019; Reynders *et al.*, 2020).

The second indicator is related to determine analytical indicators in critical thinking skills. These indicators are the basic characteristics of thinking skills (Bassham and Wallace, 2013; Crews-Anderson, 2007; Dana S. Dunn, Jane S. Halonen, 2009; Facione, 2009; Moon, 2007) relevant to the indicators of learning achievement of learning in point a. In other words, it is an analysis in the application of work and energy learners to identify the desired and actual inferential relationships among questions, concepts, descriptions, or other forms in the work and energy frame (Negoro *et al.*, 2020; Yulianti *et al.*, 2019; Reynders, Lantz, Ruder, Stanford, and Cole, 2020).

The Third, evaluation indicator, some experts have the same thought in determining evaluation indicators in critical thinking skills (Facione, 2009; Wallace, 2001) relevant to learning achievement of learning in point b. The evaluation itself can be applied in work and energy learners as a process of assessing a statement or information related to concepts contained in work and energy (Yulianti *et al.*, 2019; Reynders *et al.*, 2020).

The fourth indicator is related to inference. Some experts have the same thought in determining indicators of formulating hypotheses in critical thinking skills (Ennis, 1996) and (Dana S. Dunn, Jane S. Halonen, 2009) relevant to learning achievement of learning in point b. Formulating one's hypothesis can be applied in work and energy learners, identifying a phenomenon related to work and energy implementation to draw conclusions that make sense to form guesses or assumptions (Maknun, 2020; Reynders *et al.*, 2020).

The fifth is related to explanations indicator. Some experts have the same thought in determining explanatory indicators in critical thinking skills (Moon, 2007) and (Facione, 2009), relevant to learning achievement in point a. This

causes explanations to be applied in work and energy learners, to state and explain by considering the conceptual evidence of work and energy agreed to convince someone (Reynders *et al.*, 2020).

3.3. The basic principle of making a Test Instrument Critical thinking

After the indicator of critical thinking skills is determined, the next step is how to make the test instrument. The instrument is said to be good if it can evaluate or assess something with results following the objectives of critical thinking skills (Facione, 2009).

Based on both theoretical and research findings related to critical thinking skills, there were three basic principles in making critical thinking test instruments, namely (1) presentation of phenomena, (2) open-ended approach, and (3) measure rationality answer (Özsoy-Güneş *et al.*, 2015; Halpern, 2014b; Lawson, 2004; Willingham, 2008; Etkina and Planinšič, 2015; Sya'Bandari *et al.*, 2018) (Franco, Costa, and Almeida, 2018; Tiruneh *et al.*, 2017; Asmawati *et al.*, 2018; Mahbubah *et al.*, 2018; Negoro *et al.*, 2020; Istiyono *et al.*, 2019; Abidin, Istiyono, Fadilah, and Dwandaru, 2019; Sutarno *et al.*, 2019).

The phenomena are related to making tests in critical thinking based on events or phenomena around students (Özsoy-Güneş *et al.*, 2015; Halpern, 2014b; Lawson, 2004), and also events that have been experienced by students (Willingham, 2008; Etkina and Planinšič, 2015). The test can be in pictures, graphics, daily life events, and information from a media (Sya'Bandari *et al.*, 2018).

Second, the type of test, the design, is made in the form of an open-ended. This is because it gives more opportunity to express students' thinking strategies. Open-ended test questions can stimulate essential aspects of critical thinking like analyzing, rethinking, or generating new ideas (Franco, Costa, and Almeida, 2018; Franco *et al.*, 2018; Tiruneh *et al.*, 2017; Asmawati *et al.*, 2018).

Third, measure rationality answer. Critical thinking means someone has a reasonable explanation (Mahbubah *et al.*, 2018; Negoro *et al.*, 2020; Istiyono *et al.*, 2019; Abidin, Istiyono, Fadilah, and Dwandaru, 2019). Reasonable means the ability to think that tries to connect known facts into a conclusion (Ennis, 1996; Sutarno *et al.*, 2019; Abidin, Istiyono, Fadilah, and Dwandaru, 2019).

