TUĞCAN YILDIRIM

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# AN ACTION RESEARCH INTO A HANDS-ON SOLAR ENERGY ACTIVITY, ADAPTED TO ENHANCE STUDENTS' UNDERSTANDING OF SELECTED PHYSICS CONCEPTS AND TO ADVANCE THEIR AWARENESS OF RENEWABLE ENERGY

A MASTER'S THESIS

BY

TUĞCAN YILDIRIM

THE PROGRAM OF CURRICULUM AND INSTRUCTION

İHSAN DOĞRAMACI BILKENT UNIVERSITY

ANKARA

JUNE 2017

To my dear grandfather,

who still walks with me in the playground

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Tuğcan Yıldırım

In Partial Fulfilment of the Requirements for the Degree of

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İHSAN DOĞRAMACI BILKENT UNIVERSITY
GRADUATE SCHOOL OF EDUCATION

An Action Research into a Hands-on Solar Energy Activity, Adapted to Enhance Students' Understanding of Selected Physics Concepts and to Advance Their Awareness of Renewable Energy

Tuğcan Yıldırım

June 2017

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

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Asst. Prof. Dr. Jennie Farber Lane (Supervisor)

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

----------------------------

Asst. Prof. Dr. Armağan Ateşkan (Examining Committee Member)

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

----------------------------

Asst. Prof. Dr. Becca Franzen (Examining Committee Member)

University of Wisconsin-Stevens Point

Approval of the Graduate School of Education

----------------------------

Prof. Dr. Alipaşa Ayas (Director)

ABSTRACT

AN ACTION RESEARCH INTO A HANDS-ON SOLAR ENERGY ACTIVITY, ADAPTED TO ENHANCE STUDENTS' UNDERSTANDING OF SELECTED PHYSICS CONCEPTS AND TO ADVANCE THEIR AWARENESS OF RENEWABLE ENERGY

Tuğcan Yıldırım

M.A., Program of Curriculum and Instruction

Supervisor: Asst. Prof. Dr. Jennie Farber Lane

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The present study uses action research to investigate how a hands-on solar energy activity that highlights selected physics concepts could be used to enhance participants' understanding of physics concepts as well as their awareness of renewable energy sources. Moreover, the purpose of the study was to learn if an activity related to building a model solar car could be integrated into a physics class. Often this activity is extracurricular; therefore, it was performed to assess the challenges, conditions, and benefits of conducting the activity during class time. It was implemented at an international school in Turkey with 14 students. The quasi-experimental research design was used by dividing participants into two groups: a control and an experimental group. Only the experimental group received the intervention which is the solar-powered car design activity. Hence, the researcher was able to compare whether the activity had a better influence on participants' renewable energy awareness and related physics concepts knowledge by means of a pre-test and a post-test. In addition to the pre-test and the post-test, follow-up interviews were conducted with five participants and an expert teacher.

In conclusion, the researcher found indications that the activity may work in a regular physics class. Furthermore, the students who participated in the activity showed improvement in terms of renewable energy awareness and selected physics concepts. Nonetheless, these results only provide descriptive information due to the small sample size and the short period of implementation time which was two weeks; however, this study holds an important place that may lead to a larger study. Through this study, the researcher shared his reflections on the implementation process and developed skills on how to integrate a hands-on into a lesson.

Keywords: renewable energy education, hands-on experience, physics class, physics concepts, action research.

ÖZET

# ÖĞRENCİLERİN FİZİK KAVRAMLARI HAKKINDAKİ ANLAYIŞLARINI VE YENİLENEBİLİR ENERJİ KAYNAKLARINA YÖNELİK FARKINDALIKLARINI GELİŞTİRME AMAÇLI, SINIF İÇİNE UYARLANMIŞ, PRATİK DENEYİM İÇEREN BİR GÜNEŞ ENERJİSİ AKTİVİTESİNİN EYLEM ARAŞTIRMASI

Tuğcan Yıldırım

Yüksek Lisans, Eğitim Programları ve Öğretim
Tez Yöneticisi: Yrd. Doç. Dr. Jennie Farber Lane

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Mevcut çalışma, öğrencilerin yenilenebilir enerji kaynakları farkındalığını arttırmayı hedeflediği gibi ilgili fizik kavramlarını vurgulayarak, katılımcıların bu kavramlara bakış açılarını geliştirmeyi hedefleyen, pratik deneyim içeren güneş enerjisi ile ilgili bir aktivitenin fizik dersine entegre edilme uygulamasıdır. Bu çalışmanın amacı güneş pili ile çalışan araba tasarımı aktivitesinin sınıf içine entegre edilip edilemeyeceğini öğrenmektir. Bu aktivite genellikle müfredat dışı görüldüğü için araştırmacı tarafından sınıf içine entegrasyonu önündeki engeller ve faydalar eylem araştırması teknikleri ile değerlendirilmiştir. Bu aktivite Türkiye'de bulunan bir uluslararası okulda 14 öğrenci ile düzenlenmiştir. Öğrencileri deney ve kontrol gurubu şeklinde ikiye bölerek yarı deneysel çalışma teknikleri kullanılmıştır. Sadece deney grubuna, farklı bir yöntem olarak, güneş pili ile çalışan araba tasarımı aktivitesi uygulanmıştır. Böylece, araştırmacı ön test ve son test uygulayarak iki grubun sonuçlarını kıyaslamış ve aktivitenin öğrenciler üzerinde daha iyi bir etkiye sahip olup olmadığını anlayabilmiştir. Ön test ve son teste ek olarak, beş öğrenci ve alanında uzman bir öğretmenle tamamlayıcı görüşmeler yapılmıştır. Sonuç olarak, araştırmacı aktivitenin sınıfa entegre edilebileceği yönünde bulgular saptamıştır. Ayrıca, aktiviteye katılan öğrencilerin fizik kavramlarına bakış açılarında ve yenilenebilir enerji kaynaklarına yönelik farkındalıklarında ilerleme gözlemlenmiştir. Bunlara rağmen, küçük örneklem hacmi ve kısa zamanlı bir uygulama olması nedeniyle bu sonuçlar sadece açıklayıcı bilgiler sunmaktadır. Yine de, bu çalışma daha kapsamlı bir çalışmaya öncülük edebilecek bulgular barındırmaktadır. Çalışma boyunca, araştırmacı bu süreçle ilgili tecrübelerini ve değerlendirmelerini paylaşmış ve pratik deneyim içeren bir aktivitenin sınıf ortamına nasıl entegre edileceği ile ilgili beceriler kazanmıştır.

Anahtar kelimeler: Yenilenebilir enerji eğitimi, yaparak edinilen deneyim, fizik dersi, fizik kavramları, eylem araştırması.

