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RESEARCH ARTICLE

Validity and Reliability of the "Conservation of Mechanical Energy in Conservation Systems" Academic Achievement Test

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Abstract
In this study, a scale development study was carried out to measure the academic achievement in the undergraduate physics course "Conservation of Mechanical Energy in Conservative Systems." The developed test consists of seven openended questions, and these questions correspond the first five steps of the revised Bloom taxonomy steps. Since the test consisted of open-ended questions, an answer key was also prepared. The validity and reliability studies of the test were carried out with a total of 317 pre-service Science teachers who took the Physics 1 course. As a result of these studies, the test was found to be valid and reliable according to Cronbach's alpha value of .758, item discrimination average of .364, and item difficulty average of .264, as well as expert opinions. It can be said that the test developed in the light of all this information obtained is a valid and reliable academic achievement test for solving problems on the Conservation of Mechanical Energy in Energy Conservation Systems in Physics 1 Course, and it can be suggested for use by researchers/ practitioners.

Keywords: Academic achievement test, inventory development, mechanical energy conservation, physics education, Science Education

Introduction

One of the main purposes of physics is to interpret different phenomena in a unified way. The concept of energy allows such a unification, as it is a feature of all systems (Papadouris et al., 2008). The issue of energy has become extremely important in daily life, with the emergence of technology and science. Energy is emphasized as a subject which is defined as difficult and incomprehensible to some students, especially because it contains abstract concepts (Duit, 1992; Stylianidou et al., 2002; Yuenyong & Yuenyong, 2007). Since it is a difficult subject to understand, the teaching of the subject of energy is also important. In addition, various studies have been conducted regarding students' understanding of the concept of energy and its consideration, and these studies have revealed that serious difficulties in

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learning exist (Duit, 1981, 1984; Solbes & Tarin, 1998; Tarin, 2000, as cited in Solbes et al., 2009). How to teach energy is a controversial issue, and discussions about the effectiveness of different approaches in teaching energy still remain (Millar, 2012). Lancor (2014) defines energy as a fundamental "unifying theme" of science. Duit and Neumann (2014) emphasize the interdisciplinary nature of the energy concept. The abstract nature of energy and its use in daily life, with practical meanings different from the scientific ones, are considered as one of the main obstacles to understanding the concept of energy (Millar, 2014). Generally, students' first encounters with energy outside of physics education are in the light of daily experiences and false preliminary information (Duit, 1981, 1984; Lijnse, 1990; Trumper, 1990), which often leads to difficulties in learning the concept of energy (Park & Liu, 2016).

Misconceptions about energy, which may be the basis of students' failures in understanding the subject, have also been also indicated by some studies in the literature. Lindsey et al. (2012) stated that problems such as students' failure to apply energy transformations are not limited to novices, which is a term used for people who do not specialize in the field of physics, but also extend to advanced learners. In their study, Goldring and Osborne (1994) identified important mistakes in students' basic concept of energy and related ideas, and their application to daily situations. While students could solve numerical problems, they showed a lack of understanding of basic concepts and could not solve qualitative conceptual problems. This means that although students can apply complex formulas and solve new mathematical problems through practiced exercises, they often do not understand the basic conceptual principles (Dega, 2019). Another example of student failure in courses regarding energy is the difficulties experienced by university students in applying basic energy concepts to daily situations (Jewett, 2008; Lindsey et al., 2012). Goldring and Osborne (1994) stated that students have problems in distinguishing energy from force or temperature. Another complication is that the term energy is defined and used in different ways, depending on the context and the scientific discipline in which it is taught (Hartley et al., 2012; Nagel & Lindsey, 2015). Some studies show that students associate energy concepts to other content areas (Lin & Hu, 2003) or form new misconceptions when approaching certain aspects of energy in biology (Barak et al., 1997) or chemistry (Greenbowe & Meltzer, 2003). As the results of this research reveal, most students have difficulty in understanding the concept of energy in terms of physics and daily living activities (Warren, 1982).