3.4. Framework Critical Thinking Work and Energy Test

The test is the final part of the learning process to measure learning achievement goals and learning activities (McTighe and Wiggins, 2012). A good test must measure the learning objectives that have been set (Ennis, R.H., Millman, J., Tomko, 1985). The framework for the development of this test was determined by considering the achievement of learning objectives on work and energy in measuring critical thinking skills. Critical thinking skills include five indicators (interpretation, analysis, evaluation, inference, and explanation). Each of these indicators will be developed in the form of tests with basic principles, including (1) presentation of phenomena, (2) open-ended questions, and (3) measure the rationality of student answers. The design flow conceptual framework development is shown in Figure 1.

3.5. Examples of the application of the development of the critical thinking skills test instrument for indicator analysis

The example of the application presented was taken from appendix 1 (item number 2) to analyze critical thinking skills indicators. For instance: Description: Look at Figure 2, a pendulum is dropped from point P. Pay attention to the movement of the pendulum. The movement starts from point P, going to Q, R, S, and finally going to T.



Figure 2. A pendulum is dropped from point P to T point

Question: Why do you think the pendulum never reaches the U-point?

Scoring guide: Grading Guide for item The following are the ideal complete answers that it was expected from the students:

- The difference in the height of the positions p and U affects the difference in potential energy. Or the potential energy at point U is greater than the potential energy at point P or vice versa. This is contrary to the law of

conservation of mechanical energy, namely the amount between potential energy and kinetic energy is always constant. (Substance score answer: 4 points)

- The potential energy at point U is greater than the potential energy at point P or vice versa. (Substance of the answer score: 3 points)
- There is a potential energy difference. (Substance of the answer score: 2 points)
- Altitude impacts potential energy. (Substance of the answer score: 1 point)
- Answering with a wrong concept or not responding. (Score: 0 points)

Information:

Analyze indicator, an indicator that explains the causal effect relationship in a particular phenomenon (Negoro *et al.*, 2020; Yulianti *et al.*, 2019; Reynders, Lantz, Ruder, Stanford, and Cole, 2020). The final goal in the problem presented is that students are asked to determine why the pendulum does not reach U-point.

Presentation of phenomena, providing information on the situation that has been experienced around students or experimental activities (Özsoy-Güneş *et al.*, 2015; Halpern, 2014b; Lawson, 2004; Willingham, 2008; Etkina and Planinšič, 2015). Presentation of the phenomenon in the example problem is the pendulum image that is given information P, Q, R, S, and T accompanied by the direction of the arrow

The open-ended approach gives students opportunities to express their ideas (Franco *et al.*, 2018; Franco *et al.*, 2018; Tiruneh *et al.*, 2017; Asmawati *et al.*, 2018). The form of the open-ended test in the example questions is the question sentence, "Why do you think the pendulum never reaches the U-point?"

Measure rationality answer, answers based on understanding concepts, in fact, to conclude (Mahbubah *et al.*, 2018; Negoro *et al.*, 2020; Istiyono *et al.*, 2019; Abidin, Istiyono, Fadilah, and Dwandaru, 2019; Sutamo *et al.*, 2019; Abidin, Istiyono, Fadilah, and Dwandaru, 2019). The form of rationality testing for each student's answer is a standard reference assessment guideline.

Five indicators of critical thinking skills that include interpretations, analyzes, evaluations, inferences, and explanations in the material business and energy in detail are explained in appendix 1.

4. CONCLUSIONS:

1. Indicators of critical thinking skills on work and energy include interpretation, analysis, evaluation, inference, explanation.
2. The basic principles of making critical thinking test instruments include presenting phenomena, open-ended tests, and testing the rationality of answers.
3. There was an example of applying the development of the critical thinking skills test instrument for indicator analysis.