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TABLE OF CONTENTS

LIST OF TABLES

# CHAPTER 1: INTRODUCTION

## Introduction

This study involved a hands-on activity in which renewable energy concepts and related physics concepts were combined. The purpose of the study is to ensure the activity works smoothly and could be integrated into a physics lesson. To monitor this process, the researcher engaged in action research methods to reflect on and refine his actions. The study used a quasi-experimental design to investigate whether involving students in designing, building, and testing solar-powered model cars increases their awareness of renewable energy concepts and improves their understanding of selected physics concepts. Only descriptive statistics were used to assess the activity's influence on participants.

Another purpose of the study was to develop a teaching guide to help educators integrate the renewable energy activity into their physics curriculum. The results of this study could lead to further investigations that examine the outcomes of the project more extensively.

## Background

### Energy resource issues

As a result of the industrial revolution, the world has been harvesting vast amounts of energy resources and is now facing energy problems to meet the demand of being a technologically advanced civilization. These energy resources are non-renewable which means that their supply is not limitless and once they are consumed they are not regenerated. Furthermore, these resources are usually used inefficiently and creating excessive by-products. These by-products include greenhouse gases such as carbon that are responsible for trapping heat energy and credited with altering the climate (Holdren, 2008).

Research by Benli (2013) claims that Turkey is encountering serious problems related to the residual energy needed to offset its economic growth. This growing economy is causing the electricity consumption increase by an average of 8-9% per year. Thus, considerable investments in renewable energy need to be made in order to compensate the energy expenditure for transmission and distribution facilities since Turkey try to dispose of the dependence on imported gas from Russia and Iran.

**Renewable energy solutions**

"A renewable energy source can be defined as a simple sustainable resource available over the long term at a reasonable cost that can be used for any task without negative effects" (Manzano-Agugliaro, et al., 2013, p. 135). Thus, renewable energy sources (RES) provide a solution to sustain and reuse energy resources by switching from non-renewable energy sources to RES.  That is why RES may provide meaningful results in the long term.  In addition, renewable energy applications and technologies could enhance our daily basis without threatening our future because they can be replenished in a way that it would cause no harm to the environment (Ellabban, Abu-Rub, & Blaabjerg, 2014).

**Renewable energy usage**

RES are becoming more popular in a number of countries around the world, especially in more developed countries such as Australia, Finland, Sweden, Norway, and Germany. However, most still heavily rely on fossil fuels which are non-renewable energy sources that cannot be used again. Increasing the amount used in RES, encouraging the attempts to switching to RE, and raising its awareness are important goals to issue global warming, energy efficiency, and protecting the environment are some of the serious efforts. Turkey has also deficits in terms of RES. International Energy Agency (IEA) (2016) reported that Turkey's domestic energy production is dependent on fossil fuels, only 12% of its energy production comes from RES (p. 23). Despite these global efforts to date, the process of switching to RE is still unsatisfying. According to United Nations Development Programme (UNDP), renewable energy sources provide just 14% of the earth's energy need (as cited in Panwar, Kaushik, Kothari, 2011, p. 1513).

**Renewable energy education**

To make real the transition from non-renewable energy sources to RES, there is a need for the global economy and its market in RES to have renewable energy applications in daily life. Consequently, becoming part of the energy issues as a global society composed of those who are aware of the fact that RES are crucial for our future takes an important place.  Cherni and Kentish (2007) argue that "in satisfying the increasing demand for electricity and water supplies, [RES] could encourage technology updates and national manufacturing" (p. 3616). Namely, as a society, we need to have politicians, employees, employers, scientists, students, teachers who are educated in RES and their efficiency. At that point, renewable energy education comes into play. In order to have a society that is aware of renewable energy, we need to elaborate on the ways of implementing renewable energy education into the existing education systems. For, today's students will constitute the future society that will face environmental problems more seriously than we are. Accordingly, when the conditions get worse day by day, energy issues will be harder to solve.

Jennings (2009) lists renewable energy among the goals of a developed society and includes the following recommendations for education and training:

- Promotion of greater public awareness of the technology
- Development of consumer confidence in the technology
- Training of technical support staff, who are essential for designing, installing and maintaining high-quality renewable energy systems
- Initial training of engineers, scientists, and researchers who will develop new systems, devices, and technologies for industry
- Training of policy analysts who are knowledgeable about the industry and are able to produce effective policies for industry development
- Training of people who will provide advice and assistance to future customers of the industry (p.436).

**Renewable energy education programs**

A wide variety of renewable energy programs have been applied including educational programs and it has a great importance to have students aware of renewable energy and its applications to develop a society seeking solutions to the serious problem, such as Wisconsin K-12 Energy Education Program (KEEP). The purpose of KEEP (http://www.uwsp.edu/KEEP) is to raise awareness of RES in Wisconsin K-12 schools through promoting energy education resources and such programs can be implemented into the classroom environment. Creating education programs of RES need to ensure mutual effect on the students' awareness of RES by establishing a curriculum in accordance with the trends in the industry and the demand of the region (Kacan, 2015).

### Junior Solar Sprint

Junior Solar Sprint (JSS) is a program (http://www.usaeop.com/programs/competitions/jss/) that was formed by National Renewable Energy Laboratory in the 1980s and supported by many different associations since that time. JSS enables students to design and create solar cars with hands-on skills with regard to science and math. Students are divided into groups and they begin with using their problem-solving skills. They gain teamwork abilities, awareness of the environmental issues, develop engineering skills in order to have fastest and the most stabilized car to move it along the road in favor of solar panels. Eventually, students race the cars built by groups in a certain distance.

## Problem

In physics education, experiments and first-hand experiences are important when it comes to learning its concepts, but developing a sound understanding of the concepts may turn out to be a complicated process that involves action and experience. Traditional instructions may cause misconceptions when it focuses only on grades and exams. Several research studies found that students' alternative conceptions in science are very stubborn and traditional methods in learning are not enough in supporting conceptual change (Driver, 1989). Students might also lack opportunities to apply their physics knowledge to help address real-world issues, such as energy efficiency and resource management.

An important criticism was articulated by Volpe (1984), "The student's traditional role is that of a passive note-taker and regurgitator of factual information. What is urgently needed is an educational program in which students become interested in actively knowing, rather than passively believing" (p. 433). In spite of various efforts on energy literacy, the results of preceding research in terms of RES education showed inadequacy in terms of curricula, textbooks, and hands-on experience. Overall, every educational area among many countries projected the necessity of attempts in creating greater public awareness of RES education (Bojic, 2004; DeWaters & Powers, 2011; Halder et al., 2012; Karabulut, Gedik, Keçebaş & Alkan, 2011; Keramitsoglou, 2016; Liarakou, Gavrilakis & Flouri, 2009; Tortop, 2012).

