ACTIVATION OF STUDENT RESOURCES REGARDING THE WORK-ENERGY THEOREM

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Abstract

Students' understanding of physics will increase along with learning during lectures, but thoughts on this understanding can be flexible and not always permanent, so it is necessary to explore other students' thoughts (resources) that may not have been discussed in previous research. This article focuses on the conceptual analysis of resources, namely the ideas they use in solving problems related to work-energy issues. This research aims to identify the resources used by physics students in work-energy reasoning as a work to explore students' new thoughts that have not been discussed in previous research. The research was conducted on 92 new physics department students in 2023 who took Basic Physics I lectures. Before the test was given, the lecturer gave a short review of the work-energy theorem to remind them of the knowledge they had learned in high school. The results of the research reveal that the resources that are widely used by students are (1) the concept of work in physics which is associated with the understanding of work in everyday contexts, namely as work/work/work, (2) in reasoning about motion phenomena involving potential energy and kinetic energy for students. directly apply the principle of conservation of mechanical energy. It is hoped that these findings will be useful input for lecturers in designing lectures on the topic of work-energy theorem based on resource theory or knowledge in pieces.

Keywords: Energy, Resource, Work.

INTRODUCTION

Understanding students' thinking in solving problems has received a lot of attention from researchers in the field of physics education, especially research that targets students' thinking that is not in line with physics. Various labels have been attached to this wrong thinking according to their respective nuances; including misconceptions (Docktor & Mestre, 2014; Hull et al., 2022), alternative conceptions (diSessa, 2015), and naïve theories (Docktor & Mestre, 2014). Misconceptions view students' wrong ideas as something rigid and stable where these ideas have been held by students for a long time (Docktor &
Mestre, 2014), so they will be difficult to change (Makhrus & Busyairi, 2022).

An alternative conception considers students' ideas as knowledge fragments that are developed repeatedly based on personal intuitive knowledge that is strongly believed by students and not from formal scientific knowledge (DiSessa, 2015). Meanwhile, the naive theory views students as building knowledge based on direct interaction and insight into the world and not based on scientific discussions or knowledge (Latham, Miller, & Norton, 2021). Often the naive theories built by students contain misunderstandings that conflict with scientific concepts (Docktor & Mestre, 2014). The results of the exploration of wrong thinking are then used as input for designing more effective learning to improve students' knowledge structures.

There are two genres of theory that have developed in physics education research to improve students' knowledge structures, namely misconception theory and resource theory or knowledge in pieces (Docktor & Mestre, 2014). Adherents of the misconception theory believe that students' wrong thoughts are rigid, stable, difficult to change, and tend to interfere with students' reasoning in physics correctly (Docktor & Mestre, 2014). This element of incorrect knowledge is then labeled a misconception, because misconceptions are firmly embedded in students' knowledge structures and tend to disrupt students' thinking, the most effective way to overcome them is to apply cognitive conflict strategies (Parwati & Suharta, 2020), by diagnosing misconceptions, finding out the reasons, and carrying out remediation (Ilyas & Saeed, 2018).

Even though the theoretical framework seems very reasonable, it is not an easy process to replace the understanding that students previously had with new knowledge that is considered foreign, because a high level of dissatisfaction is required so that the previously incorrect understanding can be replaced with knowledge that is more scientifically appropriate (Docktor & Mestre, 2014).

On the other hand, resource theory views the emergence of wrong thinking as solely because students activate elements of knowledge that are less suited to the problem at hand (Docktor & Mestre, 2014; Richards et al., 2020). Apart from that, resource theory believes that the wrong thoughts shown by students are not always strong/permanent so they must be removed from the student's knowledge structure as believed by adherents of misconception theory (Richards et al., 2020). Resources view that students' daily thinking involves a lot of cognitive resources that they can activate at any time (Wood et al., 2014). Therefore, supporters of the resource model believe that students do not experience misconceptions but only apply conceptions that are not appropriate for the given problem, but which may be useful in a different context (Wood et al., 2014). The main research agenda of resource theory adherents is to identify student ideas that are productive and potentially useful but are applied inappropriately (Docktor & Mestre, 2014), so that the direction of learning will be to build and perfect student intuition (Harrer et al., 2013). In other words, the resource theory research agenda emphasizes...
attention to students' specific ideas that emerge at that time (Sabo et al., 2016).

Both misconception theory and resource theory view students not coming to class with empty heads or "blank slates" (Hammer, 2000). Rather, they already have knowledge built on their experience in understanding everyday physical phenomena (Docktor & Mestre, 2014; Hammer, 2000). These students' knowledge often conflicts with scientific concepts (Docktor & Mestre, 2014). For example, based on the experience of observing the falling motion of two objects of different weights, a stone and a chicken wings, students develop a mistaken understanding that a heavier object will fall at a higher speed than a lighter object. Because the development process is like that, researchers label this informal thinking as naïve thinking or naïve theory (Docktor & Mestre, 2014). The author tends to use the label naïve theory for the student's wrong thinking.

