Analyzing Students' Understanding of Work-Energy Concept

by Artikel Scan

Journal of Physics: Conference Series

Analyzing Students' Understanding of Work-Energy Concept

Analyzing Students' Understanding of Work-Energy Concept

Y S Pramesti[1*], H Mahmudi[1] and I Setyowidodo[1]

[1]Program Studi Teknik Mesin, Universitas Nusantara PGRI Kediri, Jl. KH. Ahmad Dahlan No. 76, Kediri 64112, Indonesia

[*]Corresponding author's email: yasintasindy@gmail.com

Abstract. Work-energy is one of fundamental concept of physics. There is a subtle distinction among sources, forms and modes of transfer of work-energy process. Moreover, there are different meaning of work-energy in science and daily life which leads to misconception. This paper reported students' undestanding and the method has been used to teach work-energy concepts. This study was implemented mixed method embedded experimental design. Subject consisted of 57 students of mechanical engineering who took Physics for Engineering course, enrolling in 2018/2019 academic year. Data were analyzed quantitatively are score of student's conceptual understanding by paired sample t-test. Data were analyzed qualitatively are students' responses by constant comparative method and interviews. Students' conceptual understanding score was improved from mean's score 44,40 to 72,54 ($p < 0{,}01$) and *effect size* was improved with high category (3,79), upper-medium *N-gain* (0,51). According to students' respon and interview result, there were students' difficulties in understanding work-energy such as interpreted work-energy concept in the context of science and used work-energy process. Moreover, teachers found difficulties about the role of language in the teaching of energy.

1. Introduction

Physics is a subject that explains various natural phenomenon. Natural phenomenon are explained by identifying relevant physics principles [1]. Contextual learning provides problems directly experienced by students, so that after learning students are expected have a good problem solving skills. In addition, from a pedagogical perspective, problem solving can be used to assess learning carried out by students. Physics learning is not only an explanation of principles but also its application to problems. Problem solving is the main element in various disciplines [2]. Students who are trained in problem solving will have a good mindset in creating solutions. The problem solving process trains students to be actively involved in using knowledge innovatively.

Assessing students' problem solving skills requires diagnostic tools (assess the content learned) and evaluation tools (assess their ability to use what is learned [3]. Well-structured physics problem guide unique and unambiguous solutions that are different from solutions to common problems [2]. Therefore, problem solving has an important role in building cognitive abilities during the learning process.

Work-Energy concept is one of the important topics in natural science. These topics are also studied from the elementary school level to the university level. It is one of the concepts of science that crosses all disciplines and deals with everyday life situations [4,5]. Jewett [5] states that these concepts are important that are used to analyze physical phenomena.

The inequality between everyday understanding and the scientific explanation of the Work-Energy concept leads misconception. In everyday life, the meaning of energy is commonly associated with fuel oil for transportation, electricity for lighting lights and other household appliances, and food to supply the body's needs. Energy is defined as the ability to carry out activities (work). The idea only says that with fuel, electricity and food can do something, they give us something called energy [6] with which we can carry out activities (work). The difference in the meaning of energy between what is meant in science and in everyday life has implications for the vulnerability of misconceptions to students. Research shows that many students experience the wrong concept of energy [7, 8]. In addition, several science education studies show that many students and teachers of natural science use erroneous concepts about energy and energy-related concepts [4,9,10].

Work-energy is a difficult concept for students. In general, research shows that there are difficulties in understanding the concept of work-energy among students of all ages [4,11,12]. The concepts of work and energy are quite difficult for college students [13]. In contrary to the concept of force (pull or push), the concept of effort and energy is quite abstract so that the transfer of learning from one context to another is very difficult [13,14].

Students' difficulties in the work-energy concept have not been studied in depth. Several studies have shown that effective instruction in teaching of work-energy concept is quite difficult. Teaching work-energy concept is challenging at all levels of instruction [13,14]. Therefore, it is necessary to analyze students' understanding on the concept of work-energy and design learning that is able to anticipate students' misconception through this research.

2. Methods

This research was implemented mixed method embedded experimental design [15]. Subject consisted of 57 students of mechanical engineering in University of Nusantara PGRI Kediri, enrolling in 2018/2019 academic year. The data of this study are observational learning, students' conceptual understanding, and interviews. Quantitative data collection was done by test (pretest and posttest). The test instrument consisted of 10 questions. Pretest and posttest used the same instrument, i.e. integrated test developed from Energy and Momentum Conceptual Survey [13] and Mechanics Baseline Test [16]. By integrated test, we designed to assess those learning outcomes simultaneously. In this paper we focus on students' understanding of work-energy concept. Test was used to assess score of students' understanding. After that, it was using SPSS 23 for windows by paired sample t-test. Qualitative data in this research were students' reason and interviews. Students' reason data was obtained from test. In addition to multiple choice, the test also asked students to write down the reason of their answer. After analyzing students' understanding qualitatively, researcher conducted interviews to confirm further information student understanding of work-energy concept. According to students' respon and interview, researcher began to organize and code the data. Based on data code were obtained, it will be interpreted to explain the result. Qualitative data were validated using data triangulation, member checking, and auditing.