Within an intense curriculum, students are surrounded by theoretical knowledge about physics. But, they also need hands-on experiences about real world problems such as RES and sustainability. Nonetheless, traditional educational systems are based on paper-and-pencil exams so that energy problems of the world cannot easily be internalized in students' minds. Some research related to this problem increasingly indicated that knowledge connected to action and sustainable practice must be promoted in educational practices (Frick, Kaiser, & Wilson, 2004; Jensen & Schnack, 2006; Keramitsoglou, 2016).

Physics and science lessons have already practical work to give students a concrete understanding of the concepts. For example, laboratories serve to conduct experiments in physics lessons to provide students with a comprehensive experience. However, in the laboratory sessions, students might not have the opportunities to alter conditions, use their imaginations, and grasp the nature of science. Besides, students may not appreciate the connectedness of science with other concepts as environmental issues.

Efforts could be made for having students experience the scientific process at first hand to understand how scientists and engineers work together to solve the world's problems. At that point, hands-on experience distinguishes itself from practical work in the laboratory as Levinson (2005) pointed out "processes of science does not mean the skills of carrying out particular laboratory operations (such as using a burette, microscope or potentiometer), but the skills of carrying out the 'strategic' processes of science (such as hypothesising, inferring, designing experiments, interpreting data)" (p, 159).

International Baccalaureate Organization (IBO), which is an educational foundation that provides programmes of international education, includes objectives that value hands-on experience. IBO aims for attaining concurrency of learning by which students are exposed to a variety of phenomena simultaneously. In this way, they are encouraged to develop their own understanding of the nature of science as it is connected with many different branches (IBO, 2013, p. 8). However, achieving these objectives might be challenging for teachers in an intense curriculum to cover. For these reasons, hands-on experience in a science lesson may play a role in having students comprehend the association of knowledge and experience, therefore the present study is a first step to better integrate hands-on activities in physics lessons and to investigate how they affect student learning.

## Purpose

The purpose of this study is to integrate a hands-on activity (Junior Solar Sprint) into a physics lesson. This activity involves students in designing, building, and testing solar-powered model cars. The researcher adapted the activity to increase students' awareness of RES and also to improve their understanding and experience applying selected physics topics. Although JSS has been successfully implemented around the world, it has not been researched to learn how the activity may enhance understanding of physics. Therefore, the first step of merging JSS with physics lessons is to ensure the activity could be successfully implemented in a physics classroom setting.

In addition, this study can be a teaching guide that can be used by anyone around the world because it provides a consolidated resource for using the activity in a physics class. Because the activity aims at sparking students' creativity and curiosity toward energy issues and related physics concepts, it may help teachers provide students with practical physics experiences by developing a guide that integrates a unit on renewable energy into their physics curriculum.

Another purpose of the study is to use action research methods in order for the researcher to reflect on the process to improve his efforts in integrating hands-on activities into his regular lessons when he becomes a teacher. Especially, the qualitative part of the study includes action research to analyze the data to find possible ways to make it better for the future studies or classroom implementations.

## Research questions

This study will address these questions:

- What steps can be taken to ensure that a lesson on building solar car works as designed?
- What evidence is there that building a model solar car improves students' understanding of selected physics topics?
- What evidence is there that building a model solar car increases students' awareness of renewable energy concepts?
- Does a lesson about building solar cars support teachers' efforts to integrate RE concepts into a physics curriculum?

## Significance

Energy education is the possible tool to increase energy awareness across the world so the importance of energy awareness in physics education is considerably emphasized not only in Turkey but also around the world. Physics teachers make great efforts to implement extracurricular activities into their national and/or international curricula in a certain sense. The point is that physics education may need to be embedded in hands-on and minds-on activities to have students concretely understand how scientists work and develop solutions to the real world problems of energy sustainability. Yet, not enough attention has been paid to how teachers apply for practical work about RES. It may appear problematic to utilize the limited time that is so valuable in preparing students for exams due to the concern of academic achievement. That is why this project may seem meaningful when it comes to having students develop a better understanding of physics concepts thanks to a hand- on activity related to solar energy. Since physics is highly connected to RES, factual knowledge about physics and practical work about RES can take place side by side through applying varied physics concepts to move solar-powered cars along a road. In this way, they can learn about the applications of RES resources and gain knowledge, skills, ways of thinking to help address energy-related issues in our society.

Another significance of the study is adapting the activity. The results of the study may lead to further research and also it may resource a teaching guide for teachers who want to apply such activities into their lessons.

## Definition of key terms

Action Research: Sagor (2000) defines action research as “It is a disciplined process of inquiry conducted by and for those taking the action. The primary reason for engaging in action research is to assist the ‘actor’ in improving and/or refining his or her actions.”

Junior Solar Sprint (JSS): Army Educational Outreach Program (AEOP) defines Junior Solar Sprint in its website as:

> Junior Solar Sprint is a free educational program for 5th through 8th-grade students where students design, build and race solar-powered cars using hands-on engineering skills and principles of science and math. Students develop teamwork and problem-solving abilities, investigate environmental issues and gain hands-on science, technology, engineering and mathematics (STEM) skills to create the fastest, most interesting, and best crafted vehicle possible. JSS is designed to support the instruction of STEM (Science,

> Technology, Engineering and Mathematics) in categories such as alternative fuels, engineering design, and aerodynamics.

International Baccalaureate Organization: IBO or IB defines itself on its website as:

> Founded in 1968, the International Baccalaureate (IB) is a non-profit educational foundation offering four highly respected programmes of international education that develop the intellectual, personal, emotional and social skills needed to live, learn and work in a rapidly globalizing world. Schools must be authorized, by the IB organization, to offer any of the programmes.

Renewable energy: Ellabban, Abu-Rub, and Blaabjerg (2014) stated renewable energy is energy sources that can be extracted directly or indirectly from the sun but they can be restored over a period of time (p. 749).

# CHAPTER 2: REVIEW OF RELATED LITERATURE

## Introduction

This study focuses on integrating a hands-on activity related to renewable energy and looking into whether the activity changes students' awareness of RES and understanding of selected physics concepts. The purpose of this chapter is to review the previous research and studies to gain insights into how renewable energy and science education is applied with hands-on activities. It also presents useful insights into how to implement a hands-on activity into lessons.

## Environmental education

### Renewable energy programs in education

Environmental education is fundamentally a comprehensive approach, it is linked with various concepts such as social sciences, arts, mathematics, science, and humanities so as to have learners appreciate complicated environmental issues. For this reason, environmental education requires its educators to be aware and dedicated to understanding environmental issues to the fullest extent (Archie et al., 2005, p. 2). That is, environmental educators tries to foster a global society that acts in alternative ways to conduce to a healthier environment by searching for a chance in promoting learner's appreciation, attitudes, and abilities (Carleton-Hug & Hug, 2010). Environmental education prepares individuals to care for the land and protect it for the next generations. It is obvious that environmental education requires individuals step in energy issues. Today's energy issues contain energy concepts because the ways we harness energy affect our environment. Therefore, a hands-on activity related to RES could encompass environmental and energy education together.