Naïve theory in this context refers to students' initial understanding which is developed based on their experiences in everyday life without involving deep thinking and often contradicts correct scientific concepts (Parwati & Suharta, 2020). In other words, when faced with physical phenomena, students have built relatively coherent naïve theories based on everyday experiences (Vosniadou & Skopeliti, 2014). In accordance with the general view among physics education researchers which states that students build new knowledge based on previous knowledge obtained from everyday experience (Parwati & Suharta, 2020). Naïve theory focuses more on handling student misunderstandings without considering that students' daily experiences may have the potential to provide support for the development of their understanding (Docktor & Mestre, 2014; Young & Meredith, 2017). This means that students' naïve ideas should be an important element that is useful for constructing new knowledge, but naïve theory does not provide this explanation (DiSessa, 2015; Hammer, 1996a; Smith III et al., 1994).

As stated by Richards et al. (2020), in the case of the ball being thrown vertically upwards, students identify that there is a downward gravitational force and an upward throwing force by the hand which over time will disappear during the upward movement. However, when asked about what happened at the top point, students thought the ball stopped because the force thrown by the hand was the same as the force of gravity. This student's statement contradicts the statement they gave previously, making it difficult to express an explanation based on a naïve theoretical perspective, because strong conceptions tend to be difficult to change. Alternatively, researchers can view students' thoughts regarding the throwing force by the same hand as the gravitational force at the top as activating knowledge related to dynamic balance (Richards et al., 2020). Then, when there is a contradiction in activating the "dying away" knowledge, students may intend to use it to reason about force. Students can also activate "dying away" to refer to speed or kinetic energy, in this way knowledge activation is considered more productive (Richards et al., 2020). So instead of viewing students'
naïve thinking as mistakes that hinder the learning process, viewing naïve thinking as potential knowledge that can be utilized can be key in planning further learning (Young & Meredith, 2017).

The use of the term naïve thinking brought by students in this context can refer to all the ideas students think that can function as good input in the process of conceptual growth (Bereiter, 1985). So the question that arises here is which previous knowledge built from everyday life do students use to think? (Smith III et al., 1994). This tendency of thinking is known in the resource view, the truth of which depends on the context in which they are applied (Docktor & Mestre, 2014). Apart from that, it also depends on students' awareness of situations that require decision making about which knowledge to activate (Klein et al., 2021). Even though the concept is the same, if it is applied to a different context and makes small changes to the context it will produce different responses, answers, reasoning patterns and explanations from students.

The resource perspective also views students' naïve ideas as a "way in" into students' thinking, to develop more sophisticated understanding (Sabó et al., 2016). Therefore, this research is directed at examining students' thoughts and ideas from a resource perspective. The resource perspective places greater emphasis on productive thinking which reflects progress in students' mastery of concepts. On the other hand, it also encourages educators to design learning that utilizes resources productively (Docktor & Mestre, 2014) and allows students to make progress (Young & Meredith, 2017).

As stated by Kaniawati et al. (2019), students tend to think that work caused by friction is always negative in various situations. Halilović et al. (2021) revealed that students tend to apply the same mindset when answering problems related to work caused by frictional forces on smooth and rough inclined planes. Students hardly realize that there is a frictional force acting on a rough inclined plane. Then Liu & Fang (2023) in their research revealed that there were errors among students in understanding the magnitude of distance and displacement when determining work. For example, to calculate the work done by the force of a spring, students use the length of the spring as a substitute for the displacement of the spring (Liu & Fang, 2023). Based on the explanation above, researchers are more inclined to reveal students' thinking from the perspective of conceptual errors. This conceptual error or commonly known as naïve theory is framed as an obstacle that must be overcome in order to master the correct concept, which has been the focus of much previous research (Halilović et al., 2021; Kaniawati et al., 2019; Liu & Fang, 2023; Permatasari et al., 2018).

Researchers are interested in understanding the resources that students tend to activate in work-energy reasoning and applying them appropriately in various contexts, because work-energy is the most fundamental concept in physics (Singh & Rosengrant, 2003), because work-energy has an important role in many concepts such as projectile motion analysis, Hooke's Law, Fluid
Mechanics, and Quantum Mechanics. Several previous researchers have studied student resources on the work-energy concept in general (Sabo et al., 2016; Sparaciari et al., 2017). However, there are still few who study the work-energy theorem specifically and look at students’ thinking from a resource perspective. So to fill this gap, this research is focused on identifying student resources related to the work-energy concept specifically in Newtonian mechanics. This research aims to analyze the resources used by physics students when reasoning about the work-energy concept. Recognizing and identifying the resources that students activate when solving work-energy problems can also help educators in designing further learning.