3. Result and Discussion

Quantitative data on students' conceptual understanding were pretest and posttest score. Students' conceptual understanding score was improved from mean's score 44.40 to 72.54 ($p < 0,01$). The strength of the increase in pretest to posttest was measured using the value of d-effect size and N-gain. From the calculation results, the effect size is 3.79 which indicates that the strength of difference between the posttest and pretest was very large category [17]. While the results of the calculation of N-gain scores were obtained at 0.51 which is included in the upper middle category [18].

Qualitative data were obtained from interview, students' reason from pretest and postest, interview. Students' understanding concept was discussed in this paper are defining work-energy in the context of science and work-energy process. According to pretest and posttest, students' still found difficulties about this concept.

3.1. Defining work-energy in scientific meaning

Students' understanding basic concept of work-energy is explored through question problem 1 below.

Question:
You lift a suitcase from the floor to a table. In addition to the weight of the suitcase, select all of the following factors that determine the work done by the gravitational force on the suitcase.

(1) Whether you lift it directly up to the table or along a longer path
(2) Whether you lift it quickly or slowly
(3) The height of the table above the floor

a. (1) only
b. (3) only
c. (1) and (3) only
d. (2) and (3) only
e. (1), (2), and (3) only

Figure 1. Question problem 1 that used to analyze students' understanding to define work-energy in scientific meaning adopted from Energy and Momentum Conceptual Survey [13]

According to the question above, students' answer during pretest and posttest shown in **Table 1**.

Table 1. Students' answer during pretest and posttest toward problem 1.

Student' answer	N	
	Pretest	Posttest
A	12	0
B	8	34
C	27	15
D	0	0
E	10	8

The correct answer is B. Students' difficulties about the relationship between work and gravitational potensial energy can identified through this question. According to Table 1, there are changes in students' answer from the pretest to the posttest. At pretest, there are only 8 students answered correcty (14%). At posttest, there are 34 students answered correctly (60%). This shows that students' understanding is increased. In contrary, there are 23 students (40%) who had misconception. According to the students' responses and interviews, student assumed that if they lift the suitcase quickly and take longer path means that doing more work. In addition, they assoiated with everyday life that doing more work means getting more tired. Therefore, it is important for educators to pay attention to the use of language in teaching. This is in accordance with the results of research which states that one of the difficulties students understand a concept because of the use of ambiguous language [19,20].

Gravitational potential energy is one form of energy. Potential energy is always associated with a system of two or more interacting objects. Serway and Jewett [6] stated that When a small object moves near the surface of the Earth under the influence of gravity, we may sometimes refer to the potential energy "associated with the object" rather than the more proper "associated with the system" because the Earth does not move significantly. To increase the distance of Earth-objects as far as needed external work of mgh. Because the work is positive, the Earth-object system has additional energy. The addition of energy equal to mgh is stored as gravitational potential energy. The amount of work done by the gravitational force depends only on changes in height (h). That is, changes in gravitational potential energy are more important than their own gravitational potential energy. Because only the changes are important, its free to determine the reference point to which gravitational potential energy is given a zero value. In general, the Earth's surface is more often used as a zero point of Earth's gravitational potential energy. So, to lift a suitcase from the floor to a table depends only on the height of the table above the floor.

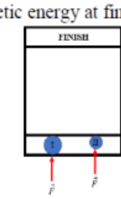
To prevent students had misconception about work-energy in scientific meaning, we developed a strategy. First, identify students' understanding about work-energy. Through this result, we gave reinforcement that work-energy in everyday life is different from scientific meaning. Second, discuss two form basic energy in scientific (kinetic and potensial energy). At this session, use verbal definition and mathematic equation. After that, engage students to investigate through demonstration or practice, so students have a meaningful understanding. Third, introduce student about work-energy transformation.

3.2. Analyzing work-energy process

Students' understanding basic concept of work-energy is explored through question problem 2 below.

Question:

There are two objects. ObjectI is 4 times greater mass than object II. The two objects are moved with the same force and take the same path as shown in figure below. Which one of the following statements best describes who has a kinetic energy at finish line ?