## Need for renewable energy education

The importance of switching to renewable energy sources could be realized by the society through renewable energy education (Adlong, 2012, p. 147). Thus, renewable energy applications are important to sustain the energy sources of the world. It will become more important in the future because of the lack of energy sources and the damage of fossil fuels. The people, who are aware of the benefits of renewable energy, would seek alternative ways to produce it; therefore, educating people at an early age could be meaningful in order to have them prepare in dealing with energy issues (Ziolkowski, 2007, p. 11). For that reason, elaborating on renewable energy concepts in education might help people attach importance to the energy problems of the future (Wisconsin K-12 Energy Education Program, 2005).

Turkey is an energy importing country which means that more than half of the energy demand has been supplied from other countries. That is, there is increasing energy depletion over years so renewable energy resources become to prominence to the effective and clean solutions for sustainable future.  For these reasons, the necessity of renewable energy education to promote RES awareness arises to solve this energy problem in the future since the traditional educational methods do not fit in this case (Acikgoz, 2011, p. 610).

## Renewable energy and sustainability in physics education

At the World Conference on Physics and Sustainable Development (WCPSD, 2005), people argued that supporting the idea of physics and sustainable development shares the same ground, such as energy production. That is, physics teachers should adopt these concepts into their instructions as themes. In addition, Chen, Huang, and Liu (2013) argue that energy education should be implemented into school education and into K-12 curriculum. Another important finding comes from the research conducted by DeWaters and Powers (2011) as they pointed out that trying to raise awareness of RES with traditional teaching methods seems not enough to have students understand the importance of energy issues.  That is to say, teachers could seek ways to have students become aware of the importance of their energy usage habits and the effects of their actions on the environment (Engström, Gustaffsson, & Niedderer, 2011, p. 1286).

## Renewable energy trends and renewable energy education

### Renewable energy programs in education

Energy education is a way to teach and guide students through learning the world's energy sources and energy need. Therefore, education programs must support and be adaptive to the energy education. Opinion Dynamics Corporation (2012) grouped energy education programs into four categories: curriculum-based offerings, curriculum-based with proactive energy savings, curriculum-based with hands-on activities or projects aimed at energy savings, and curriculum-based with energy saving kits (as cited in Lane, Baker, Franzen, Kerlin &Schuller, 2015). To gain a better understanding of renewable energy programs, National Energy Education Development Project (NEED) and the Wisconsin K-12 Energy Education Program (KEEP) are to be featured. These two programs are based on curriculum development and use of hands-on activities.

## The NEED Project

About 35 years ago, The NEED Project was established when National Energy Education Day was acknowledged with the aim of spreading energy education throughout the world. The aim of this project was to encourage students to explore, experiment, and engage with groups by means of raising awareness of renewable energy and technologies in the lessons. The Need project supports schools, teachers, and students by fostering them to be leaders and addressing the energy issues in school or beyond. The NEED considers teachers and students as experts and leaders in the community to take responsibility, have discussions, make decisions, and educate their own family to change the world. The NEED project proposes and yields curriculum and materials for any classroom at any level of grade. The main idea of the program is to have students make use of hands-on activities and inquiry-based lessons to learn about the physics and chemistry of energy.

## The KEEP

In 1993, the Wisconsin Center for Environmental Education (WCEE) designed an extensive activity guide to K-12 energy education. In 1995, the Energy Center of Wisconsin which is a nonprofit energy-efficiency constitution founded in Madison accepted to invest this project. (KEEP, 2005). Although it was made for aiming at being a regional guide, it consists of many activities and knowledge adapted to classrooms to encourage teachers all around the world to have students become sensible about RES. Their ultimate purpose for preparing this guide was to make students acquire basic knowledge about energy by experience in favor of the activities within the classroom or beyond. That is how the Wisconsin K-12 Energy Education Program (KEEP) came into existence. They have a clear and logical rationale such that the decisions about energy use must be made by educated people so that this guide was made to serve in giving a comprehensive understanding of RES to students at an early age. Theme one begins with energy basics and gives a general idea of the energy, such as, where it comes from, which forms it takes. As clear explanations about these resources mentioned, Jennie Farber Lane, who was one of the authors of this guide, and her colleagues probed how to develop energy resources and explained them step by step. They also expressed effects of energy resource development with giving economic, sociopolitical, cultural, management and future outlook issues. The KEEP and some of the other programs have adopted best practices to engage students and teachers in hands-on school projects, directly work with utility administrators, adopt actionable tips for the home, parental engagement, and tracking of energy data in a daily basis (Energy Center of Wisconsin, memorandum, January 11, 2013).

**Solar energy and solar-powered car design activity**

Quinn, Schweingruber, and Keller (2012) define science as "Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge.  Both elements—knowledge and practice— are essential" (p. 26). In science education, practical work and knowledge could not be separated from each other since they both are important in its learning process. Therefore, hands-on experiences in science education could be relevant to deliver students practical work and knowledge together.

**Solar-powered car design**

The sun is our primary energy source that we benefit from its process in which rays of sunlight reach out the surface of Earth. As it sends that form of energy in light, we convert it into other forms of energy in order to get efficient energy like heat and electricity. Because the sun has a limitless source compared to the lifetime of our planet, we can use it as an inexhaustible energy source to be able to sustain the life on Earth (Plitnik, 2016). Thus, solar energy is one of the most important renewable energy resources so the importance of utilizing it is an important issue. That is why a solar-powered car design activity could be meaningful to teach students how a renewable energy source powers a car to help them face energy challenges in the future.

The opinion of conducting an activity for school students to build solar-powered cars came from World Solar Challenge, which was carried out in 1987 as the first intercontinental race for solar vehicles. One of the aims of this project was to trigger high school students' curiosity and creativity so that they take responsibility for energy problems and change the future (Wellington, 1996).

Research by Schnittka and Richards (2016) explains the steps of the solar-powered car activity as students use a solar panel, engine, wheels, and axle during the design process. By doing so, they use their problem-solving skills and apply their theoretical physics knowledge into practice. Students can apply the physics concepts like basic force and motion, electric circuits, torque, and friction during the activity. Furthermore, comparing different types of tires, motors with small gears or big gears, and how to make a balanced car would be other challenges to take into consideration in terms of physics concepts. Apart from all of those, they work with groups and race their designs at the end of the process. Competence and group work might transform traditional learning environment into a creative process in which they develop multidisciplinary skills.

