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Date of publication: February 15th, 2019

Edition period: February 2019- June 2019

To cite this article: Guven, G., Sulun, Y. (2019). Interdisciplinary Approach-Based Energy Education. *Multidisciplinary Journal of Educational Research*, 9(1), 57-87. doi: 10.17583/remie.2019.3734

To link this article: <http://dx.doi.org/10.17583/remie.2019.3734>

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Abstract

The purpose of the current study is to investigate the effect of interdisciplinary approach-based energy instruction on pre-service science teachers' academic achievement and conceptual understanding regarding the concept of energy. To this end, the current study was designed as a quasi-experimental study in line with the pretest-posttest control group design. The activities related to the concept of energy were conducted by using the interdisciplinary approach and the same activities were conducted by using the methods and techniques based on the existing approaches. A total of 66 pre-service science teachers participated in the study lasting for 10 weeks. In the analysis of the data, ANOVA/Post Hoc Test was used. As a result of the study, it was found that the use of the interdisciplinary instructional approach in teaching the concept of energy increased the pre-service teachers' academic achievement and conceptual understanding more than the traditional approaches. Thus, it can be suggested that during the instruction of the energy concept, the features of this concept should be taught in a certain developmental order and the interdisciplinary approach should be used in the activities conducted to teach this concept.

Keywords: energy instruction, energy concept, interdisciplinary teaching, conceptual understanding



Enfoque Interdisciplinario de Educación en Energía

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Resumen

El objetivo de este estudio es examinar el efecto de la educación energética basada en el enfoque de la enseñanza interdisciplinaria sobre el logro académico y la comprensión conceptual de los candidatos a docentes de ciencias sobre el concepto de energía. Para este propósito, la investigación se diseñó como un estudio cuasi-experimental de acuerdo con el modelo de prueba previa - prueba final. Un grupo experimental y un grupo control se utilizaron en el estudio. Las actividades relacionadas con el concepto de energía son enseñadas por la enseñanza interdisciplinaria en el grupo experimental y las mismas actividades en el grupo de control por los métodos y técnicas basadas en los enfoques existentes. 66 posibles maestros participaron en el estudio y el proceso de investigación duró 10 semanas. En el estudio, se utilizaron "Prueba de Logro de Conceptos de Energía" y "Prueba de la Identificación de Conceptos de Energía de Dos Etapas" como herramientas de recolección de datos y se aplicaron a los participantes como prueba previa y final. Se utilizó la técnica de análisis de varianza de una vía (ANOVA / Post Hoc Test) para analizar los datos. Como resultado del estudio, se ha encontrado que el uso del enfoque de enseñanza interdisciplinaria en la enseñanza del concepto de energía aumenta los niveles de éxito académico y la comprensión conceptual de los candidatos a docentes hacia este concepto. A este respecto, se recomienda utilizar el enfoque de la enseñanza interdisciplinaria en la aplicación del concepto de energía en un cierto orden de desarrollo y la aplicación de este concepto.

Palabras clave: educación en energía, concepto de energía, enseñanza interdisciplinaria, comprensión conceptual



The system in which different disciplines come together and we try to make sense of the life by exploring the environment and natural phenomena we encounter can be defined as science. In other words, science is an attempt to define and explain the physical and biological world (Ministry of National Education [MEB], 2017). Therefore, what is aimed in science education is to train science literate individuals who can manage the process of converting their theoretical knowledge and skills into practice and product by integrating science and other disciplines. Science literate individuals are those who research, question, decide through reasoning, think innovatively, have self-confidence, are open to cooperation, express themselves, are enterprising and go on learning throughout their lives with the consciousness of sustainable development. Moreover, these individuals have knowledge, skills, positive attitudes about natural sciences, moral and national values, the understanding of the relationship of natural sciences with engineering, technology, society and environment and psychomotor skills (MEB, 2017). Scientific meanings and science concepts have an important place in training students as science literate, students' converting the basic concepts and principles of science into a natural part of their lives and gaining daily life experiences (Bennett, Lubben & Hogarth, 2007). Therefore, it is of great importance to teach science concepts accurately and precisely throughout the education lives of individuals because these concepts lay the ground for learning other related concepts (Dykstra, 1986). Particularly the correct understanding of the energy concept, which is a core and unifying concept of science, is an important stage in the development of science literacy (Jin & Anderson, 2012; Liu & Tang, 2004).