When the literature is reviewed, it is seen that there are various misconceptions about energy because students see energy as a tangible thing, confuse force, power and energy with each other, assume that only moving objects will have energy, define energy as a kind of life force, and cannot understand the logic of conservation of mechanical energy (Kruger, 1990; Tatar & Oktay, 2007; Trumper, 1998; Trumper et al., 2000; Wijanarka et al., 2019). Yürümezoğlu et al. (2009) found that middle school students have deficiencies in structuring the concepts of energy, energy source, energy form, and energy transfer. Toman and Çimer (2016), in their study in which the misconceptions of students at different education levels regarding the concept of energy were determined, concluded that misconceptions about the subject and concepts of energy continue at every education level. In the literature review, it is seen that there are many studies on the determination and development of success at the secondary school, high school, and university levels, identifying and eliminating misconceptions on the subject of energy (Atasoy & Akdeniz, 2007; Ateş, 2008; Avcı et al., 2012; Eryılmaz & Tatlı, 1999; Gülçiçek & Yağbasan, 2004; Kartal-Taşoğlu, 2009; Kruger, 1990; Küçüközer, 2010; Solomon, 1985; Watts, 1983; Yıldız & Büyükkasap, 2006; Yılmaz et al., 2002).

Misconceptions are accepted as an important factor affecting academic success. It is seen that different data collection tools in the literature have been developed to reveal this problem. The concept test prepared by Gülçiçek (2002) in their master's thesis study to determine secondary school students' misconceptions about mechanical energy conservation consists of 28 multiple-choice questions. Singh and Rosengrant (2003) developed a scale of 25 multiple-choice items to measure the level of university students' perception of the concepts of energy and momentum, and 14 items of the scale cover the subject of energy. The scale developed by Demirbaş and Yağbasan (2006) covers two units and consists of 65 multiple-choice questions, and 35 items of the scale are about energy. The achievement test about the conservation of energy, developed for secondary schoolers by Ağgül et al. (2008), consists of 12 multiple-choice questions. The achievement test developed by Aydoğmuş (2008) during their master's thesis, inspired by the studies of Gülçiçek (2002) and Armut (2005), consists of 27 multiple-choice questions concerning energy. The Work-Energy Unit Achievement Test, which Kartal-Taşoğlu (2009) developed for their master's thesis study with the participation of future teachers, consists of 17 multiple-choice and 12 open-ended questions. The Energy Unit Conceptual Achievement Test, developed by Tekbıyık (2011) for secondary school students, has an explanatory-multiple-choice structure with 20 items. The measurement tool developed by Töman et al. (2013) to determine the misconceptions of university students about energy consists of 13 open-ended questions. Açıkgöz and Karslı (2015) developed an achievement test regarding energy, consisting of 18 multiple-choice questions. Park and Liu (2016) developed an Interdisciplinary Energy Concept Evaluation scale for university students in their studies. The scale consists of 49 multiple-choice items along with the reasons. Sixteen of the items cover the discipline of physics. The achievement test about energy developed by Aydoğdu (2017) during their doctoral thesis consists of twenty multiple-choice, nine fill-in-the-blank, and six open-ended questions. The achievement test developed by Gidena and Gebeyehu (2017) consists of 20 multiple-choice questions. The test developed by Sakchai and Sura (2017) to measure the success of secondary school students in energy conservation consists of 3 two-stage items. The reason for the answers in the first stage is expected in the second stage.

As can be seen, multiple-choice items are mostly preferred in the measurement tools developed to determine the misconceptions and academic achievements regarding the topic of energy. In multiple-choice questions, the correct answer is given within the question itself. For this reason, the luck factor due to the fact that the answer is among the options in multiple-choice questions is also included in the measurement (Yılmaz, 2019). Individuals who have little or no idea about the subject can reach the right answer with the luck factor or with the tips they receive from the options (Boud, 2007). In open-ended items, the student constructs the answer, finds the opportunity to explain the reasons for their answer, and has the space to express their thoughts more freely (Gronlund, 1998). In this respect, open-ended questions are the most appropriate for measuring high-level skills such as problem solving, organizing problems, generating new and original ideas, evaluating ideas, applying information in different situations, establishing cause–effect relationships, making generalizations, generating hypotheses, and making comparisons between alternatives (Bahar et al., 2010; Başol, 2013; İlhan, 2016; Tan & Erdoğan, 2004; Turgut & Baykul, 2012). Answers from open-ended questions generally provide rich, comprehensive, and in-depth information (Grover & Vriens, 2006). Studies that the data obtained from open-ended questions are more useful in determining the scope and effect of an applied instructional intervention (Anbar, 1991). Since open-ended questions can contain more than one solution, they do not limit students' creativity (Sverin, 2011). Although multiple-choice questions can be designed to measure high-level cognitive skills, many thought to not elicit important constructive cognitive processes as effectively as open-ended items, which are more appropriate for testing reasoning abilities such as analyzing, evaluating, and synthesizing information more abstractly (Stiggins, 2005). Memory retrieval is a cognitive process that works differently in answering open-ended questions and multiple-choice questions. It is an active productive process versus the passive automatic activation of topic-specific knowledge that arises when reading questions. Unlike answering open-ended questions, the processes involved in answering multiple-choice questions are partially supported by automated access or familiarity. However, open-ended question exams require both trained and reliable raters and a time-consuming grading process (Epstein, 2007; Ruit & Carr, 2011).