(a). Both of the objects have the same kinetic energy at finish line.
(b). Object I, because it has greater mass.
(c). Object II, because lighter objects are easier to accelerate.
(d). Both of the objects have greater kinetic energy at the finish line than at the start line.

Figure 2. Question problem 2 that used to analyze students' understanding to work-energy peocess adopted from Mechanics Baseline Test [17]

According to the question above, students' answer during pretest and posttest shown in **Table 2**.

Table 2. Students' answer during pretest and posttest toward question problem 2.

Student' answer	N	
	Pretest	Posttest
A	0	36
B	42	14
C	0	0
D	15	7

The correct answer is A. Most of students answer (73,7%) is B that the kinetic energy of object I is greater than that of object II. The reason is the object mass I which is 4 times the mass of object II, so that the kinetic energy of object I is obviously greater than object II. Some of students also used mathematical representation to calculate the kinetic kinergy

$$\left(Ek = \frac{1}{2}mv^2, \text{so that } EkI > EkII\right) \tag{1}$$

In the other hand, students also believed that kinetic energy of object I and object II have a greater kinetic energy at finish line than at the initial position. Students should used the work done by force

$$(W = \Delta Ek) \tag{2}$$

Because the direction of force is same as the diplacement, so the work done by force is

$$\boldsymbol{W = Fs} \tag{3}$$

If the magnitude of force and diplacement at the initial position are the same, so do the kinetic energy. So, the kinetic energy of this problem is not depends on the mass of the object.

Students' difficulties in this problem because students have not been able to determine the system and environment of a problem. Students' difficulties in determining the system and environment have an impact on students' ignorance of the process of transfer and energy transformation. Students'ignorance of the transfer process and energy transformation is the main reason of students' difficulties in work-energy process [21-22].

To help students forgot a formula-centered problem solving method and acquire a coherent expert-like problem solving strategy, Zhou [23] developed a multiple-representation approach for solving work-energy problems. A work-energy process can be represented in verbal, pictorial, and mathematical representations. The bar chart has represents the conservation of energy. A bar chart usually is an effective external representation to help people reason about information that it represents. The work-energy bar chart can be used as a physical representation for work-energy processes.

4. Conclusion

We have analyzed a students' conceptual understanding of work-energy concept. We found that students have difficulty in qualitatively interpreting the basic principles related to work-energy concept in applying them in physical situations. This study revealed the students' difficulties such as students were not been able to distinguish energy in the scientific context and everyday life, determine system and environment of work-energy process. These difficulties must be addressed immediately. One of the solution to remediate the students' misconception is emphasize the basic concept and work-energy related concept such as kinematics and Newtons' Law. It was clear from the literature that work-energy was a difficult concept to understand and it was proved in this study. Building concepts through modelling can strengthen understanding of basic concepts of students which are then developed to be applied to other situations.

5. References

[1] Lin S Y and Singh C 2013 Using an isomorphic problem pair to learn introductory physics: Transferring from a two-step problem to a three-step problem *Phys. Rev. Spec. Top. - Phys. Educ. Res.* **9** 2 020114
[2] Ibrahim B and Rebello N S 2012 Representational task formats and problem solving strategies in kinematics and work *Phys. Rev. Spec. Top. - Phys. Educ. Res.* **8** 1 010126
[3] Hegde B and Meera B N 2012 How do they solve it? An insight into the learner's approach to the mechanism of physics problem solving *Phys. Rev. Spec. Top. - Phys. Educ. Res.* **8** 1 010109
[4] Sağlam-Arslan A and Kurnaz M A 2009 Prospective physics teachers' level of understanding energy, power and force concepts *Asia-Pacific Forum* *Sci. Learn. Teach.* **10** 1 pp 1-18
[5] Jewett J W 2008 Energy and the Confused Student II: Systems *Phys. Teach.* **46** 2 81-6
[6] Serway R a and Jewett J W 2008 *Physics for Scientists and Engineers with Modern Physic, 7 ed.*
[7] Beynon J 1994 A few thoughts on energy and mass *Phys. Educ.* **29** 2 86
[8] Küçük M Çepni S and Gökdere M, 2005 J p t e o **3** 2
[9] Barak J Gorodetsky M and Chipman D 1997 Understanding of energy in biology and vitalistic conceptions *Int. J. Sci. Educ.* **19** 1 21-30
[10] Goldring H and Osborne J 1994 Students' difficulties with energy and related concepts *Phys. Educ.* **29** 1 26

[11] Bécu-Robinault K and Tiberghien A 1998 Integrating experiments into the teaching of energy *Int. J. Sci. Educ.* **20** 1 99-114