Energy Concept

Energy is an abstract concept; it is not directly observable and it is not possible to measure the energy directly. In addition, it is not easy to make the definition of the concept of energy because the concept of energy is defined differently in each discipline (Lancor, 2014a). However, when related to science, the concept of energy is seen to be a core and unifying concept in all the disciplines of science and across all the levels of

schooling (Park & Liu, 2016). In this connection, it is of great importance to develop correct and adequate conceptual understanding in students because acquisition of adequate and correct conceptual knowledge allows the interconnection of basic science concepts from different disciplines (Schaal, Bogner, & Girwidz, 2010). For example, for the explanation of many phenomena in science subjects such as work, power, force, movement, photosynthesis, respiration, chemical reactions, chemical bonds, heat and temperature, the energy concept is used (Ellse, 1988; Watts, 1983). The concept of energy makes it possible to interconnect and easily understand these subjects. Moreover, the concept of energy is confronted with in the daily life and we make use of this concept to explain and interpret many occurrences (Taber, 1989). In particular, the production and use of fossil-based energy causes many adverse effects on human and environmental health, causing air pollution, acid rain, global warming and climate changes (Panwar, Kaushik & Kothari, 2011; Worrell, Bernstein, Roy, Price & Harnisch, 2009). The concept of energy is an important concept in terms of understanding and explaining such environmental phenomena (Boylan, 2008; Rizaki & Kokkotas, 2013). This concept also allows the interpretation of some socio-scientific issues such as energy sources, use and distribution of energy, evaluations of the country's energy policies and explaining the role of energy in healthy nutrition (Hinrichs & Kleinbach, 2002). In this regard, it is important to promote students' cognitive development about the concept of energy, which is a central concept in science education and energy education because developing students' conceptual understanding of the concept of energy facilitates finding solutions to the problems encountered in daily life related to this concept and makes it possible to adapt these solutions to different situations (Liu & McKeough, 2005; Lee & Liu, 2010). In this regard, teaching the concept of energy in such a way that it can be learned, understood and constructed in the mind by students from every level of schooling is of great importance.

Teaching of Energy Concept

Within science teaching curriculums and applications, the concept of energy should be included and activities should be conducted to make the features of this concept clear and comprehensible (Liu & McKeough, 2005). The concept of energy has some features such as form, source, transfer, and conversion. These features make the holistic understanding of the concept possible and indicate that energy is a multi-dimensional concept. In this connection, to develop a holistic and multi-dimensional understanding of the concept of energy, these features should be taught by addressing them separately (Domenech & et al., 2007; Liu & Mckeough, 2005; Liu & Tang, 2004; Neumann, Viering, Boone & Fischer, 2013). However, these futures should be placed in curriculums according to a certain developmental order and while designing activities to teach these features, this order should be taken into consideration because in the understanding of this concept by students and their construction of it in their minds, the development of the cognition plays an important role. In this respect, the first thing to be known by students in relation to the concept of energy should be the types of energy and they should recognize the sources of these types of energy. Then, they should learn how energy forms are transformed from one place to another within a system and converted from one form to another (Hermann-Abell & DeBoer, 2011; Liu & McKeough, 2005; Liu & Ruiz, 2008; Neumann et al., 2013; Töman & Odabaşı-Çimer, 2013). In short, in teaching of the concept of energy, the features of this concept should be addressed separately and the instructional activities should be conducted according to a certain developmental order.

Literature Review about Understanding of Energy Concept

When the literature is examined in terms of the understanding of the concept of energy by students from all levels of schooling, it is seen that a great difficulty is experienced in the construction of this concept (Amettler & Pinto, 2002; Kaper & Goedhart, 2002; Köse, Ayas & Taş, 2003; Köse & Uşak, 2006; Stylianidou, Ormerod & Ogborn, 2002). The research conducted in the last twenty years supports this view.

In studies particularly focusing on the concept of energy, it is seen that elementary and secondary school students (Boylan, 2008; Hermann-Abell and DeBoer, 2011; Lay, Khoo, Treagust & Chandrasegaran, 2013; Lee & Liu, 2010; Liu & Tang, 2004; Neumann, Viering, Boone & Fischer, 2013; Opitz, Harms, Neumann, Kowalzik & Frank, 2015; Opitz, Neumann, Bernholt & Harms, 2017; Töman & Odabaşı-Çimer, 2013; Yürümezoğlu, Ayaz & Çökelez, 2009), high school students (Güneş & Taştan-Akdağ, 2016; Opitz, Blankenstein & Harms, 2016; Yuenyong, Jones & Yutakom, 2008), university students and pre-service teachers (Benzer, Karadeniz-Bayrak, Dilek-Eren & Gürdal, 2014; Chabalengula, Sanders & Mumba, 2011; Köse, Bağ, Sürücü & Uçak, 2006; Kurt, 2013; Lancor, 2014a; Lee, 2016; Park & Liu, 2016; Sabo, Goodhew & Robertson, 2016) experience difficulties in understanding the subject of energy, constructing this concept in their minds and explaining issues related to the concept of energy. In addition to this, it has been revealed that elementary, secondary and high school teachers have various misconceptions related to the subject of energy and have not adequately internalized the concept of energy (Bezen, Bayrak & Aykutlu, 2016; Kruger, 1990). Thus, it can be argued that energy instruction cannot be given properly and efficiently in elementary, secondary, high schools and teacher training programs.