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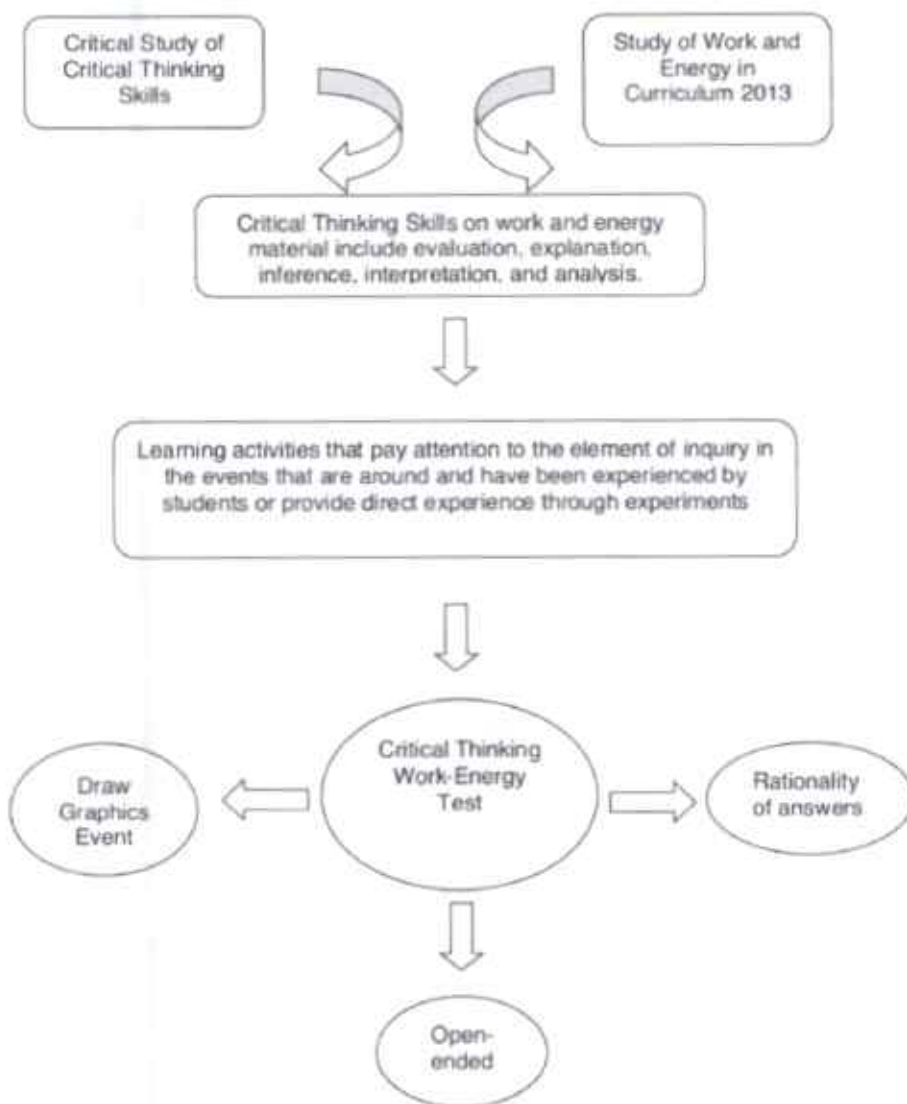


Figure 1. Conceptual Framework of Critical Thinking Work-Energy Test

Table 1. Determination of Critical Thinking Skills Indicators on Work and Energy Material