METHOD

This research uses a qualitative research design with a one shot case study method (Creswell & Plano Clark, 2018). The research was conducted on 92 new physics department students in 2023 who had previously received work-energy material in high school. Even though a review has been given in the Basic Physics I lecture, there has not been an in-depth discussion. Research was conducted to analyze students' thoughts regarding the concept of work-energy based on the resources they use to solve problems. Resources can be seen through a conceptual assessment process that has previously been developed and has gone through a previous research validation process. This conceptual assessment can play a role in documenting the thoughts used by students in reasoning about the work-energy concept. The conceptual assessment is given in the form of multiple-choice questions with each choice option reflecting the resources they use in reasoning about work-energy. There are other alternative options as additional options to include student thoughts that are not yet included in the available options.

Data was obtained through students' concept mastery test questions, which consisted of 18 multiple-choice questions with each choice arranged based on resources that might be used by students. For example, in question number 3, students are faced with three factors that determine the work done by gravitational force when lifting a suitcase from the floor to a table, including how to lift it directly or using an inclined plane, the speed at which it is lifted, and the height of the table from the floor. Option (a), namely how to lift the suitcase via an inclined plane or directly, is one of the factors that determines the amount of work done by the gravitational force on the suitcase. Students who choose option (a) tend to activate work resources based on the term work in daily physical activities, such as exerting greater force means doing greater work. Compared to pulling a suitcase using an inclined plane, a person needs much more force to lift the suitcase directly onto the table.

Option (b) is that the amount of work done by the Earth's gravitational force only depends on the change in height, not on the vertical position. Option (b) shows the resource linkage between work by gravitational force and potential energy and the relationship \( W_{\text{gravity}} = mgh_1 - mgh_2 = -(mgh_2 - mgh_1) = -\Delta Ep \) is obtained. Option (c), namely the way of lifting and the height of the table are factors...
that determine the amount of work done by the earth's gravitational force. Option (c) shows the activation of work resources by the earth's gravitational force correctly so that it chooses the third statement (table height from the floor). However, ideas regarding how to lift a suitcase obtained based on students' daily experiences will become obstacles for students in reasoning, so that the knowledge they use will be inconsistent.

Option (d), namely lifting speed and height are factors that determine the work done by the gravitational force on the suitcase. Option (d) represents the resource, the greater the speed of lifting the object, the greater the work that needs to be exerted. The tendency for students to think like this is obtained based on an understanding of the relationship between Newton's Law $\sum F = m.a$ and the definition of work $W \equiv F \cdot s$, so that students think that increasing speed when lifting an object can be interpreted as increasing the force applied, all of which can influence the amount of work done.

The questions are adapted from the Energy Concept Assessment (ECA), Energy and Momentum Conceptual Survey (EMCS), Mechanics Baseline Test (MBT), all of which can be downloaded on the Physport website (https://www.physport.org/assessments/). The main ideas of work-energy that students need to master include the work-kinetic energy theorem, work-potential energy theorem, work-mechanical energy theorem.

Table 1. Distribution of work-energy concepts.

<table>
<thead>
<tr>
<th>Topics</th>
<th>Concept Application</th>
<th>Question Number</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Definition</td>
<td>Analyze the concept of work as a dot product between the force acting on an object and its displacement</td>
<td>1</td>
<td>ECA, EMCS</td>
</tr>
<tr>
<td>Work-Kinetic Energy Theorem</td>
<td>Apply the work-kinetic energy theorem to solve mechanics problems in rectilinear motion</td>
<td>2</td>
<td>EMCS, MBT</td>
</tr>
<tr>
<td>Work by Earth's Gravity</td>
<td>Analyzing the effect of work by the Earth's gravitational force on changes in the potential energy of objects</td>
<td>3,4</td>
<td>EMCS</td>
</tr>
<tr>
<td>Work-Mechanical Energy Theorem</td>
<td>Applying the Work-Mechanical Energy Theorem to systems without any influence of work by external forces</td>
<td>5,6</td>
<td>EMCS</td>
</tr>
<tr>
<td></td>
<td>Applying the Work-Mechanical Energy Theorem to systems influenced by external forces</td>
<td>7,8</td>
<td>EMCS</td>
</tr>
</tbody>
</table>
Test result data is grouped based on student answer choices that are similar to each choice option that represents their thinking. Next, descriptive data analysis was carried out based on the resource theory framework that frames students' thinking as something potentially useful based on experiences and phenomena they encounter every day (Richards et al., 2020). Next, it is presented in percentage and descriptive form to map the resources that students generally activate to solve work-energy problems.