In this regard, many studies have been conducted to explore how the concept of energy can be understood accurately and thoroughly by students and how they can develop an understanding at the conceptual level (Akpınar & Ergin, 2004; Aydın & Balım, 2005; Diakidoy, Kendeou & Ioannides, 2003; Kurnaz, 2011; Seraphin, Philippoff, Parisky, Degnan & Warren, 2013). These studies have revealed that interdisciplinary instruction based on the cognitive and constructivist approach (Aydın & Balım, 2005), establishment of interdisciplinary integration (Akpınar & Ergin, 2004), the model-based learning approach (Kurnaz, 2011), conceptual change texts (Köse, Ayas & Uşak, 2006), refuting texts, conceptual change texts and exploratory texts (Diakidoy, Kendeou & Ioannides, 2003), inquiry-based instruction (Seraphin et al., 2013), out-of-school scientific activities (Ertaş, Şen & Parmaksızoğlu, 2011), digital game-based learning systems (Yang, Chien & Liu, 2012), the use of simulation in education (İspal, İshak, İspal & Abdullah, 2016) have

enhanced students' achievement and comprehension related to the concept of energy.

In these studies, it is stated that the concept of energy is used in many of the scientific disciplines related to science, is a interdisciplinary concept and should be addressed in its physical, chemical and biological respects (Akpınar & Ergin, 2004; Aydın & Balım, 2005; Gürdal, Şahin & Bayram, 1999; Lancor, 2014b; Opitz, 2016). In this regard, Opitz (2016) emphasizes the importance of the presence of interdisciplinary connections in each science discipline. Moreover, it is argued that in science curriculums, the teaching of this concept starting from the elementary school, particularly in the disciplines of Physics, Chemistry and Biology, should be performed in an integrated manner (Aydın & Balım, 2005; Benzer et al., 2014; Gürdal, Şahin & Bayram, 1999; Köse, Bağ, Sürücü & Uçak, 2006; Lancor, 2014a; Osbaldiston & Schmitz, 2011). In this regard, in the teaching of the concept of energy, the interdisciplinary approach should be used (Chen, Huang & Liu, 2013; Osbaldiston & Schmitz, 2011; Rizaki & Kokkotas, 2013).

The Current Study

The purpose of the current study is to investigate the effect of instructions in which a unity is ensured between the form, source, transfer and conversion features of the concept of energy and interdisciplinary relationships and connections are established in relation to the disciplines of physics, chemistry and biology on the pre-service science teachers' academic achievement and conceptual understanding. Though there is a great deal of research looking at the energy concept-related academic achievement and understanding of students from different levels of schooling, pre-service teachers and teachers (Benzer et al., 2014; Köse, Ayas & Taş, 2003; Köse & Uşak, 2006; Töman & Odabaşı-Çimer, 2013), there are only few studies exploring how this concept can be better understood and constructed in the mind (Akpınar & Ergin, 2004; Aydın & Balım, 2005; Kurnaz, 2011). However, what makes this study original is the implementation of an interdisciplinary instruction that emphasizes the features of the energy concept and attempts to address these features in a certain order. Moreover, applications related to teaching of this concept

should first be integrated into teacher training programs because for pre-service teachers to be able to play an effective role in teaching of this concept, they need to have a good understanding and conceptual construction of the concept of energy.

In this regard, the research questions of the current study are as follows:

(1) What is the effect of the energy-related activities conducted on the basis of the interdisciplinary instructional approach on the pre-service teachers’ academic achievement for the concept of energy?

(2) What is the effect of the energy-related activities conducted on the basis of the interdisciplinary instructional approach on the pre-service teachers’ conceptual understanding of the concept of energy?

Method

Research Design

The study was conducted as a quasi-experimental study complying with the pretest-posttest control group design in order to investigate the effect of conducting energy-related activities according to the interdisciplinary approach on the pre-service teachers’ academic achievement and conceptual understanding in relation to the concept of energy. The quasi-experimental design is the experimental design used the most commonly particularly in educational studies in which it is not possible to keep all the variables under control (Cohen, Manion & Marrison, 2000).

Table 1. Quasi-experimental Design of the Study

Groups	Pretest	Application	Posttest
Experimental	Energy Concepts Achievement Test	Interdisciplinary Instructional Approach	Energy Concepts Achievement Test
	Two-Tier Energy Concepts Diagnostic Test		Two-Tier Energy Concepts Diagnostic Test
Control	Energy Concepts Achievement Test	Traditional Approaches	Energy Concepts Achievement Test
	Two-Tier Energy Concepts Diagnostic Test		Two-Tier Energy Concepts Diagnostic Test

Participants

The sampling of the study is comprised of 66 fourth-year students attending the Department of Science Teaching at the education faculty of a state university in the fall term of 2016-2017 academic year. The reason for the selection of the fourth-year students for the current study is that they have taken the courses including the concept of energy in their first, second and third years. The students in the sampling were randomly assigned to the control and experimental groups. Thus, there are 33 pre-service teachers in the experimental group (7 males and 26 females) and there are 33 students (12 males and 21 females) in the control group.