When academic achievement tests in physics are examined, it is seen that they are designed in accordance with taxonomies. When the academic achievement tests in physics in the literature are reviewed, it is seen that the scales are mostly in the third step of the Revised Bloom Taxonomy, the application step. In the new studies that were conducted as of the 2000s, another step further was taken and an attempt was made to include the analysis step. However, in the era of rapidly developing technology, the problem in physics education is not just about mathematical solutions, and students, like individuals who are a part of society, are asked to identify, perceive, and solve problems in their daily lives in a creative way. For this, the levels in problem solving should not be limited to the application and analysis of taxonomy, and they should move to the next steps.

The subject of energy is first taught to secondary school students in the Science and Technology curriculum of our country. It is thought that this education, which is built on a quality and solid foundation, will facilitate the education of students in order to improve this subject in their further education life (Trumper, 1990). It is important for Science and Technology teachers, who are responsible for teaching the concept of energy to their students, that they learn this advanced unit during their undergraduate education without any problems, as it will help them teach this unit. In line with this information and suggestions, it was seen that an open-ended academic achievement test should be developed within the Conservation of Energy courses of the undergraduate level Physics 1. In this context, the problem statement of this study is: "Can the success of pre-service science teachers on *Conservation of Mechanical Energy in Conservative Systems* be measured in terms of valid, reliable and high-level taxonomy with a measurement tool consisting of open-ended questions?"

Method

Participants

The study group of the research consists of a total of 317 pre-service teachers who took the Physics 1 course in İstanbul University-Cerrahpaşa Hasan Ali Yücel Faculty of Education, Department of Science Education in the 2018–2019 and 2019–2020 academic years. In order to reach the desired sample size to carry out validity and reliability studies of the test in the selection of the study group, it was expected that the pre-service teachers had taken and successfully completed the Physics 1 course.

Creating the Achievement Test

Before creating the questions, a table of specifications showing the Conservation of Mechanical Energy in Conservative Systems, which is the limited subject of the energy, was prepared for the purpose of the test to be developed (Table 1). In order to create the question pool of the achievement test, domestic and foreign books, and the literature preferred by faculty members at universities, were reviewed. In this context, a question pool consisting of 20 open-ended questions was created. The prepared question pool was sent to the expert team for an expert opinion. In line with the feedback received from the experts, six questions were removed from the pool due to reasons such as "they go beyond the restricted subject, do not fully meet the achievements and taxonomy step, and cannot be solved without using extra resources in the desired time." After the expert opinion,

Table 1.
Table of Specifications Prepared for the Problems Used in the Pilot Study

Acquisitions	Problem Number
Defines the mechanical energy quantities.	1, 2, 3
Understands the effect of frictional force on kinetic energy.	4, 5, 6
Applies the conservation of mechanical energy equations on samples.	6, 7
Infers that the total energy is conserved in the transformation of energy from one form to another.	8, 9
Analyzes the variables on which translational kinetic energy, gravitational potential energy and elastic potential energy depend.	10, 11, 12
Evaluates the effects of the variables on which the mechanical energy depends on the total energy.	13, 14

there were 14 open-ended questions left in the question pool, such that there would be at least one question in each taxonomy step, in accordance with the purpose of the research and to meet all the gains.

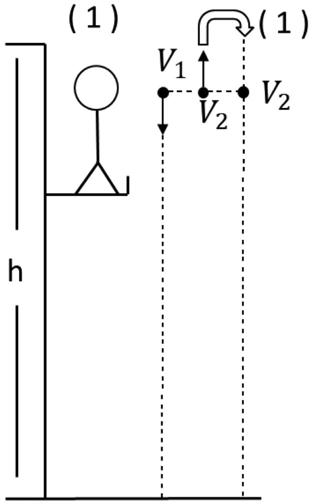
Question Format and Answer Key

Open-ended questions require a detailed answer key to clearly define the score distribution, as they contain different possible answers. It can be difficult to provide a precise rubric for questions like these. In addition, the answer key must be understandable in order to obtain reliable scores among different raters. For this reason, it has been attempted to make the answer key as simple and understandable as possible in order to achieve high reliability.