RESULT AND DISCUSSION

This research aims to analyze the conceptual resources that students activate in work-energy reasoning. Students resource activation is grouped based on student answer choices during the test and is presented in percentage form.

Question number 1 contains the concept of defining work, namely the dot product product between force and displacement. In item number 1, students are asked to calculate the value of each work on a system consisting of people and an elevator moving upwards at a constant speed. To find out the resource that students activated in solving problem number 1, the distribution of students answers in presented in Table 2.

According to Table 2, the majority of students (45.65%) have succeeded in activating resources correctly according to the context related to positive, negative and zero value works. Meanwhile, there are 20.65% of students think that when an elevator goes up, the work done by the elevator floor and Earth's gravity on people is zero. Students' responses to this problem show the activation of the resources they use, namely considering force as the value of work. Activation of this resource is triggered by their memories and knowledge regarding Newton's First Law ΣF=0, where there are two forces (normal force and earth's gravity) acting on people whose directions are opposite so that the resultant of the two forces is zero. This resource is scientific, but it is not appropriate to use it to solve the context of the problem presented.

Another resource that was activated by 5.43% of students was related to work as a vector parameter, where if it is in the direction of the positive axis, the work is positive and otherwise. Students tend to consider positive and negative values of a quantity as characteristics of a vector that reflects the direction of movement of an object at a point. However, work resources as vector parameters are not appropriate to use to determine positive, negative and zero values for work because work is not a vector quantity. It seems that students need to remember the definition of work as the result of multiplying the dot product between force and displacement, where multiplying the dot product between two vectors will produce a scalar quantity and not a vector.

Table 2. Percentage of Student Answer to Question Number 1

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>A (%)</td>
<td>20.65</td>
</tr>
<tr>
<td>B (%)</td>
<td>11.96</td>
</tr>
<tr>
<td>C (%)</td>
<td>15.22</td>
</tr>
<tr>
<td>D (%)</td>
<td>45.65</td>
</tr>
<tr>
<td>E (%)</td>
<td>5.43</td>
</tr>
<tr>
<td>F (%)</td>
<td>0.00</td>
</tr>
</tbody>
</table>
There are also 11.96% of students who activate work resources by a gravitational force whose value is always negative. It seems that students who activate resources related to work by the force of gravity which always has a negative value, use information on work by the earth's gravitational force $W_{\text{gravity}} = -\Delta E_p$ in solving problems. Even though students succeeded in activating work resources by the Earth's gravitational force and these resources were scientific, the connection was not correct, resulting in wrong answers (DiSessa, 2018; Wood et al., 2014). The positive, negative, and zero values of work depend on the angle between the force and the displacement. If the force acting is in the same direction as the displacement (forming an angle of $0^\circ$) then the work is positive, if it is opposite (angle of $180^\circ$) the work is negative, and if it is perpendicular (angle of $90^\circ$) the work is zero (Halliday et al., 2013).

Table 3. Percentage of Student Answer to Question Number 2

<table>
<thead>
<tr>
<th></th>
<th>A (%)</th>
<th>B (%)</th>
<th>C (%)</th>
<th>D (%)</th>
<th>E (%)</th>
<th>F (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.17</td>
<td>15.22</td>
<td>18.48</td>
<td>28.26</td>
<td>17.39</td>
<td>8.70</td>
</tr>
</tbody>
</table>

In question number 2, students are asked to reason using the concept of work-kinetic energy to solve mechanics problems in rectilinear motion. In question number 2, students are asked to calculate the amount of work done by each force and the total work acting on a box that is pulled along a horizontal surface at a constant speed. To find out the pattern of student resource activation in solving problem number 2, the distribution of student answers is shown in Table 3.

According to Table 3, most students (28.3%) chose option (d) and thought that the work done by the pushing force was the same as the work done by the friction force but in the opposite direction and thought that the total work was positive. Students who choose this option tend to activate the total force resource as the work value, so that they assume there is work done by the total force in the direction of the object's motion. Similar things were also found in research (Singh & Rosengrant, 2003). The thoughts of students who choose this option seem inconsistent, because the two statements are contradictory. In the first statement, namely the work done by the pushing force is the same as the work done by the friction force but in the opposite direction, it has been shown that a constant speed result in the value of the change in kinetic energy is equal to zero. However, when they move on to the second statement, namely the total work is positive, students are trapped by the illustration of a box moving to the right and consider the total force to be the value of the work so they think that the total work is positive. Students who use this resource tend to ignore changes in kinetic energy in the box.