Materials

In the study, activities related to the concept of energy were carried out. These activities were developed by the researcher and their piloting was performed.

Activities related to the concept of energy. Within the context of the study, various activities were developed related to the concept of energy. In the design and development of these activities, the seven stages proposed by Roberts and Kellough (2000) were used. The operations conducted in each stage are explained below.

a) Determinations of the subjects. In this stage, the content and subjects in connection with the features of the concept of energy that are form, source, transfer and conversion were determined. This content and the subjects cover the topics in which the concept of energy is addressed within the science curriculums of elementary education (3rd and 4th grades) and secondary education (5th, 6th, 7th and 8th grades).

b) Revision. The anticipated learning outcomes that should be targeted in the instruction of the content and subjects having been determined in line with the features of the concept of energy were determined. The opinions of four experts (biology, chemistry, physics and science educator) about the scope of the determined outcomes were sought. In line with these opinions,

it was determined that in relation to which outcomes, the subjects related to the features of the concept of energy would be incorporated into the activities.

c) Development of activities (determination of educational resources).

In this stage, various activities were designed in compliance with the certain subjects and learning outcomes determined in relation to the features of the concept of energy. For this purpose, various books, science textbooks, university general physics, general chemistry and general biology books including the subjects determined in the current study were examined and various experiments and activities in the internet environment were investigated. In this way, a total of 24 activities and 4 worksheets were produced. Some of these activities were produced by making some changes on previously developed activities and redesigned in line with the purpose of the current study. The other activities were originally created by the researcher. As a result, the activities designed and which feature of the energy concept and which subject they belong to are given in Table 2.

Table 2. The Content of the Activities related to the Concept of Energy

Activities	Feature	Subjects
1. Bulb that look like four-leaf clover Worksheet -1.Disintegrating the light into its components		Light Energy
2. Energy stored in foods Worksheet -2: Let's make out concept map		Chemical Bond Energy
3. Exploration with dart and rubber band	Energy Form	Potential Energy
4. Energy of the dart		Kinetic Energy
5. Rutherford's planet atom model		Ionization Energy
6. Energy in chemical reactions		Bond Energy
7. Let's make a circuit without a battery		Electrical Energy
8. Wave the flame		Sound Energy
9. Watch-feel sorry-discover		Nuclear Energy
10. Is it temperature or heat?		Heat Energy
11. Energy generation with solar panels		Solar Energy
12. Energy in power plants	Energy Source	Power Plants
13. Formation of sound		Formation of Sound

Table 2 (Cont.). The Content of the Activities related to the Concept of Energy

Activities	Feature	Subjects
14. Making a simple battery		Chemical Energy Sources
15. Energy in a plant leaf		Energy in Foods
16. From power plants to our house: Electricity		Transfer of Energy Forms
17. Transfer in marbles		Transfer of Energy Forms
18. Which sound is heard?	Energy Transfer	Sound Propagation
19. Let's drop the pin?		Heat Transfer
20. Energy of our body Worksheet -3. Energy journey		Energy Transfer in Living Organisms
21. Newton Balance Balls		Physical Energy Conversions
22. Let's convert the energy Worksheet -4. Let's find the converted ones	Energy Conversion	Physical Energy Conversions
23. Energy conversions in pictures		Energy Conversion in Living Organisms
24. Electrolyze		Chemical Energy Conversions

d) Organization of the activities. In the organization of the activities, two stages were followed. In the first stage, it was determined which concepts the activities would involve, how long the activities would last, which tools and equipments would be needed for experiments, which methods and techniques would be used while conducting the activities, how the evaluation would be conducted at the end of the activity and what the stages of the experiments would be. In the second stage, questions such as what was achieved at the end of an activity, how the activity was associated with the subject and how it would be related to the daily life were prepared.

e) Organization of the classroom environment. The activities developed in relation to the concept of energy were designed as suitable to be conducted in groups in a science lab environment because lab environments have various tools and equipments and allow working in groups. Moreover, science laboratories have every type of tools and equipments to intervene with any emergency that may occur while experiments are being conducted.

f) Conducting the wrap-up activity. For the wrap-up or summarization of each activity, it was planned to conduct whole-class discussion at the end of each activity. In this discussion, students talk about the result of the related activity, its connection with the real life and which concepts have been learned.

g) Performing evaluation. Evaluation of the activities related to energy was performed by analyzing the responses given to the open-ended questions in the activity worksheets. These responses were analyzed by the researcher each week and then with the feedbacks given they were handed out the groups in the following week.

Instruments

In order to collect data in the study, “Energy Concepts Achievement Test” and “Two-Tier Energy Concepts Diagnostic Test” were employed.