Carroll and Hirtz (2002) stressed the purpose of the activity similarly. It is to have students learn how to handle multi-disciplinary design projects; they are encouraged to design a solar-powered car in a limited time. Students need to brainstorm and model their cars within a certain period of time. Therefore, leadership and project management skills come into play throughout the process.

**Hands-on activities and student learning**

Learning can be considered in two different ways: learning facts and learning how to do things (Michael, 2006, p. 161). Teaching students factual knowledge may not mean that they know how to do it or perceive the concepts exactly. Ryle (1949) put forward the difference between those two kinds: knowing something and knowing how to do something. Teaching students how to use their theoretical knowledge to solve a real-world problem may require different teaching methods than traditional ones (Michael, 2006, p. 161). By contrast with just hearing and reading something, science education requires students examine their ideas and develop their own understanding (Ewers, 2001). That is why science education is hard to perform without hands-on experiences.

Hands-on experiences could be implemented into a teaching program in which students are involved and directly exposed to the natural phenomenon so they begin to manipulate or change settings, therefore they develop a better understanding of the concepts (Haury & Rillero, 1994). Such terms as activity centered and practical activities are interchangeable. However, laboratory work and hands-on activities are different things. Jodl and Eckert (1998) explained these difference as hands-on activities do not require using special equipment and environment so the activities can be conducted with simple and cost-effective materials that one can find and gather them easily.

Many studies in the related literature indicated that hands-on activities promote students with a better comprehension of the concepts compared to those who learned them in traditional teaching ways (Bredderman, 1985; Freedman, 1997; Glasson, 1989; Shymansky, Kyle, Alport, 1983; Turpin, 2000). Moreover, hands-on activities seemed even helpful to detect and correct alternative conceptions in science topics (Costu, Ünal & Ayas, 2007). Some other studies showed that hands-on activities change students' attitudes towards science and scientific literacy in a good way (Bredderman, 1985; Jaus, 1977; Kyle, Bonnstetter, & Gadsten, 1988; Schibeci & Riley, 1986). In addition, these activities are found to be effective to increase students' problem-solving skills and creativity in real world situations (Haury & Rillero, 1994; Staver & Small, 1990). National Center for Education Statistics (NCES) (2001) conducted some science assessments and found that the students who participated in hands-on and collaborative activities exhibited remarkable performance on the assessments (Aud et al., 2001). Hence, hands-on activities could contribute students' academic achievement in science courses and help them develop their own understanding.

The learning process needs to provide students with a convenient environment to learn by discovering and exchanging ideas between each other (Ateş & Eryılmaz, 2011). Similarly, along with hands-on activities, a learner may reflect on what he or she is learning during the process so combining hands-on and minds-on activities would present a suitable environment for students to be engaged, creative, and problem solvers (Hofstein & Lunetta, 1982). For physics courses, a research conducted on 6500 students by Hake (1998) revealed that many hands-on activities can be implemented into physics courses. In this way, students internalize physics concepts; keep the knowledge longer and better than the students who follow the traditional lecture and laboratory sessions (Halloun, 1996; Perkins, Adams, Pollock, Finkelstein & Wieman, 2005).

A research by Flick (1993) argued the benefits of hands-on activities in science classes. Since students are engaged in scientific phenomena with hands-on activities, they are encouraged to develop a solid understanding of science concepts through manipulating subject materials during those activities. Thus, scientific concepts may become less discrete in order for students to perceive the nature of science and technology as a compound process. Another research conducted by Stohr-Hunt (1996) analyzed the relation between the amount of time students exposed to hands-on activities in science classes and their academic achievement. The study revealed that students who participated in hands-on activities every day or once a week have significantly higher scores on a standardized test of science achievement rather than the students who participated in hands-on activities once a month, less than once a month, or never.

Scientific knowledge given as factual knowledge by traditional text-based lectures might have students comprehend them as a static body of knowledge (Roth & Roychoudhury, 1994). On the other hand, students who participate in the learning process actively perceive the scientific knowledge as not an absolute truth. They begin to discover the concepts at first hand as teachers just guide them throughout their learning process. Likewise, a study by Marusic & Slisko (2014) reported that students who follow experimenting and discussion methods in the learning process have a sound understanding of the physical laws and a positive attitude toward how physics knowledge can be implemented into the real world.

### Teacher-researchers' perspectives on renewable energy education

In science and technology education, teachers could take initiative and challenge students with hands-on activities about alternative energy and transportation technologies within which competence and creativity are highly involved. Students need to be exposed that kind of experience and to build their own understanding so they could make contributions to the future development (Busby & Carpenter, 2009, p. 20).

Hecht & Werner (2013) tried to apply hands-on teaching in weekly sessions by working with professionals. They conclude that co-teaching model with professionals in learning by doing activities, such as JSS gives students opportunity to create and design a team project. Throughout the process, students learn basic mechanical and electrical engineering principles along with solar energy. Therefore, solar car design activity might be a useful activity in teaching physics concepts.

David Garlovsky, who is a science teacher, found a different way to have students design solar cars. He visits schools with his solar-powered car and lets students examine it. Yet, he doesn't give this car to students. Instead, he gives some kit form of a solar-powered car to students so they want to assemble it. The components were designed to teach students several physics and environmental topics while they are building the car (Walker & Garlovsky, 2016, p. 12). Similarly, Campbell and Neilson (2009) found that students in a design project, which related to frictional force, learned not only the friction itself. The researcher reported that students also become accustomed to the scientific process and evidence-based learning through their efforts.

Additionally, during a weeklong unit on solar-energy to have students design solar cars may have a positive influence on students. It could help them feel comfortable with the science concepts and appreciate collaborative work by designing a solar car. At the end of the design, they race their cars so the competence comes to light among the groups. Further, students might comprehend the complexity of a design by bringing their theoretical knowledge to the real world problems. In this way, they could learn cause and rationale of the concepts on their own (Ing, Ward & Haberer, 2013, p. 29).

## Summary

Renewable energy sources and physics concepts are closely related, especially in hands-on activities. Therefore, both of them could be covered during a hands-on activity. In general, the literature review in this chapter showed that students' attitudes, knowledge, and perceptions related to a variety of physics and renewable energy concepts might change due to hands-on activities. Since environmental education includes some physics concepts, teachers may touch on these concepts during their lessons in order for students to build a sound rationale about renewable energy and its connection to the physical laws. Because it's hard to understand solar energy without comprehending related physics concepts, trying to conduct such an activity as solar-powered car design could be beneficial. That is why combining physics and renewable energy is at the center of this study. As it is discussed in this chapter, learning by doing seemed more effective than traditional text-based instructions. Then having students imagine, create, and test their design are important components in order for students to be active learners. Therefore, many studies supported the idea of environmental and science education should be meshed together in or beyond the school environment.