The answer key was prepared for the 14 questions remaining after the expert opinion. Echevarría (2017) suggested that open-ended problems should be standardized before reliability studies can be conducted. Since each problem in the test is evaluated with the help of an answer key, and it is not possible to score each question equally due to the question types and contents, it was thought that it would be more appropriate to complete the questions to 16 common points and standardize them. As in the example question, 8 points obtained from the answer key were completed with a factor of 2–16 points and fixed to equal points with each question.

In answering the problem, if the visual of the problem is given, two points are given as one point for each ball; one point is given if the equality of the first ball is written,; one point is given if the equality of the second ball is written; two points are given if the initial velocity and final velocity equations are stated; and two points are given if the reason for the answer is stated exactly, making eight points in total. It is multiplied by a factor of 2 to 16 points.

> Example question: Sinan throws equal-mass blue and red balls to his younger brother Zeynep, who loves to play balls with different colors, from the balcony of the house. He threw the first ball, the blue one, at a downward (vertical direction) velocity, and the second ball, the red ball, with the same velocity upwards (in the vertical direction). Assuming no air resistance in either case, please compare the mechanical energies of both balls compared at the time of impact. Please explain your answer in detail. ($8 \times 2 = 16$ points)



Answer: (6)

For the first ball; (1)

$$m \times g \times h + \frac{1}{2} m \times V_1^2 = \frac{1}{2} m \times V_{1son}^2$$

For the second ball; (1)

$$m \times g \times h + \frac{1}{2} m \times V_2^2 = \frac{1}{2} m \times V_{2son}^2$$

$$V_1 = V_2 \text{ and } V_{1son} = V_{2son}$$ (2)

Reason for my answer: (2)
Since their initial velocities are equal, the impact velocities are equal. Because when the red ball is thrown up and returns to its original height, it returns to its initial energy because there is no air resistance and friction. Since the continuation of the motion is the same, their mechanical energies are also equal.

Pre-work

Before the pilot study of the measurement tool was begun, the draft test was applied to 60 pre-service science teachers who had taken the Physics 1 course earlier. This application was made in order to determine the adequacy of the response times given for the measurement tool, to organize the application instructions in the measurement tool booklet, to see the readability of the measurement tool during the application, to sort out the obscure terms, and to reveal the items that are not suitable for the level of the pre-service teachers. The participants were especially asked to state any difficulties they had in understanding the questions, concepts, or words. All the feedback given by the pre-service teachers during the application process was noted by the researcher. According to the feedback received, it was determined that some questions were difficult to understand. For this reason, three questions were removed from the test. Since there were other questions that have the same function as these questions in terms of acquisitions, there was no problem in removing these questions from the measurement tool.

Pilot Study

The measurement tool prepared for the pilot study consists of 11 open-ended questions. The pilot study for the reliability studies of the measurement tool and answer key was carried out with the participation of 257 pre-service teachers studying in the first, second, third, and fourth grades of the Science Education department. In line with the data obtained from the application made before the pilot study, the participants were given 150 minutes as the response time for the measurement tool and the pilot study was carried out in a single session. Although the time given for the test was found to be long during the pilot study, it was considered that it included 14 open-ended physics problems and these problems covered the first five steps of taxonomy. According to the feedback received from the students during the pre-work, the fact that they needed to think more in the last questions and demanded that more time be given was effective in fixing this timing for the pilot study. Each study is a pre-work for the correct determination of the time to be given for the final version of the test.

Validity

Validity is the study of whether test scores accurately measure the intended concept or construct. For the validity of the developed measurement tool, answers were sought for three questions. Does the developed measurement tool give similar results as other measurements with a similar structure? Do the experts agree that the questions match the acquisitions? Can pre-service teachers interpret the questions as intended?

Criterion Validity

This can be defined as the similarity of results between the developed scale and other independent scales. For this reason, the correlation between the data obtained from the developed test and the scores of the same pre-service teachers from the questions in the same subject area in the Physics 1 course final exam was examined (Pearson's correlation $r = .51$, $p < .001$, $N = 127$). This correlation value can be considered moderate for criterion validity between .3 and .5, and strong for .5 and 1.00 (Chasteen et al., 2015). It can be said that the test developed based on these results is suitable in terms of criterion validity.

Validation by Experts

The expert team consisted of a total of five experts, two of whom are in physics education, two in Renewed Bloom taxonomy and one in the Turkish Language. Expert opinions were obtained through one-on-one interviews with them. The questions that were asked to the experts were important while making evaluations. These questions were: "If asked to your own students or students taking this course, would they have trouble answering?" "Is there a discrepancy between the questions and the acquisitions?" An expert opinion form was created in order to facilitate the evaluation of experts. In the form, there are "Appropriate, Should Be Edited, Not Appropriate" options for each question and the experts were asked to choose an option and then explain the reason. Based on the feedback received from the experts, the necessary changes were made and it was agreed by all the experts that the questions met the targeted acquisitions and were valid in Turkish.