There are also several new resources activated by students that have not been found in previous research and have been revealed in this research. Among them, 2.17% of students think that work caused by gravitational force is positive. This student seems to be activating positive value resources as indicated by the orientation of the gravitational force which is in accordance with the
orientation of the earth's gravity (downwards) itself, so that his works have a positive value. In other words, students have the view that the gravitational force works along the direction of the box's movement, and the work done by the gravitational force is considered positive.

Then 15.2% of students thought that the work done by the pushing force was the same as the work done by the friction force but in the opposite direction. Students who choose this option successfully activate the work-kinetic energy theorem resource correctly according to the context of \( W_{\text{total}} = \Delta E_k \), namely because the box is moving at a constant speed, the change in kinetic energy is equal to zero. So the work done by the pushing force of the hand is equal to the negative work done by the friction force. There were also 8.7% of students who activated other resources that had not been accommodated in the selected options. Students who choose this other option include their thoughts that the work caused by the gravitational force is negative, the work done by the pushing force \( F \) is not the same as the work done by the friction force, and the total work is not positive. This student tends to activate resources work by gravitational force is always negative. Then the students also activate the resource because the box moves to the right, there is a total force whose direction is in the same direction as the direction of movement, which causes the amount of work done by the pushing force to not be the same as the work done by the friction force. Students who activate this resource also seem to think of force as work.

Resources related to the influence of work caused by the Earth's gravitational force on changes in the potential energy of objects are contained in questions number 3 and 4. To see how student resources are activated in solving problems number 3 and 4, the distribution of student answers is presented in Table 4.

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>18,48</td>
<td>19,57</td>
</tr>
<tr>
<td>B</td>
<td>18,48</td>
<td>9,78</td>
</tr>
<tr>
<td>C</td>
<td>39,13</td>
<td>14,13</td>
</tr>
<tr>
<td>D</td>
<td>7,61</td>
<td>34,78</td>
</tr>
<tr>
<td>E</td>
<td>13,04</td>
<td>11,96</td>
</tr>
<tr>
<td>F</td>
<td>1,09</td>
<td>4,35</td>
</tr>
</tbody>
</table>

In question number 3, students are faced with three factors that determine the work done by the gravitational force when lifting a suitcase from the floor to a table, including how to lift it properly, directly or using an inclined plane, the speed of lifting it, and the height of the table from the floor. There are 18.5% of students who choose option (a) and think that lifting the suitcase via an inclined plane or directly is one of the factors that determines the amount of work done by the gravitational force on the suitcase. Students who choose option (a) tend to activate work resources based on the term work in daily physical activities, such as exerting greater force means doing greater work. Compared to pulling a suitcase using an inclined plane, a person needs much more effort to lift the suitcase directly onto the table. The resources that students activate are obtained from their daily experience or knowledge regarding how to lift objects using an inclined plane or lifting them directly.
As many as 18.5% of students have succeeded in activating the work resource by Earth's gravity correctly according to the context of the problem and chose option (b), where the amount of work by Earth's gravity only depends on changes in height, not on vertical position. If it is related to potential energy, we get the relationship $W_{\text{gravity}} = mgh_1 - mgh_2 = -(mgh_2 - mgh_1) = -\Delta E_p$. Meanwhile, the majority of choices fell on option (c), namely 39.1% of students thought that the way the table was lifted and the height of the table were factors that determined the amount of work done by the earth's gravitational force. Maybe students have succeeded in activating resources work by the Earth's gravitational force correctly so they choose the third statement (height of the table from the floor). However, ideas regarding how to lift a suitcase obtained based on students' daily experiences will become obstacles for students in reasoning, so that the knowledge they use will be inconsistent (Wood et al., 2014).

Then 7.60% of students chose option (d) where lifting speed and height were the factors that determined the work done by the gravitational force on the suitcase. Students who choose option (d) activate the resource, the greater the speed of lifting the object, the greater the work that needs to be exerted. The tendency for students to think like this is obtained based on an understanding of the relationship between Newton's Law $\Sigma F = m.a$ and the definition of work $W \equiv F.s$, so that students think that increasing speed when lifting an object can be interpreted as increasing the force applied, all of which can influence the amount of work done.

The knowledge that students activate is scientific, but it should be noted that speed itself is not a parameter that influences the amount of work done by the force of gravity.

Furthermore, there were 1.09% of students who chose the other option, where they thought that the factors that influence the amount of work done by the Earth's gravitational force on the suitcase are distance and speed. Students who choose this option tend to activate the work definition resource $W \equiv F.s$ and the work-kinetic energy theorem $W = \Delta E_k = \frac{1}{2} mv^2$ but less precisely. Students tend to plug and chug and indicate entering equations that have been embedded in their minds without understanding how these equations are suitable for solving the problem (Wood et al., 2014).