Energy Concepts Achievement Test (ECAT). In order to measure the pre-service science teachers’ cognitive domain levels related to their knowledge of the energy concepts, ECAT was developed. With this test, it was aimed to determine the pre-service teachers’ cognitive levels related to the concept of energy by asking questions at the levels of phenomenal, conceptual, operational and metacognitive knowledge in the knowledge dimension of the Bloom taxonomy and at the levels of recall, comprehension and application at the cognitive process dimension of this taxonomy. To this end, a question pool including multiple-choice questions related to the learning outcomes included in each subject determined in the study in relation to the concept of energy was constructed. In the preparation of these questions, the knowledge dimension and cognitive process dimension of the renewed Bloom taxonomy were taken into account. In the current study, it was particularly intended for the questions in the energy concepts achievement test to be at the phenomenal, conceptual, operational and metacognitive knowledge dimensions and recall, comprehension and application cognitive process dimensions. Thus, a test consisting of 30 multiple-choice questions was developed to be

administered to the third and fourth-year pre-service science teachers. For the content validity of the test, expert opinions were sought. Within the context of item analysis, item difficulty and item discrimination coefficients were analyzed. In the achievement test, the item difficulty level of 7 questions was found to be ranging from 0.00 from 0.34, indicating that they are difficult; 21 questions were found to have medium difficulty with a coefficient ranging from 0.35 to 0.64 and 2 questions were found to be easy with a coefficient ranging from 0.65 to 1.00. Moreover, the discrimination indices of all the questions in the test are over .020. Furthermore, the reliability coefficient of the achievement test consisting of 30 questions was calculated by using Spearman Brown formula and the reliability coefficient was found to be $r_x = .75$. Finally, for the correct response given to each question in ECAT “1” point was assigned and for the wrong or missing response “0” point was assigned.

Two-Tier Energy Concepts Diagnostic Test (TTECDT). In order to measure the pre-service science teachers’ cognitive domain levels related to the concept of energy and to determine their conceptual understanding of this concept, TTECDT was developed. With this test, it was aimed to determine the pre-service teachers’ conceptual understanding of the energy concept by asking questions at the levels of phenomenal, conceptual, operational and metacognitive knowledge in the knowledge dimension of the Bloom taxonomy and at the levels of recall, comprehension and application at the cognitive process dimension of this taxonomy. In the development of the two-tier diagnostic test, the steps proposed by Karataş, Köse and Coştu (2003) were followed. In this connection, knowledge hypotheses covering the subjects related to the concept of energy and the concept map for the content was developed. Then, the knowledge hypotheses were associated with the concept map developed and expert opinions were sought for the content validity. After that, within the context of this content for the energy concept, misconceptions reported to be held by students about the concept of energy in the literature were determined. By using these misconceptions, the rational part of the diagnosis test was formed. Thus, two-tier diagnostic test consisting of 21 multiple-choice

questions was developed. Finally, the table of specifications of this two-tier test was constructed.

In order to determine the content validity of TTECDT, expert opinions were collected and interviews were conducted with pre-service teachers to check the comprehensibility and clarity of the questions. In addition, the item difficulty and item discrimination coefficients of the test were calculated. Thus, it was found that there are 8 questions with the item difficulty coefficients ranging from 0.00 to 0.34, indicating that they are difficult; 12 questions with the item difficulty coefficients ranging from 0.35 to 0.64, indicating that they moderately difficulty and there is 1 question with the item difficulty coefficient in the range of 0.65 and 1.00, indicating that it is easy. Moreover, the discrimination indices of all the questions in the test are over .20. Moreover, as a result of the analyses, the Cronbach alpha reliability coefficient of the two-tier diagnostic test was found to be .88.

In the two-tier diagnostic test, following each multiple-choice question, the reason for the response of the related question is also asked for with “because”. There are six answer alternatives to be selected to explain this reason, five of which are multiple-choice and one of which is an open-ended. In some questions, the correct reason is among the response options and in some others, the respondent is asked to indicate his/her reasons by filling the empty space given as one of the response options. To illustrate this, one example is shown in Table 3. Moreover, the items in TTECDT are scored by assigning “3 points” for the correct response and the correct reason; “2 points” for the false response but correct reason; “1 point” for the correct response but the false reason and “0 point” for the false response and the false reason.

Table 3. A sample question for the two-tier diagnostic test

Question-3. Which of the following is **wrong** for the energies possessed by a basketball along the way it follows towards the basket in a projectile motion?

- A) While the ball is approaching the basket, the potential energy decreases, kinetic energy increases.
- B) The ball has kinetic, potential and heat energy until it reaches the basket.
- C) While the ball is at the highest point, its attraction potential energy is also the highest.
- D) *While the attraction potential energy of the ball is converting into kinetic energy, its total energy increases.
- E) When the ball falls on the ground and stops, it has some certain energy.