Reliability

Reliability refers to whether the scale produces similar results under similar conditions. In reliability studies, answers were sought for two questions. These questions are as follows;

- "Is pre-service teacher performance on any test item related (internal consistency) to the rest of the test items?"
- "How well do different raters agree with each other on the same pre-service teachers (consistency between raters)?"

Internal Consistency

A review of the literature shows that the two most commonly used reliability tests in academic achievement tests are KR-20/21 and Cronbach's alpha methods. While KR-20 is considered appropriate for scales with a result of "1–0," Cronbach's alpha is accepted for scales scored by the grading method. Tan (2009) emphasizes the misuses in reliability studies in his study. Although Kindle (2017) stated that the most appropriate reliability study for scales consisting of open-ended questions is consistency between raters, in our study, we also performed the Cronbach's alpha reliability analysis, which was suggested for the reliability of open-ended problems by Perdana et al. (2019). The value of Cronbach's alpha is between 0 and 1. A larger value means that there is a better correlation between test items. Conceptually, if the items in the test measure different constructs and are completely independent of each other, the sum of the variances on the individual items would be expected to be similar to the variance in the total scores, resulting in a small alpha value. The Cronbach's alpha value of the developed test was calculated as .758. A Cronbach's alpha value between .7 and .9 is said to be good (Taber, 2017).

Inter-rater Reliability

The reliability of the answer key of the developed test was calculated with the method of consistency between raters (Cohen's kappa). Cohen's kappa is a statistical measure of how often raters give the same score for a question compared to the expected rate, by random chance (Brennan & Prediger, 1981). The formula for Cohen's kappa is a calculation method that considers the fact that raters can make similar decisions by chance, and eliminates this effect in high coefficients. In order to apply this method, which aims to determine the consistency of the opinions of the raters about the appropriateness of the test items, the raters should act independently of each other (Şencan, 2005). According to Şencan (2005), a value of kappa .00–.20 indicates weak agreement, .20–.40 indicates acceptable agreement, .40–.60 indicates moderate agreement, .60–.80 indicates strong agreement, and .80–1.00 indicates very strong agreement.

Discrimination

This section explains the calculation of the item–scale correlation, item discrimination, and item difficulty values of the developed test.

Item-Scale Correlation

Students who receive a good score on the test in general are expected to tend to score well on individual items as well. Therefore, the correlation of each item with the whole test was examined. While the whole test was being handled, the compared item was not included in the total score. The Pearson correlation values between each item and the entire test ranged from .21 to .37. The minimum acceptable correlation coefficients are generally considered to be around .2 (Pepper et al., 2012).

Item Discrimination

The item discrimination index distinguishes between a student who knows an item and a student who does not. The number of correct answers to any item in the applied test in the upper group should be higher than the number of correct answers in the lower group. The larger this difference, the more distinctive the item (Gömleksiz & Erkan, 2014). In the study, the formula suggested by Alshannag (2016) to measure the item distinctive index (r_{jx}) was used:

$$r_{jx} = \frac{P_{dü} - P_{da}}{P_M} \times (N)$$

In the formula, $P_{dü}$ expresses upper group total score, P_{da} expresses subgroup total score, P_M expresses the maximum possible score, and N expresses the number of participants in a group. Tekin (1977) stated that it is not recommended if the discrimination index of the items is .19 and lower, it is recommended if the value is between .20 and .29, it is good if it is between .30 and .39, and very good if it is .40 and higher.

Item Difficulty

The item difficulty index is a numerical indicator of the response rate of a question. In the study, to measure the item difficulty (P_j), the formula suggested by Alshannag (2016) was used:

$$P_j = \frac{P_{dü} + P_{da}}{P_m} \times (N_ü + N_a)$$

In the formula, $P_{dü}$ expresses upper group total score, P_{da} expresses the subgroup total score, P_m expresses the maximum score that can be obtained from one item, $N_ü$ expresses number of upper group participants, and N_a expresses the number of subgroup participants. Özgüven (1994) stated that the items were difficult if the item

Table 2.
Item Difficulty, Discrimination, and Inter-rater Consistency (Kappa) Analysis Values of the Measurement Tool After the Pilot Study

Question Number	Difficulty	Discrimination	Kappa
1	.698	.413	.965
2	.367	.253	.892
3	.212	.254	.955
4	.519	.643	.946
5	.190	.280	.980
6	.282	.466	.966
7	.276	.475	.973
8	.262	.412	.960
10	.156	.269	.985
11	.337	.563	.990
13	.294	.421	1.000

difficulty level is close to .00, medium if it is around .50, and easy if it is close to 1.00 Accordingly, the difficulty level of the items is required to be close to 0.