# CHAPTER 3: METHOD

## Introduction

The purpose of this study was to implement a hands-on activity that involves students in designing, building, and testing solar-powered model cars into a physics lesson. Another aim of the study was to use action research strategies to provide the researcher with indications that the activity could be integrated into a physics class. Then the researcher looked into whether it contributes students' awareness of RES and understanding of selected physics concepts. These selected physics topics such as force, motion, electricity, and momentum were chosen because they relate to the topic of solar energy and the design of the model cars. In this way, the fundamental physics concepts were connected with a renewable energy lesson. The outcome of the study includes a guide that implements a hands-on activity into a physics classroom.Thus, physics or science teachers can benefit and then apply it into their lessons.

## Research design

In the study, action research methods were used for the researcher to interpret and reflect on the descriptive information acquired from participants (pre-test and post-test) and the expert teacher through interviews. Action research is an inquiry-based process in which planning, acting, observing, and reflecting take place (Lewin, 1946). Its goal is to support educators to find weaknesses in schools, academia, or organizations and devise convenient solutions by following these steps: collecting data on the problem, analyzing, and interpreting the data, developing a plan to address the problem, implementing the plan and evaluating the results of the actions taken (Calhoun, 1994).

Action research is also meant for improving the actor, who is applying it, while he investigates the problems and developing solutions. To this end, the implementation of the study depended on aforementioned steps to make the study beneficial for the researcher who is a pre-service teacher. As a pre-service teacher, the researcher went to different schools during his internships and had to work with students some of whom participated in this study. Namely, he met the participants before the study and decided to include them in his study last semester since they are already in two separate, comparable level classes. Then the researcher sought possible ways to implement the activity into their physics lesson. During this process, he asked for advice from expert teachers, professors, and professionals in the area so that he developed some skills on integrating hands-on activities into lessons as action research methods require.

To gain insights into the effectiveness of the hands-on activity, the researcher applied a quasi-experimental research design to see the activity is effective. It allowed the researcher to investigate the influence of the activity. Another reason for using the quasi-experimental design is to have a conveniently selected sample size. There was an experimental group and a control group, thus the study had a pretest-posttest design under the umbrella of quasi-experimental design. While the experimental group receives the intervention, the control group does not receive any intervention (Leedy & Ormrod, 2005, p. 207).

In the current study, the intervention (solar-powered car design activity) was applied to the experimental group, although only traditional teaching about renewable energy was performed with the control group. In addition to the pre-test and the post-test, follow-up interviews with five participants from the experimental group and with an expert teacher who observed the activity took place.

Steps of the study can be shown in a table as:

Table 1
Timeline

| | | | | |
|---|---|---|---|---|
| Experimental Group | Pre-test March 14, 2017 | Intervention March 14, 2017 | Student Independent Work | Post-test March 22, 2017 |
| Control Group | Pre-test March 14, 2017 | No intervention | Not Applicable | Post-test March 22, 2017 |

This research took two years to devise, conduct, and complete. There were a number of factors that affected this process. One of the factors was finding the school where the activity was going to be conducted. In order to do this, permissions obtained from the school and the Ministry of National Education (MoNE) in Turkey. Then this process proceeded with designing and making searches in the literature to investigate possible ways of implementing the activity into a physics lesson. Moreover, the instruments used in the study were found during the literature review and then permissions to use them were taken.

Extending the activity over a period of time was an important part in the study. The time allocation for the treatment was two weeks in this study, but it may have lasted longer if the school spared more time. Since the teachers of every school already have a curriculum to cover, finding a school willing to participate in conducting such a project was challenging for the researcher.

Then the researcher contacted some experienced teachers from the USA and Turkey, who conducted activities similar to JSS. The teacher from the USA shared her activity plans, schedule, and some advice about how to find the materials for the activity because providing required equipment was crucial to have the activity work smoothly. For that reason, the researcher provides a teaching guide for this activity in Appendix A.

Before conducting the activity in a high school, the researcher performed the project with his peers who were pre-service teachers in an MA program. In this way, the researcher gained the chance to experience the activity beforehand in order to see possible issues such as malfunctioning of the materials and missing instructions through the feedback coming from his peers. The researcher also practiced building solar cars during the last summer to gain experience beforehand. Thereby, the researcher prepared the actual activity to be conducted in the school.

Parental permissions for students to participate in the project were taken with the help of the responsible teacher in the school. Participants were ensured that information coming from the instruments was going to be kept confidential. As part of the study, the solar energy lesson was taught to both groups as a traditional teaching method and it took one lesson period. The treatment, which only applied to the experimental group, involved the participants in designing, building and testing the solar cars took two weeks in total. Participants of the experimental group were supposed to come up with their own designs. They were responsible for working on their designs gradually in their free time such as breaks, lunchtime, and after school. At the end of the second week, they finished their model solar cars and raced them. However, only one car out of three was able to function properly so it was the winner of the race.

## Context

This study was conducted at Bilkent Laboratory and International School (BLIS) with 11$^{th}$ grade IB physics students who have high socio-economic status and highly educated parents compared to the general student profile of Turkey. The researcher was provided with two physics classes to work with during the study. Prior to conducting the study, the researcher secured permission from the Ministry of National Education (MoNE) in Turkey, the school administration, and parents.

## Sampling

In the current study, convenience sampling was used because involved students were provided to conduct the study by the physics teachers at the school. Namely, these students were selected because they were the available students at that time for the researcher. Participants of this study come from two different classes in an international school. Each class has seven students who are eleventh grade students in the International Baccalaureate Diploma Programme (IBDP) and the total sample size adds up to 14 (N=14).

Participants' gender distribution is shown in the table below.

Table 2
Gender Distribution

| Gender | Number of Students | Percentage of Students |
|---|---|---|
| Female | 5 | 35 |
| Male | 9 | 65 |
| **Total** | 14 | 100 |

## Instrumentation

The pre and the post-test used in the study were comprised of two parts. One part (energy survey) focused on assessing renewable energy knowledge and attitudes. The second part included physics concepts related to the activity.

### Energy survey

Through a review of the literature, the researcher identified instruments that addressed the research questions of the study. The energy literacy tool developed by DeWaters, Qaqish, Graham, & Powers (2013) included items relevant to student awareness and knowledge of energy and was selected for the study.  The researcher received permission to use the survey and selected 16 items for the pre- and the post-test.

The energy survey consists of three sections (see Appendices B and C). The first section contains self-assessment to assess if students think they are knowledgeable about renewable energy. The second section includes Likert scale type questions for students to indicate how they feel about energy education, global energy policy, and how they act on renewable energy issues. The third section was comprised of energy knowledge-related multiple choice questions.