Because-3:

- A) A stable object does not have energy.
- B) *According to the conversion of energy, even if the kinetic and potential energy of an object changes, the mechanic energy that is the total energy does not change.
- C) When an object is left falling, all of its attraction potential energy simultaneously changes into kinetic energy.
- D) Attraction potential energy is not dependent on the height.
- E) Kinetic and heat energies; as in potential energy, change depending on the height and mass of objects.
- F)
- ...

*Both correct response and correct reason.

Procedure

The current study lasted for ten weeks, two class hours (2x50 minutes) a week. During this ten-week period, activities were conducted within the first eight weeks and the data collection tools were administered within the last two weeks. In the current study, the activities related to the concept of energy were conducted on the basis of the interdisciplinary teaching approach in the experimental group, while they were conducted on the basis of the traditional approaches in the control group. In the experimental group, each activity was conducted by relating it to the disciplines of physics, chemistry and biology in a unifying manner in compliance with the interdisciplinary teaching approach. Moreover, the activities performed in the experimental group were also classified according to the features of the energy concept (energy form, source, transfer and conversion). On the other hand, in the control group, each activity was classified as belonging to one of the disciplines of physics, chemistry and biology and performed within the context of a single discipline as independent from the others by using the traditional methods. These traditional methods were demonstration,

experiment, discussion, sample case and analogy, and the brain-storming technique and group work. These methods and techniques were selected according to the structures of the activities. Thus, in both of the group, activities were carried out by using the same methods and techniques. However, while the activities were carried out in the experimental group in an interdisciplinary manner and following a certain developmental order of the features of the concept of energy, these activities were performed in the control group as required in the existing program separately within the context of the disciplines of physics, chemistry and biology.

Instruction of the experimental and control group. Prior to the applications, the data collection tools were administered to both of the groups as pretest for two weeks. Moreover, the experimental and control group students were informed about the applications in the first week. They were informed about how the activities related to the concept of energy would be conducted, how and when classroom discussions would be conducted and how feedback would be given for activity worksheets. In addition, both in experimental and control groups, groups of five students were formed. The activities were conducted in the experimental and control groups for eight weeks. In the experimental group, the energy forms were studied for three weeks, energy sources for two weeks, energy transfer for two weeks and energy conversion for one week. Yet, in the control group, the energy concept-related activities were done for five weeks in relation to the discipline of physics, for two weeks in relation to the discipline of chemistry and for one week in relation to the biology. Prior to these applications, the researcher had already provided the tools and equipments and activity worksheets for the experimental and control group students. The participants conducted the activities according to the given instructions and the activities were discussed within groups. Moreover, the questions involved in the activities were answered by means of group discussions. Yet, though they conducted group discussions, they answered the questions in their own activity worksheets. At the end of the activities, the pre-service teachers conducted classroom discussions about the related activity. During the classroom discussions, it was addressed what the students hadn't understood and internalized in relation to the activities, every type of

information about the events which had drawn their attention in the experiments was shared; in short, a summary of the activities was made. Furthermore, during the discussions, the activities were connected to each other and related to the daily life. Following the classroom discussions, the researcher collected the activity worksheets of each student to give feedbacks for their responses to the questions in the worksheets. The activity worksheets with the given feedbacks were distributed to the students. In addition, the answer key to the activity worksheet of the previous week was hung on the student board. In this way, the students found the opportunity to compare their answers given in the previous activities and to see the correct answers. Finally, the data collection tools were administered to the students as posttest.

Data analysis. In the analysis of the data, in cases in which there was one dependent variable, one independent variable and one or more covariables, One-way ANCOVA was run to determine whether there is a statistically significant difference between the groups. In this connection, as the independent variable, the groups (experimental and control groups) were taken; as the dependent variable, the posttest scores of the experimental and control group students taken from “Energy Concepts Achievement Test” and “Two-Tier Energy Concepts Diagnostic Test” were taken. As the covariance, pretest scores of the both groups of students taken from these tests were taken. The reason for taking the pretest scores as the covariance is that these pretest scores might have exercised some influence on the posttest scores (Pallant, 2007). Thus, the problem that could emerge when the groups are not equal was eliminated.

Results

Findings Related to the First Research Question of the Study

What is the effect of the energy-related activities conducted on the basis of the interdisciplinary instructional approach on the pre-service teachers’ academic achievement for the concept of energy?

Table 4. Descriptive data of the pre-test and post-test scores.

		N	Mean	S.D.	Std. error.
Pre-test	Experimental group	33	13.75	3.22	.56
	Control group	31	13.61	2.97	.53
Post-test	Experimental group	33	19.09	2.69	.46
	Control group	33	17.39	3.38	.58

When Table 4 is examined, it is seen that while the mean score of the pre-service teachers from ECAT prior to the applications was 13.75, it became 19.09 after the applications. In a similar manner, while the mean score of the control group students prior to the applications was 13.61, it became 17.39 after the applications. Therefore, the ECAT pretest and posttest scores of the experimental group and control group students were checked and determined to be the common variable and whether there is a significant difference between the ECAT posttest scores of the groups was tested by using one factor ANCOVA. Moreover, prior to the analysis, normality, linearity, homogeneity of the variance, homogeneity of the regression curves hypotheses were satisfied. In this connection, the results of the ANCOVA analysis are given in Table 5.