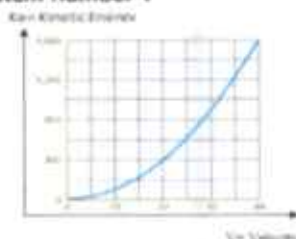
No	Literature	Indicator of Critical Thinking	Basic Competencies	Relevance Indicators
1.	Ennis, 1996	a. formulate a hypothesis b. question, c. alternative, d. and activity plan		
2.	Dana S. Dunn, Jane S. Halonen, 2009	a. Formulate a hypothesis b. conclusion, c. calculating possibilities,		Interpretation (Dana S. Dunn, Jane S. Halonen, 2009; Facione, 2009)
3.	Moon 2007	a. understanding analysis b. explanation	3.9 Analyzing the concepts of energy, work, work relations (work) and energy changes, energy conservation laws, and their application in everyday events	Analysis (Bassham and Wallace, 2013; Crews-Anderson, 2007; Dana S. Dunn, Jane S. Halonen, 2009; Facione, 2009; Moon, 2007)
4.	Crews-Anderson, 2007	Analysis Interpretation		
5.	Mason, 2009	Analysis		
6.	Willingham, 2008	Analysis		
7.	Dana S. Dunn, Jane S. Halonen, 2009	a. asking question, b. examine the evidence, c. analyze assumptions d. avoid emotional reasons, e. avoid oversimplification, f. interpretation, and g. tolerate uncertainty	4.9 Propose ideas for solving motion problems in daily life by applying scientific methods, energy concepts, work, and energy conservation laws	Evaluation (Bassham and Wallace, 2013; Facione, 2009)
8.	Bassham and Wallace, 2013	a. identify, b. analyze, and c. evaluate arguments, and d. truth claims;		Inference (Dana S. Dunn, Jane S. Halonen, 2009; Ennis, 1996)
9.	Facione, 2009	a. interpretation, b. analysis, c. evaluation, d. Inference, e. explanation f. self-regulation		Explanation(Facione, 2009; Moon, 2007)

APPENDIX 1

Example Assessment of Thinking Skills Tests on Work Materials and Energy

The application of making critical thinking tests of students in grade 11 high school students to provide an overview related to indicators, answer keys, and guiding guidelines which include indicators (1) Interpret the experimental data, (2) analyze kinetic energy, (3) evaluating work concept statements correctly, (4) making inference related to kinetic energy and (5) explaining the concept of kinetic energy.

A. Item number 1



Description of the problem

An object moving with a certain mass moves with a change in speed and then measured its energy value as a graph.

Question

What do you understand about the chart?

Information

Item number 1 measures one sub-skill in the element of critical thinking skills, namely **interpretation indicator**: Students Interpret experimental data on the relationship of kinetic energy with speed

(see Table 1). The figure is the observational data related to the relationship between speed and the kinetic energy produced.

Scoring guide: Grading Guide for item problem number 1

- The following are the ideal complete answers that the authors expect from a student:
With the same period, kinetic energy is proportional to the speed quadrant. (Substance of answer, score: 4 Point)
- The greater the speed, the kinetic energy also increases. (Substance score answer: 3 points)
- Kinetic energy is related to the speed of forming a curve. (Substance score answer: 3 points)
- Kinetic energy is determined by speed (Substance answer score: 3 points)
- Answering with a wrong concept or not answering. (Score: 1 point)

B. Item number 2



Description of the problem

A pendulum is dropped from point P, pay attention to the movement of the pendulum. The movement starts from point P, going to Q, going to S, and finally going to T.

Question

Why do you think the pendulum never reaches the U-point?

Information

Item number 2 measures one sub-skill in the element of critical thinking skills, namely **analyze indicator**: Students explore the kinetic energy in a pendulum (see Table 1). The item requires that why the pendulum removed does not exceed the initial height when the object was removed, associate the phenomenon with the laws of conservation of mechanical energy.

Scoring guide: Grading Guide for item problem number 2

- The following are the ideal complete answers that the authors expect from a student:
The difference in the height of the positions p and U affects the difference in potential energy. Or the potential energy at point U is greater than the potential energy at point P or vice versa. This is contrary to the law of conservation of mechanical energy, namely the amount between potential energy and kinetic energy is always constant. (Substance score answer: 4 points)
- The potential energy at point U is greater than the potential energy at point P or vice versa. (Substance of the answer score: 3 points)
- There is a potential energy difference. (Substance of the answer score: 2 points)
- Altitude impacts potential energy. (Substance of the answer score: 1 point)
- Answering with a wrong concept or not responding. (Score: 0 points)

C. Item number 3



Description of the problem

An employee in a company always chooses a sloping area to put goods into a car that has a high body. According to him this is due to the work needed to move objects lighter than directly lifting up.