Results

In line with the preliminary work and expert opinions, the item difficulty, discrimination, and consistency between raters for 11 items of the test for the pilot study are shown in Table 2.

As can be seen in Table 2, the item difficulty analysis values of the measurement tool developed from the pilot study range between .156 and .698, item discrimination analysis values are between .253 and .643, and inter-rate consistency (kappa) values are between .892 and 1.000.

Based on the results of the pilot study and item analysis, questions 1, 4, 5, and 11 were removed from the measurement tool. Since the items 1 and 4 were not of the desired difficulty among the item difficulty questions, items 5 and 11 were thought to be less useful than the alternatives in determining the appropriate time for the final test based on the feedback received, and it was removed from the test with the initiative of the researchers, considering expert opinions. The necessary adjustments were made to the questions that were decided to be retained in the measurement tool, according to the results of the item analysis, emphasis was placed on measuring each acquisition and taxonomy step with at least one question. There are seven open-ended questions in the final ready-to-apply measurement tool.

The item analysis data, specification table, and taxonomy step equivalents of the final version of the measurement tool are shown in the tables below.

As can be seen in Table 3, there are seven open-ended questions in the finalized measurement tool, with at least one question for each acquisition. While the first and

Table 3.
Indication Table Showing the Distribution of Problems According to Acquisitions Based on the Bloom's Revised Taxonomy

	The Cognitive Process Dimension					
Acquisitions	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
1: Expresses the mechanical energy relationship in conservative systems.	2, 3					
2: Understands the effect of frictional force on kinetic energy.		6				
3: Applies the conservation of mechanical energy equations on samples.			6.7			
4: Infers that the total energy is conserved in the transformation of energy from one form to another.			8			
5: Analyzes the variables that kinetic energy and potential energy depend on.				10		
6: Assesses the effects of variables on the total energy to which mechanical energy depends.					13	

third acquisitions are measured with two questions, the other acquisitions are measured with one question each. Question six covers both the second and third learning acquisitions.

In the finalized version of the test, there are two questions in the factual information dimension of Bloom's Revised Taxonomy, one in the conceptual information dimension, three questions in the procedural information dimension, and two questions in the metacognitive information dimension. In the cognitive process dimensions, there are two questions in the remembering dimension, one in the understanding dimension, three in the application dimension, one in the analysis dimension, and one in the assessment dimension. Question 6 covers both understanding and application dimensions.

As seen in Table 4, the item difficulty analysis values of the questions in the finalized test range between .156 and .367, the item discrimination analysis values range between .253 and .475, and inter-rater consistency (kappa) values range between .892 and 1.000.

After the answer key was created, each problem was determined to be worth 16 points, with a certain multiplier in order to have equal points. While the lowest score that can be obtained from the measurement tool developed consisting of seven open-ended questions is 0, and the highest score is 112.

Discussion, Conclusion, and Recommendation

As the importance of improving student performance in academic achievement, along with problem solving, researchers and practitioners need to have a valid and reliable test to evaluate the effectiveness of various teaching efforts. In this study, in which a total of 317 pre-service teachers participated, it was found that, together with problem solving in physics, academic achievement could be reliably measured using a measurement tool consisting of open-ended questions. It has been certified, with the approval of the experts, that the developed test ensure that the aimed acquisitions were achieved. This means that the test is valid. Since open-ended questions require more time than multiple-choice questions, the number of questions in the test is also limited. For this reason, the gains to be measured should be well defined and prepared.

An analysis of the findings obtained in the reliability studies shows that the values are at acceptable levels. Cronbach's alpha value of .758 can be perceived as low. The reason for this is that the participants who performed well in the questions below the application level in the test could not show the same performance in the questions above the application level. In addition, it is recommended to increase the number of samples in order to increase the value of Cronbach's alpha (Gömleksiz & Erkan, 2014). When the reliability study results of similar academic achievement tests in the literature are reviewed, the values of Cronbach's alpha in different studies were found to be .72 (Aydoğmuş, 2008), .689 (Açıkgöz & Karslı, 2015), .78 (Gidena & Gebeyehu, 2017), .513 (Aydoğdu, 2017), .71 (Singh & Rosengrant, 2003), and .68 (Ağgül et al., 2008). There are also studies with KR-20 reliability coefficients of .87 (Demirbaş & Yağbasan, 2006) and .71 (Tekbıyık, 2011). In addition to these, there are also researches that conduct reliability studies using the Pearson Product Moments Correlation Coefficient formula. The reliability coefficient values obtained in these studies were calculated as .97 (Kartal-Taşoğlu, 2009) and .85 (Töman et al., 2013). In this respect, it can be said that the test developed in our study consists of open-ended questions and its reliability value is above the average values, which can contribute to the literature.