Table 5. ANCOVA results for the effects of interdisciplinary teaching approach on the ECAT.

Source	Sum of squares	df	Mean square	<i>F</i>	<i>p</i>	μ^2
Corrected Model	74.250	3	24.750	2.987	.038	.130
Intercept	985.335	1	985.335	118.909	.000	.665
Pre-test	.211	1	.211	.025	.874	.000
Group	40.921	1	40.921	4.938	.030	.076
Error	497.187	60	8.286			
Total	22254.000	64				
Corrected Total	571.438	63				

When Table 5 is examined, it is seen that the pre-service science teachers' ECAT posttest scores differed between two applications [$F(1,60) = 4.938, p = .03$] and this difference has a moderate effect size (partial eta

squared = .076). This difference is in favor of the experimental group students' ECAT posttest scores. Also using the commonly used guidelines proposed by Cohen (1988) (.01=small effect, .06=moderate effect, .14=large effect), this result suggests a moderate effect size. Thus, it can be argued that the interdisciplinary approach implemented in the control group is more effective in enhancing the pre-service teachers' academic achievement for the concept of energy.

Findings Related to the Second Research Question

What is the effect of the energy-related activities conducted on the basis of the interdisciplinary instructional approach on the pre-service teachers' conceptual understanding of the concept of energy?

Table 6. Descriptive data of the pre-test and post-test scores.

		N	Mean	S.D.	Std. error.
Pre-test	Experimental group	32	21.21	4.44	0.78
	Control group	31	19.93	6.11	1.09
Post-test	Experimental group	29	35.79	7.30	1.35
	Control group	30	29.43	8.72	1.59

When Table 6 is examined, it is seen that while the experimental group students' TTECDT pretest mean score was 21.21, it became 35.79 after the application. In a similar manner, while the control group students' pretest TTECDT mean score was 19.93, it became 29.43. Thus, the experimental and control group students' TTECDT pretest mean scores were checked and determined to be the common variable and whether there is a significant difference between control and experimental groups' TTECDT posttest mean scores was tested by using one factor ANCOVA. Moreover, prior to the analysis, normality, linearity, homogeneity of the variance, homogeneity of the regression curves hypotheses were satisfied. In this connection, the results of the ANCOVA analysis are given in Table 5.

Table 7. ANCOVA results for the effects of interdisciplinary teaching approach on the TTECDT.

Source	Sum of squares	df	Mean square	<i>F</i>	<i>p</i>	μ^2
Corrected Model	1154.237	3	384.746	6.739	.001	.269
Intercept	4089.483	1	4089.483	71.624	.000	.566
Pre-test	19.044	1	19.044	.334	.566	.006
Group	431.308	1	431.308	7.554	.008	.121
Error	3140.305	55	57.096			
Total	66841.000	59				
Corrected Total	4294.542	58				

When Table 7 is examined, it is seen that the pre-service science teachers' TTECDT posttest scores differed between two applications [$F(1,55) = 7.554$, $p = .008$] and this difference has a large effect size (partial eta squared = .121). This difference is in favor of the experimental group students. Also using the commonly used guidelines proposed by Cohen (1988) (.01=small effect, .06=moderate effect, .14=large effect), this result suggests a very large effect size. Thus, it can be argued that the interdisciplinary approach implemented in the experimental group is more effective in enhancing the pre-service teachers' conceptual understanding of the concept of energy.

Discussion and Conclusion

In relation to the first research question of the current study, it was concluded that teaching of the activities related to the concept of energy by using the interdisciplinary instructional approach is more effective in enhancing the pre-service science teachers' academic achievement. There might be four different factors leading to the emergence of this result. First of these elements is making the students realize all the features of the concept of energy. That is, the activities related to the concept of energy include the features of the concept such as form, source, transfer and conversion and they can be presented in a unifying manner only by means of the interdisciplinary teaching approach. In this way, the pre-service teachers learn what the forms of energy are and how these forms of energy are obtained and recognize how the forms of energy are transferred and