[12] Liu X Ebenezer J and Fraser D M, 2002 Structural characteristics of university engineering students' conceptions of energy *J. Res. Sci. Teach.* **39** 5 423-41

[13] Singh C and Rosengrant D 2003 Multiple-choice test of energy and momentum concepts *Am. J. Phys.* **71** 6 607-17

[14] Van Heuvelen A and Zou X 2002 Multiple representations of work–energy processes *Am. J. Phys.* **69** 2 184-94

[15] Creswell J W and Plano-Clark V L 2011 Choosing a mixed methods design *Des. Conduct. Mix. Method Res.*

[16] Hestenes D and Wells M 2006 A mechanics baseline test *Phys. Teach.* **30** 3 159-66

[17] Morgan G a Leech N L Gloeckner G W and Barrett K C 2004 SPSS for Introductory Statistics: Use and Interpretation *SPSS Introd. Stat.*

[18] Sutopo 2010 *Improving Students ' Representational Skill and Generic Science Skill 2009*

[19] Brookes D T and Etkina E 2007 Using conceptual metaphor and functional grammar to explore how language used in physics affects student learning *Phys. Rev. Spec. Top. - Phys. Educ. Res.* **3** 1 010105

[20] Pramesti Y S and Setyowidodo I 2018 Students' mental model in electric current *J. Phys. Conf. Ser.* **1013** 1 p 012024

[21] Sabo H C Goodhew L M and Robertson A D 2016 University student conceptual resources for understanding energy *Phys. Rev. Phys. Educ. Res.* **12** 1 010126

[22] Rahmatina D I Sutopo and Wartono 2018 Identifikasi Kesulitan Siswa SMA pada Materi Usaha-Energi *Momentum Phys. Educ. J.* **2** 1 p 15

[23] Zou X 2016 *The Role of Work-energy Bar Charts as a Physical Representation in Problem Solving* **239**

Acknowledgments

This research would not have been possible without sponsorship from Ministry of Research, Technology and Higher Education of the Republic of Indonesia. The people involved in this research are warmly thanked for allowing their daily routines to be disturbed.

Analyzing Students’ Understanding of Work-Energy Concept

ORIGINALITY REPORT

14%	11%	9%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	jurnalkwangsan.kemdikbud.go.id Internet Source	1%
2	Neslihan Ültay, Ümmü Gülsüm Durukan, Eser Ültay. "Evaluation of the effectiveness of conceptual change texts in the REACT strategy", Chemistry Education Research and Practice, 2015 Publication	1%
3	igneous.scis.ecu.edu.au Internet Source	1%
4	doi.org Internet Source	1%
5	acikerisim.deu.edu.tr Internet Source	1%
6	core.ac.uk Internet Source	1%
7	docplayer.net Internet Source	1%
	researchbank.rmit.edu.au	

8	Internet Source	1%
9	ulir.ul.ie Internet Source	1%
10	www.researchsquare.com Internet Source	1%
11	Submitted to University of Nottingham Student Paper	1%
12	www.colorado.edu Internet Source	1%
13	Jordi Solbes. "Teaching Energy Conservation as a Unifying Principle in Physics", Journal of Science Education and Technology, 02/24/2009 Publication	1%
14	koreascience.or.kr Internet Source	1%
15	Submitted to University of Liverpool Student Paper	<1%
16	M. Agung Setiawan. "PENGARUH MODEL PEMBELAJARAN PROBLEM BASED LEARNING DIPADU STUDENT FACILITATOR AND EXPLAINING TERHADAP KEMAMPUAN BERPIKIR KRITIS SISWA KELAS X SMAN 6 KEDIRI PADA POKOK BAHASAN FUNGI", Florea : Jurnal Biologi dan Pembelajarannya,	<1%

2017
Publication

17 modeling.asu.edu
Internet Source
<1%

18 Submitted to University of Cape Town
Student Paper
<1%

19 Submitted to University of Sydney
Student Paper
<1%

20 repository.unhas.ac.id
Internet Source
<1%

21 www.pnas.org
Internet Source
<1%

22 Ruth Chabay, Bruce Sherwood, Aaron Titus. "A unified, contemporary approach to teaching energy in introductory physics", American Journal of Physics, 2019
Publication
<1%

23 repository.uinjkt.ac.id
Internet Source
<1%

24 "Pedagogical Content Knowledge in STEM", Springer Science and Business Media LLC, 2018
Publication
<1%

25 Khayotha Jesda, Sitti Somsong, Sonsupap Kanyarat. "The curriculum development for
<1%

science teachers training: The action lesson focusing on science process skills", Educational Research and Reviews, 2015
Publication

26	pure.uva.nl Internet Source	<1%
27	update.aps.org Internet Source	<1%