It is seen that the item difficulty analysis values of the questions are between .156 and .367. Özgüven (1994) stated that the item difficulty level should be less than .5 and that the closer it is to 0, the more reasonable it is. In the developed scales, the difficult, moderately difficult, and easy items should all be at an acceptable level (Gömleksiz & Erkan, 2014). It is seen that the item difficulty of the test developed in line with this information is at an acceptable level. Likewise, the item discrimination values are between .253 and .475. As Tekin (1977) reported, there are three questions valued at less than .3 in the item discrimination index. Since these questions are at an acceptable level, it can be said that the discrimination level of the test is reasonable in general. When the mean values of item difficulty and discrimination of similar academic achievement tests in the literature are examined, it can be seen that there are research studies that have a difficulty value of .67 (Açıkgöz & Karslı, 2015), between .2 and .7 (Gidena & Gebeyehu, 2017), between .28 and .98 with an average of .612 (Aydoğdu, 2017), .2–0, between .8 (Singh & Rosengrant, 2003) and .43 (Tekbıyık, 2011), between .4 and .76 (Töman et al., 2013), and between .15 and .76 (Demirbaş & Yağbasan, 2006). The item discrimination values of the same studies are respectively; between .44 and .33–.66, between 0 and .42 mean .197, between .21 and .48, between .44, .23–.71, and .30 and above transferred. When these observed values are compared with the item difficulty and discrimination values of the developed test, the values of the developed test are seen to be above the average. Since the developed test consists of open-ended questions, the consistency values between the referees investigated within the scope of the reliability studies of the answer key were found to be between .892 and 1.000, which is accepted as a very good agreement between the values given by Şencan (2005).

Levels of the Bloom's Revised Taxonomy were taken into consideration while creating the questions in the developed test. In today's world, it is required that individuals are familiar with problems, understand the problems easily, and to have advanced skills to come up with solutions (İnce, 2016). In this direction, students are expected to be able to solve problems not only in the application stage of the taxonomy, but also in all levels. The distribution of the questions in the scale developed by Demirbaş and Yağbasan (2006) according to Bloom's taxonomy levels is reported as 30.76% in the knowledge level, 52.30% in the comprehension level, and 16.94% in the comprehension level. The distribution of the questions in the 18-question scale developed by Açıkgöz and Karslı (2015) based on Bloom's taxonomy is followed as five questions in the knowledge dimension, five questions in the application dimension, four questions in the analysis dimension, and four questions in the synthesis dimension. The distribution of the questions in the 20-question scale developed by Gidena and Gebeyehu (2017) according to Bloom's taxonomy is followed as five questions in the knowledge dimension, seven questions in the understanding dimension and eight questions in the application dimension. In the currently developed scale, questions were formed to correspond to each stage of the taxonomy. However, in the final version of the scale, no questions pertain to the step Creation, which is the last step of taxonomy. The reason for this is that the questions in the creation step in the preliminary and pilot studies could not be answered by the students in the desired time. Students need more time and additional information for questions at the creation level. It can be suggested that the evaluation of this level can be done by process evaluation, over projects that can be developed over a longer duration. The fact that the developed test consists of open-ended questions covering the first five levels of taxonomy is thought to contribute to the literature. In addition, the fact that new measurement tools to be developed in this field can contain questions or questions at the level of creation will contribute further to the literature.

It can be said that the test developed in the light of all this information obtained is a valid and reliable academic achievement test for solving problems on the Conservation of Mechanical Energy in Energy Unit Conservation Systems in the Physics 1 Course, and it can be suggested for use by researchers/practitioners.

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Appendix 1 University Level “Conservation of Mechanical Energy in Conservative Systems” Problem Solving Success Inventory

Dear students, this inventory has been prepared to measure your level of problem solving success in the university level "Conservation of Mechanical Energy in Conservative Systems" topic. The inventory consists of seven open-ended questions. While solving the questions, please read all the questions carefully and answer them. Answering the questions sincerely is very important in terms of obtaining healthy information as a result of the research. Gravity acceleration is $g=9.8m/s^2$ for all questions. Your answers will be kept strictly confidential and will only be used for scientific research. Thank you for your participation (Duration is 90 Minutes).