In question 4, two cases of problems are presented for pulling a block with a rope vertically upwards or pulling a block along an inclined plane without friction. Students are asked to choose the correct statement regarding the amount of tension in the rope and the work done by the rope between the two cases. Referring to Table 4, only 14.1% of students chose option (c), only 14.1% of students chose option (c) and succeeded in answering the question correctly. On the other hand, 19.6% of students chose option (a) the tension force on the rope in the first case (pulling the rope vertically) was smaller than in case 2 (using an inclined plane without friction). Students who choose option (a) think that the force in the first case only has 1 component which is parallel to the direction of displacement so that the tension force in the rope is considered smaller than in case 2 which has 2 force components.
Then 9.78% of students chose option (b) and thought that the amount of tension in the rope in both cases was the same. Students who choose this option may tend to assume that the tension force in the string must always be balanced by the gravitational force mg to maintain a constant speed. Activation of this resource also appears to be based on students' understanding of Newton's First Law $\sum F = 0$ and thinking that the tension force in the rope, both on an inclined and vertical plane, is the same as the weight of the block (mg). They tend to ignore the fact that there are two components of the tension force in a rope on an inclined plane, a perpendicular component, namely $T \sin \theta$, and a parallel component, namely $T \cos \theta$.

Another resource that was activated a lot by students was 34.8%, where choosing option (d) the work by the rope in case 2 was smaller than in case 1. Students who choose option (d) tend to think that they often relate the amount of force exerted on an object to the value of the work produced. In the context of an inclined plane, they tend to think that because the tension force is smaller, the work done by the tension or gravitational force should also be lower. This phenomenon has also been observed in Singh & Rosengrant, (2003) research, which highlights students' difficulty in distinguishing between the magnitude of an applied force and the work produced by that force. Furthermore, 11.9% of students chose option (e), namely the work done by the gravitational force in case 2 is greater than in case 1. Students who chose option (e) might reason using $W = F.s$ and think that in case 2 the gravitational force acts on the track, which is longer than route 1. This student indicated that activating the resources of the longer route resulted in greater work. The difference in the number of students who think effort depends on the trajectory between numbers 3 and 4 is almost twofold, indicating that students' knowledge depends on context. These results are strengthened by statements from several researchers such as A. DiSessa, (2018); Docktor & Mestre, (2014); and Wood et al., (2014), who emphasized that resource theory views students' knowledge structures as dynamic and easily changing according to context.

Questions related to the Work-Mechanical Energy Theorem in systems without the influence of work by external forces are contained in question numbers 5 and 6. To gain an understanding of how students activate resources when solving problems number 5 and 6, the distribution of their answers is presented in Table 5.

<table>
<thead>
<tr>
<th></th>
<th>Answer to Question Number 5</th>
<th>Answer to Question Number 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (%)</td>
<td>45.65</td>
<td>15.22</td>
</tr>
<tr>
<td>B (%)</td>
<td>3.26</td>
<td>17.39</td>
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<tr>
<td>C (%)</td>
<td>29.35</td>
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<tr>
<td>D (%)</td>
<td>1.09</td>
<td>13.04</td>
</tr>
<tr>
<td>E (%)</td>
<td>16.30</td>
<td>45.65</td>
</tr>
<tr>
<td>F (%)</td>
<td>0.00</td>
<td>2.17</td>
</tr>
</tbody>
</table>

In question number 5, the problem of two skateboards with the same height but different levels of steepness is presented. Students are asked to determine the highest speed experienced by them. when a person slides from the bottom point while standing still between the two skateboards. Most students (45.7%) chose option (a) and thought that the highest speed was possessed by people who faced steeper slopes because there
was an opportunity to speed up. Students who choose option (a) tend to think that steep slopes have greater gravity, making people slide at high speeds. These resources are activated based on everyday experience, such as when using slides or curved water rides, it is often seen that objects move faster on curved paths. These resources are a form of conceptual structure that students have based on previous experiences when they interact with the physical world (Hammer, 1996b; Richards et al., 2020). This perspective is in line with the views expressed Silseth, (2018), which states that knowledge becomes more meaningful for students when they can relate it to everyday experiences. In other words, students tend to look for connections between the knowledge they learn and the realities of life to facilitate understanding and retention of these concepts. Even though the resources activated are based on everyday experience, this thinking does not properly take into account physics. Based on the resource perspective, the idea "objects move faster in curved paths" obtained from everyday experience is seen as the beginning of more normative ideas (Disessa, 1993), rather than an obstacle to learning (Scherr, 2007).