All of the energy survey questions listed in Tables 3 and 4 address the research question below:

- What evidence is there that building a model solar car increases students' awareness of renewable energy concepts?

Table 3
Energy literacy survey section one

| |
|---|
| **1.1** How much do you feel you know about energy? (rate yourself as "expert" to "novice" or less, as described below) |
| **1.2** When it comes to energy use, how would you describe yourself? |
| **1.3** Which of the following thing has contributed most to your understanding of energy issues and problems? |
| **1.4** How often do you talk to your family about ways you can save energy in and around your home? (for example, shutting off lights when they are not in use, turning down the heat, closing doors, and windows) |

Table 4
Energy literacy survey section two

| |
|---|
| **2.1** Energy education should be an important part of every school's curriculum. |
| **2.2** I believe that I can contribute to solving energy problems by working with others |
| **2.3** I don't need to worry about turning the lights or computers off in the classroom because the school pays for the electricity. |
| **2.4** We don't have to worry about conserving energy because new technologies will be developed to solve the energy problems for future generations. |
| **2.5** All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and operating costs. |
| **2.6** The government should have stronger restrictions about the gas mileage of new cars. |
| **2.7** We should make more of our electricity from renewable resources. |
| **2.8** Efforts to develop renewable energy technologies are more important than efforts to find and develop new sources of fossil fuels. |

**Multiple choice questions for physics concepts**

The study received permission to use a physics concept test designed and validated by Pierce James, Minnesota State University, Mankato, USA. A set of 14 questions was taken from his website to use in assessing the changes in students' understanding of related physics concepts. These multiple choice questions were generated to measure students' knowledge of motion, inertia, force, acceleration, work, momentum, and electricity that are all related to solar car design.

These physics concept questions, which can be found in Appendix C, address the research question below:
What evidence is there that building a model solar car improves students' understanding of selected physics topics?

**Interviews questions**

To provide further insight into the study, the researcher conducted an interview with the classroom instructor and administered a follow-up survey with the five students in the experimental group.

The interview with the classroom teacher was intended to evaluate the activity and identify areas for improvement and addressed the research question:

- Does a lesson about building solar cars support teachers' efforts to integrate RE concepts into a physics curriculum?

Following are the interview questions asked of the expert teacher:
-What did you think about the activity?
-Did you find the context of the lesson adequate?

-What would you do differently?

-What can a teacher learn from this experience/activity?

-Which physics topics can be covered with this activity?

-Would you implement this activity into physics classroom or does it have to be something extra to the physics classes?

The interview protocol for the students was developed based on the outcome of the questionnaire results. With this interview, the researcher tried to obtain students' opinions of the activity and how it could be performed better from their perspective in terms of instructions, materials, and the methodology. To examine the face and content validity of the items, before the interview, the researcher discussed the questions with his peers, supervisor and with the expert teacher.

The following questions were asked to gain further insight into the research question:

- What steps can be taken to ensure that a lesson on building solar car works as designed?

-What did you think of the experience?

-Did the instructions help you and guide you? What additional guidance or support would you have liked?

-Did you see something missing in the process? Would you add something necessary to the activity or the lesson?

-Do you want to do this activity differently?

To gain additional insights into research questions about whether the activity contributed to students understanding of physics concepts or/and awareness RES, the following question was asked:

-Did the activity contribute your awareness of renewable energy and related physics concepts?

## Method of data collection

Data collection for this study contains a pre-test and a post-test. Each has an energy survey and physics concept questions developed for students. Before applying these, consent forms sent to the parents and collected in March 2017.

Prior to the solar energy lesson, the pre-test implemented for both groups and then collected after 15 minutes. Then two weeks after, when the experimental group finished the activity and created solar cars, the post-test was administered and collected one after another on the same day from both groups. The reason for this action is to avoid memories of the pre-test which could influence responses to the post-test. That is why the control group also had to wait two weeks to take the post-test.

The follow-up interviews took place to help the researcher gain further insights into whether or not participants are satisfied by the activity. To this end, five participants from the experimental group were interviewed using a focus group approach and it took 15 minutes. Separately, the expert teacher who is the IBDP teacher in the school was interviewed and it took 10 minutes. Their responses were recorded and transcribed.

Action research methods played an important role in gaining insights from participants during the interviews. Qualitative data was interpreted by the researcher so that there might be subjective conclusions due to his positive opinions on hands-on activities. For this reason, he is open to any criticism and objection against his interpretation of the data coming from interviews.

Participants were free to express any opinion. Although there were not many negative opinions on the activity, the researcher tried to probe what they thought that was not worked well throughout the activity. By this way, the researcher reflected on the results for improvements in the integration process and his skills at actualizing it.

## Method of data analysis

Data analysis of the surveys consisted of simple statistics to calculate frequency and means for the quantitative data. After collecting these data, students' responses were compiled and inserted into tables in Microsoft Excel. Students were assigned numbers in order to track their responses as student one, student two, student three, etc. Their frequencies and means were calculated with the help of Microsoft Excel then shared in chapter four.

Participants' responses were evaluated in their groups as the experimental and the control group. Hence, the total amount of correct answers was shown in the tables so as to determine whether there is a difference in between the pre-test and the post-test. Another analysis was to see if participants of the experimental group have changed their attitudes towards energy issues to make sure the activity's objectives achieved.

The qualitative data coming from interviews were asked and analyzed by the researcher. Interviews were conducted with participants from the experimental group (focus group) and also with the expert teacher in order to make sure the activity worked smoothly. If not, the interview questions were to analyze how the activity could have been done better. Interview questions were short answer questions involved finding the common opinion of the focus group. All of the questions designed by the researcher as he discussed them with his supervisor to address the research questions of this study. Then the researcher recorded the responses and summarized to present them in chapter four.

The qualitative data was reviewed and common statements combined to identify the main message which is a hands-on activity can be useful for multiple purposes. For this aim, the differences in the tests and in the interviews were assessed subjectively because the study does not provide statistically inferential results due to the small sample size.

# CHAPTER 4: RESULTS

## Introduction

This chapter presents the results of the study. The purpose of the study was to adapt a hands-on activity that combines renewable energy concepts with related physics topics to a lesson. The instruments used to assess student understanding of these concepts were comprised of two parts: the energy literacy survey and physics concept questions. In addition, the researcher conducted interviews with five participants of the experimental group and their classroom teacher. In this way, the researcher gained insights into how the activity affects the participants' understanding of selected physics concepts while trying to see if it raises awareness of renewable energy sources.

The study included a control group and an experimental group. The latter received the intervention which is the solar-powered car design activity, whilst the other did not. Accordingly, this chapter shares the results of the data analysis obtained from the pre-test and the post-test given to both groups.