Yavuz ACAR

Prof. Dr. Elif INCE

Student's Name-Surname: Number:

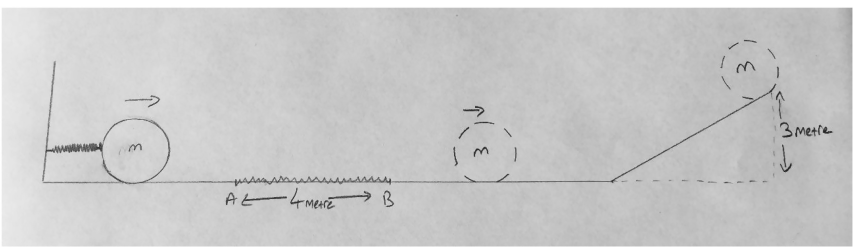
1- In an environment where there is no air friction, a ball is free-falling from a certain height and hits the ground. During this movement of the ball, which of the three, namely, kinetic energy, gravitational potential energy, or mechanical energy, is conserved? Please explain the reason behind your answer in detail.

My answer:
Reason behind my answer:

2- Sinan throws equal-mass blue and red balls from the balcony of the house to his younger brother Zeynep, who loves to play with balls with different colors. He threw the first ball, the blue one, at a downward (vertical direction) velocity, and the second ball, the red ball, with the same velocity upwards (in the vertical direction). Assuming that there is no air resistance in either case, please compare the mechanical energies of both balls at the time of impact. Please explain the reason behind your answer in detail.

My answer:
Reason behind my answer:

3- A 2 kg block is released from the tip of a 0.2m compressed spring with k=3200 N/m, as shown in the picture below. The block climbs the ramp on a frictionless plane, except for the 4m long AB road, and stands 3m above the ground. In this regard, please calculate the coefficient of kinetic friction between the road surface and the block on the road AB (ignore the mass of the spring).



My answer:

4- Assuming the jumping motion of an average-sized kangaroo occurs in a conservative system, what would be the speed of the kangaroo in one jump? Please explain your solution using the Conservation of Energy equations and giving numerical values to the variables yourself (ignore air friction).

My answer:

5- Jerry carries the piece of cheese he snatched from Tom in his mouth, and while running away, his foot slips off the counter and they fall to the ground with the piece of cheese (Jerry is holding the piece of cheese with his teeth). Assume the mass of the piece of cheese is 1/10 of Jerry's mass. What is the velocity at which the piece of cheese hits the ground compared to the velocity at which Jerry hit the ground? Please explain the reason behind your answer in detail, taking into account the laws of conservation of energy (ignore air friction and height differences).

My answer:

Reason behind my answer:

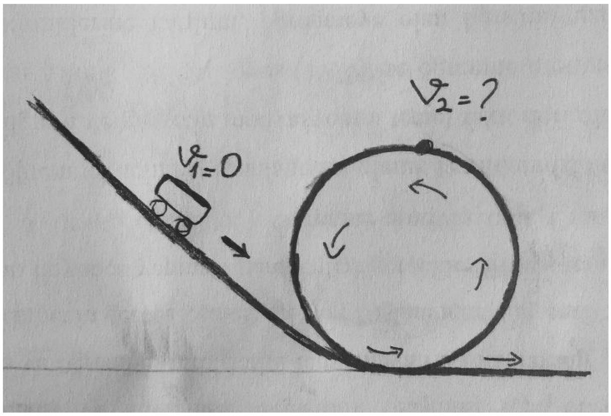
6- Write the problem whose solution is given below based on the Conservation of Energy equation. Please explain your reason behind your answer in detail.

$$(4.00kg) \times (9.80m/s^2) \times (5.00m) = (3.00kg) \times (9.80m/s^2) \times (5.00m) + 1/2\ (4.00kg + 3.00kg) \times V^2$$

My answer:

Reason behind my answer:

7- On the frictionless circular loop path with a radius of 20 cm, a toy car with a mass of 10 g is released from a height of 30 cm without the initial velocity. In this case, the toy car is **unable to complete the loop.**



My answer: a)
b) Reason behind my answer:

a) Which value(s) should be changed in order to have the toy car complete the loop? Please explain your reason in detail.

b) Calculate the velocity of the toy car at the top of the loop using one of the changes you made.