Then 3.26% of students chose option (b) and thought that people who slide on steep slopes cover a longer distance so there is no opportunity to speed up. Students who choose this option may activate the resource "moving objects gradually decrease in speed" based on daily experience where they realize that moving objects will eventually stop. Activation of this resource is based on the concept of friction force which is embedded in students' memories. It seems that the student ignored the fact that both skateboards are slippery, so there should be no friction force that hinders people's movements when sliding.

Furthermore, 29.3% of students chose option (c), namely the highest speed on the first skateboard because the skateboard they were traveling on had a constant trajectory so they had the opportunity to speed up. Students who choose option (c) seem to relate speed to the slope of the track, thinking that a constant track has the opportunity to continue to accelerate the movement of the person sliding. This is different when compared to the trajectory on the second skateboard which, although initially steep, eventually becomes sloping, which might be interpreted as a lost opportunity to maintain or increase speed.

1.09% of students thought that when traveling a short distance, people would arrive faster, so they would not lose too much speed compared to a longer route. Students who activate this resource may tend to misinterpret the time needed to travel along the track to a certain point and the speed at a certain point. Then only 16.3% of students succeeded in solving the problem correctly and chose option (e). Students who choose option (e) succeed in identifying that the only force acting on the object is the gravitational force, so the total work is all work done by internal forces, so the work done by external forces is zero. As a result, the change in kinetic energy is equal to the negative change in potential energy, \( W_{\text{External}} = \Delta E_k + \Delta E_p \), because the initial height and speed of the person on both
skateboards are the same, the final speed of both is also the same.

In question number 6, the problem of two identical stones being shot from a cliff with the same height and the same initial speed is presented. The first stone is shot vertically upwards while the second stone is shot vertically downwards. Students are asked to determine which stone has the higher speed. The distribution of student answers to questions number 6 is presented in Table 6 to provide an overview of student resource activation in solving these problems.

<table>
<thead>
<tr>
<th>Question Number 6</th>
<th>A (%)</th>
<th>B (%)</th>
<th>C (%)</th>
<th>D (%)</th>
<th>E (%)</th>
<th>F (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.22</td>
<td>17.39</td>
<td>2.17</td>
<td>13.04</td>
<td>45.65</td>
<td>2.17</td>
</tr>
</tbody>
</table>

15.2% of students have succeeded in using the concept of mechanical work-energy correctly and chose option (a), namely that both stones have the same speed. Then 17.4% of students chose option (b) and thought the first stone had a higher speed because it took a longer path. Students who choose option (b) use their understanding of the equation $\Delta v = \Delta s / \Delta t$ where the greater the distance traveled, the greater the speed.

Most students (45.7%) chose option (e) and thought that the second stone had a higher speed because there was no work working against the force of gravity. Students who choose option (e) call on their understanding of kinetic energy and potential energy, where students may understand that when the first stone is thrown upwards, its kinetic energy decreases and is converted into gravitational potential energy when the stone reaches its maximum height. Then when the stone falls again, the gravitational potential energy is converted back into kinetic energy, but some of the kinetic energy may be lost due to air resistance so that the speed of the first stone is smaller than the second stone.

Based on the results of the analysis of problems number 5 and 6, it appears that in solving the Mechanical Work-Energy problem in a system without the influence of work by external forces, students tend to activate resources that are inappropriate and easy to change according to the context of the problem at hand. In a resource perspective, the tendency to think like this, as explained by (Docktor & Mestre), is very dependent on the context in which the thinking is applied.

Questions number 7 and 8 contain the Work-Mechanical Energy Theorem on systems that are influenced by external forces. The distribution of student answers to questions number 7 and 8 is presented in Table 7 to provide an overview of student resource activation in solving these problems.

<table>
<thead>
<tr>
<th>Question Number 7 and 8</th>
<th>A (%)</th>
<th>B (%)</th>
<th>C (%)</th>
<th>D (%)</th>
<th>E (%)</th>
<th>F (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>4.35</td>
<td>36.96</td>
<td>4.35</td>
<td>35.87</td>
<td>6.52</td>
<td>2.17</td>
</tr>
<tr>
<td>8</td>
<td>20.65</td>
<td>26.09</td>
<td>16.30</td>
<td>4.35</td>
<td>5.43</td>
<td>15.22</td>
</tr>
</tbody>
</table>

Question number 7 is given the problem of three cyclists on a hill, Cyclist 1 lets his bicycle go up the hill
without pedaling, so that his bicycle slides up more and more slowly, and cyclist 2 continues to pedal his bicycle up the hill so that the speed is constant, rider 3 pedals harder, so the bike goes faster up the hill. Students are asked to choose a driver with constant total mechanical energy if ignoring the effects of friction. Only 4.3% of students chose option (a) where rider 1 has fixed mechanical energy and succeeded in solving the problem correctly using the definition of mechanical energy EM = Ek+Ep. Students who choose option (a) can understand that when the bicycle is allowed to slide up a hill without pedaling and the movement becomes slower and slower, the amount of kinetic energy will decrease while the amount of potential energy will increase as the bicycle moves because h is getting higher. So the total mechanical energy of cyclist 1 is constant.