Question

Do you think that the employee statement is true or false?

Information

Item number 3 measures one sub-skill in critical thinking skills, namely **evaluate indicator**. Students consider work concept statements correctly (see Table 1). The item requires that students criticize or evaluate the general statement that 'in the incline of the work required to move objects lighter than directly raised,' whether the principle is following the concept of work.

Scoring guide: Grading Guide for item number 3

- The following are the ideal complete answers that the authors expect from a student:
The statement of employees of works of lighter value compared to being directly lifted is not quite right. The work should be of the same amount. What is different is the style, the force required by the employee is lighter because the resultant force between the weight of the object and the normal force towards the back is lighter than the weight of the object. So the employee needs less force than the weight of the object. [Score: 4 points];
- The statement is not quite right. The right thing is the style is smaller because it forms an angle so that the style is smaller. (Substance of the answer score: 3 points)
- The statement is less precise, which is precisely the small force due to the length of the track. (Substance of the answer score: 2 points)
- The statement is incorrect. (Score: 1)
- Answering is not following the concept. Or not at all (Score: 0)

D. Item number 4

Description of the problem

Mima has three marbles with size difference

- a. Large marbles
- b. Medium-sized marbles
- c. Small marbles

Of the three marbles dropped with a height of 2 meters on the floor prepared plasticine to measure the depth of the marbles.

Question

Which marbles do you think to have the deepest basins?

Information

Item number 4 measures one sub-skill in the element of critical thinking skills, namely **interference indicator**. Students make hypotheses related to kinetic energy (see Table 1). The item requires that the phenomenon when marbles with different mass sizes are dropped at the same height impacts the speed of the law of conservation of mechanical energy.

Scoring guide: Grading Guide for item problem number 4

- The following are the ideal complete answers that the authors expect from a student:
The kinetic energy of the object determines the depth of the plasticine basin. The greater the kinetic energy of the plastic depth, the deeper the plastic basin. The amount of mass and speed determine kinetic energy. Kinetic energy is proportional to the mass and the speed of the quadrants. Therefore the greater the mass, the greater the kinetic energy. So that the biggest number one marble has the deepest basin. (Substance of answer, score: 4 Point)
- Depth will be different, differences in kinetic energy cause this. So that the most significant number one marble has the deepest basin. (Substance answer score 3)
- The most significant number one marbles have the deepest basins because they have the most prominent time. (Substance score answer: 2 points)
- Marbles number one. (Score: 1 point)
- Answering with a different concept or not answering (Score 0)

E. Item number 5.

Description of the problem

When riding a bicycle, when going down the bridge without us, the speed of the bike decreases faster and faster.

Question

Why do you think so?

Information

Item number 5 measures one sub-skill in the element of critical thinking skills, namely **explanation indicator**: Students explain the concept of mechanical energy (see Table 1). The item requires that the phenomenon when traveling downhill the speed gets bigger 'relate the phenomenon to the law of conservation of mechanical energy.

Scoring guide: Grading Guide for item problem number 5

- The following are the ideal complete answers that the authors expect from a student:
This is caused by the existence of the law of conservation of energy. in that case, there are three main concepts, namely potential energy, work, and kinetic energy, the amount when the main component is equal to the value of the object at maximum height. If the bicycle decreases, the amount of gravitational potential energy decreases to impact the magnitude of kinetic energy and work. (Substance of answer, score: 4 Point)
- This is due to the law of conservation of energy so that in time decreases, potential energy decreases, and kinetic energy increases. (Substance score answer: 3 points)
- This is due to the law of conservation of energy (Substance answer score: 2 points)
- Gravitational potential energy decreases (Score: 1 point)
- Answering with a different concept or not answering (Score: 0)

5. Sigit-Tukiran-Imam-Budi Jat (Co-Author)

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