how it is converted from one form to another. In this way, the pre-service teachers can learn the features of the concept of energy in a unifying manner by relating them to each other without making any discrimination between disciplines. This is claimed to increase the academic achievement in relation to the concept of energy. Similarly, Domenech et al. (2007) and Neumann et al. (2013) emphasize that energy form, source, transfer and conversion should be involved in teaching of the concept of energy; that these features should be addressed holistically and students should be made to realize this; thus, their academic achievement can be enhanced. In this regard, according to Liu & McKeough (2005) multi-directional and holistic approach needs to be adopted in teaching of the concept of energy. Here what is meant by Liu & McKeough (2005) with the multi-directional approach is conducting activities by using an approach including all the aspects of the concept of energy and its features. Similarly, it is stated by Liu and Tang (2004), the concept of energy should be addressed within a curriculum by using a multi-dimensional and holistic approach. The second factor is that in the activities related to the concept of energy, the features of the concept should be taught in a certain developmental order and through an interdisciplinary approach. In the literature, it is stated that in teaching of the concept of energy, first energy forms and sources should be taught, followed by its features such as transfer and conversion (Hermann-Abell & DeBoer, 2011; Liu & McKeough, 2005; Liu & Ruiz, 2008; Neumann et al., 2013) because students first need to know the forms of energy related to the concept of energy and recognize what the sources of these energy forms are. Then, they need to learn how energy forms are transferred from one place to another within a system and how they are converted from one form to another. Thus, the student can learn the concept of energy in a comprehensive and unifying manner. In this respect, the activities developed within the context of the current study first introduce the forms of energy to the students, then make them recognize the sources of energy, after that present experiments related to energy transfer and finally provide the students with opportunities to understand the conversion of energy. The activities are presented to the students by means of interdisciplinary connections. In this way, the students do not have to make discrimination across the disciplines and do not experience the confusion of which energy

form belongs to which discipline. For instance, students experience difficulties in deciding whether the light energy belongs to the discipline of physics or biology. This prevents the holistic understanding of energy. Thus, the interdisciplinary instructional approach, which interconnects the disciplines and addresses the concept of energy in a holistic manner, has come to the fore (Klemow, 2015; Nordine, Krajcik & Fortus, 2010). Moreover, Opitz et al. (2015) emphasize that there should be more interdisciplinary connections between the contents related to the each discipline of science for energy instruction. The related research has revealed that the use of integration and interdisciplinary approach-based activities enhances students' achievement (Akpınar & Ergin, 2004, Aydın & Balm, 2005). The third factor might be the pre-service teachers' questioning the results of the experiments by relating to the concept of energy in the group discussions and during the classroom discussion, their questioning the features of energy in a more extensive and holistic manner. Seraphin et al. (2013) stated that the use of inquiry-based activities in classes focusing on the teaching of energy is effective in improving students and teachers' course achievement. The final factor might be the reification of the concept of energy, which is an abstract concept, by means of activities and worksheets addressing all the dimensions of energy. Similarly, in their works on the concept of energy, Rizaki and Kokkotas (2013) used worksheets and proposed an effective instructional model to be used in energy instruction. In this model, worksheets occupy an important place as they help reify the concept of energy; thus contributing to students' cognitive development.

In relation to the second research question of the current study, it was determined that teaching energy-related activities on the basis of the interdisciplinary instructional approach is more effective in developing the pre-service teachers' conceptual understanding of the concept. There might be three factors leading to this result. The first factor might be that the interdisciplinary instructional approach increased the pre-service teachers' knowledge about the concept of energy because increasing understanding and knowledge of the concept of energy might have positively affected the development of the conceptual understanding. In the literature, it has also been reported that there is a positive correlation between students'

knowledge level and conceptual understanding (Diakidoy, Kendeou & Ioannides, 2003; Ispal et al., 2016; Lee, 2016). In addition, Boylan (2008) argued that lack of knowledge about the concept of energy prevents creating connections between the features of the concept and thus, the thorough understanding and conceptual understanding cannot develop. The second factor can be the discussions conducted by relating the samples concerned with the daily life to all the disciplines because when the interdisciplinary approach is used, the features of energy in all the disciplines are taught in a unifying manner, leading to construction of related concepts. In this connection, discussion of the concept of energy by relating it to the daily life in such a way as to include all the disciplines is of great importance for the development of conceptual understanding. The last factor might be that within the interdisciplinary instructional approach, the concept of energy is introduced in a unifying manner in connection with the other disciplines, resulting in better conceptual understanding because in general students try to explain the occurrences regarding the concept of energy by relating it to a single discipline and create connections with only concepts and phenomena specific to this discipline (Lancor, 2015). This makes the understanding of the concept of energy more difficult. However, adoption of the interdisciplinary approach eliminates this problem and helps students better develop their conceptual understanding.

In light of the findings of the current study, it can be suggested that the interdisciplinary approach be used in the instruction of the concept of energy in teacher training programs. During this instruction, all the features of the concept of energy should be addressed separately and the activities should be planned considering a specific developmental order such as energy form, energy source, energy transfer and energy conversion. Moreover, in order to enhance pre-service teachers' information and conceptual understanding of the concept of energy, the features of the concept should be addressed by means of different experiments and activities and should be related to the daily life.

Acknowledge

This paper is part of the doctoral thesis entitled “Interdisciplinary Teaching Approach-Based Energy Education for Pre-Service Science Teachers” that carried out by researcher in 2017 year.

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