Then 37% of students chose option (b) where rider 2 is the one who has constant mechanical energy. Students who choose option (b) seem to activate a constant speed resource indicating constant or conservation mechanical energy. However, actually in the case of rider 2, when the rider's speed is kept constant, it is true that the kinetic energy is constant, but the amount of potential energy will increase as the bicycle moves because h is getting higher. Then the mechanical energy of driver 2 will increase.

In question number 8, the problem of a beam sliding on an inclined plane is presented. Students are asked to find the average friction force exerted by the surface of the board on the beam where, right when it touches the bottom of the floor, the beam has a certain kinetic energy. 4.3% of students chose option (d) and used the Law of Conservation of Mechanical Energy to solve the problem. 5.43% of students activate work resources as the product of force and displacement, the average friction force can be calculated using the equation \( W_{\text{friction}} = F \cdot s \), where s is the distance traveled by the block (the length of the inclined board) and the work done by the friction force is calculated from the mechanical energy equation. The work-mechanical energy theorem resources and definitions of work activated by these students are scientific, but they only apply mathematical equations in a plug-and-chug manner without understanding in depth the concepts behind them. Likewise, 26.1% of students only rely on mathematical memorization, without understanding the underlying concepts. Here students activate the work-kinetic energy resource \( W_{\text{total}} = \Delta EK \) in solving the problem, but there is an error when interpreting \( W_{\text{total}} \) as work caused by friction alone.

As many as 4.35% of students were able to activate the mechanical work-energy resource correctly according to the context, but there were errors in interpreting the work caused by the friction force as the value of the friction force itself. In the context of this problem, when we talk about "work by friction force," we are referring to the work done by friction force during the movement of the block on an inclined board. Then only 15.3% of the 92 students were able to activate the resource appropriately according to the context, namely using the external mechanical work-energy theorem.
$W_{\text{external}} = \Delta EM$, where work by external external forces is the forces that act on the system other than gravitational force.

Based on the results above, it appears that students tend to activate the Law of Conservation of Mechanical Energy resource in solving all problems. This finding is also supported by research by Lindsey et al. (2009) which shows that in applying the mechanical work-energy theorem, students tend to apply conservation of mechanical energy to answer all problems, without considering whether these assumptions are appropriate to the context of the problem at hand. Based on a resource theory perspective, when students call on knowledge related to the Law of Conservation of Mechanical Energy, this is not completely wrong, but this thinking still needs to be refined (Elby, 2001) and adapted to the context of the problem (Docktor & Mestre, 2014).

Students need to verify whether the law really applies in the context of the problem at hand, such as considering the forces acting on the system, and whether there is external work other than work by the gravitational force acting on the system. Students' thinking can be refined through their intuitive ideas regarding the Law of Conservation of Mechanical Energy, which actually only applies if kinetic energy and potential energy are constant. Meanwhile, in a context where these two energies change, the Law of Conservation of Mechanical Energy does not apply. In this case students are guided to find appropriate ways to integrate appropriate knowledge into their thinking (Scherr, 2007).

CONCLUSION AND RECOMMENDATION

The researchers discovered that students’ comprehension remained fragmented, often relying on incomplete memories of prior concepts without proper interpretation, based only on intuition about daily phenomena. Analysis of test result data shows that when reasoning about work, students tend to activate work resources based on the term work in daily physical activity, such as exerting greater force means doing greater work. Then some others interpret the work done by particular force as the value of the force itself. Mistakes in understanding this difference need to be clarified in further study to understand this basic concept better.

The resources that students activate in various contexts indicate that the same ideas may appear in many knowledge contexts. Resource also describes learning in terms of reorganizing, refining, and activating concepts in appropriate contexts. Researchers hope that these findings can expand educators' knowledge and increase physics education research literacy regarding the resources most frequently activated in the work-energy concept. Considering the context of the problem has a big influence on which resources are activated by students. Hopefully, the results of this research can also provide guidance for educators in developing more optimal learning methods. In this way, it is hoped that in the future, students will be able to more effectively face various problems with many contexts, with the ability to activate and analyze whether the
resources they have can be applied to the context of the problems they face.

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