In addition to the data analysis and response frequencies, information from the interviews conducted with five participants in the experimental group and an expert teacher are also provided. The researcher also used action research methods to reflect on the results and these findings are reported in chapter five.

1) **What steps can be taken to ensure that a lesson on building solar car works as designed?**

Three questions in the survey were designed to learn if the participants thought the activity was effective. To that end, participants answered these questions: “I enjoyed the activity a lot”, “I learned a lot from this activity”, “This activity was worthwhile” and agreed by a total mean of 4.57 out of 5.0 that lends itself into the middle of strongly agree and moderately agree. In addition to insights the researcher learned from the quantitative data and reflected on during action research (see Chapter 5), the interviews provided key insights into learning if the lesson was implemented as designed. The following presents the interview responses obtained from five participants from the experimental group and an expert teacher who observed the activity.

**Student interview responses**

Interviewees reported that this experience was different than their regular physics classes. Since they learn physics too much based on theoretical work, therefore they are in need of using the concepts onto a design freely. In addition, most of them stressed that they did think that the activity was going to be boring but it did not turn out to be so. One of the participants expressed himself as “I thought it was going to be a boring activity that would make me frustrated, but during the activity I wanted it to last longer.” In fact, all interviewees indicated that they would want the activity to last longer. They stated that one month would be decent to come up a better design and also to appreciate the activity’s physics part more.

Most of the interviewees reported that the instructions were clear and enough to guide them through their learning processes. However, one of them pointed out that more clear instructions could have been better to design a solar car because they did not experience such an activity before. At that point, another interviewee objected this idea, he stated that it would prevent them from being creative since they needed to be alone to meet the challenge that the activity offers.

When asked if they felt anything was missing or if something should be added, most of the interviewees agreed that everything was adequate but they added that it could be better if there were extra materials like more different types of wheels, different shapes of solar panels. In addition, one of the interviewees reported that materials could be better in quality.

**Responses from the teacher interview**

The expert teacher reported that he liked the activity very much since it created an inquiry process in which students design, discuss, and test their ideas. The point he liked the most is they were enjoying while strengthening their physics concepts knowledge.

When asked what he would do differently, he said he could make the activity last longer if he was able to allocate more time. Furthermore, he reported that he might add the design Arduino which is a programmable device that could be used on any type of electrical design.

**2) What evidence is there that building a model solar car improves students' understanding of selected physics topics?**

This research question and the next were primarily addressed through the survey responses. Following is information about the items in the survey and the results. This section of the survey is about the selected physics concepts addressing the change in students' understanding of the physics concepts situated in the solar-powered car design activity. In the activity, there were a number of physics concepts to consider in designing a solar car, such as force and motion, work and energy, electricity and circuit analysis.

For the control group, a slight change might have been expected between the pre-test and the post-test because of the solar lesson (the traditional teaching method). As expected, the physics concept questions revealed that students in the control group have almost the same frequency in the pre-test and the post-test.

Contrariwise, there is a notable change for the experimental group between the pre-test and post-test. It is possible that the impact of the hands-on activity during two weeks may have contributed to this increase. These results can be found below in the table below.

Table 5
Results of physics concepts questions

| | Control | | Experimental | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| 1 | 5 | 6 | 3 | 6 |
| 2 | 7 | 6 | 5 | 7 |
| 3 | 6 | 3 | 6 | 4 |
| 4 | 3 | 4 | 2 | 6 |
| 5 | 7 | 7 | 6 | 7 |
| 6 | 6 | 7 | 5 | 6 |
| 7 | 7 | 7 | 7 | 6 |
| **Total** | **41** | **40** | **34** | **42** |
| **Mean** | **5.85** | **5.71** | **4.86** | **6** |

The table above shows participants' means and frequencies by groups. The number of incorrect and correct responses to physics question before and after the treatment, but the control group did not receive the treatment; they only took a traditional solar energy lesson. There is a decrease in the control group that goes from 41 to 40 in frequency (or from 5.85 to 5.71 in the mean) which corresponds to a decrease of *2 %*. On the other hand, there is an improvement in the experimental group, which goes from 34 to 42 in the frequency (or from 4.86 to 6 in the mean) which accounts for an increase of *23 %*.

There is an obvious difference between groups for the benefit of the experimental which exactly addresses one of the research questions. Yet, further details are to be discussed in chapter five.

Student interview responses also provided insights into this research question. When students were asked what they learned, they expressed that this activity had them appreciate physics concepts because they tried to apply them and see how they work. They agreed on applying a concept is a more valuable experience than just learning it. In addition, seeing solar energy powers a car convinced them renewable energy technologies are applicable if people work together.

**3) What evidence is there that building a model solar car increases students' awareness of renewable energy concepts?**

The analysis of the survey responses which is about energy literacy was used to address this research question. As presented in Chapter 3, there were three sections in the energy survey. Following key results from each section are presented.

**Section I**

In section one of the instrument, four self-assessment questions were asked to students and these questions were kept the same in the pre-test and the post-test to see how their opinions on energy changed. The first item asks participants to assess themselves on energy issues. In the pre-test, eight participants of the total population (*n=8; 57%*) agreed that they are a bit informed, while the remaining reported that they are somewhat informed about energy. The mean of all participants' responses corresponds to 3.57 out of 5 which can be interpreted as quite a bit informed. In the pre-test, both the experimental and control groups had the same results: four participants from each group reported that they are quite a bit informed and three participants from each group said they are somewhat informed. However, in the post-test, responses of the control group and the experimental group vary for the same questions. For the experimental, three participants (*n=3; 21%)* reported that they are somewhat informed, and the remaining four (*n=4; 28%)* agreed that they are quite a bit informed. For the control group, five participants (*n=5; 35%)* agreed that they are experts on energy.

These results can be seen in the tables below.

Table 6
Self-assessment pre-test

| Pre-test | | | | | | |
|---|---|---|---|---|---|---|
| **1.1** How much do you feel you know about energy? | Sample Size (N) | Expert | Quite a bit informed | Somewhat informed | Novice | Nothing |
| Control Group | 7 | 0 | 4 | 3 | 0 | 0 |
| Experimental Group | 7 | 0 | 4 | 3 | 0 | 0 |
| **Total** | 14 | 0 | 8 | 6 | 0 | 0 |

Table 7
Self-assessment post-test

| Post-test | | | | | | |
|---|---|---|---|---|---|---|
| **1.1** How much do you feel you know about energy? | Sample Size (N) | Expert | Quite a bit informed | Somewhat informed | Novice | Nothing |
| Control Group | 7 | 5 | 1 | 1 | 0 | 0 |
| Experimental Group | 7 | 0 | 4 | 3 | 0 | 0 |
| **Total** | 14 | 5 | 5 | 4 | 0 | 0 |

As seen in the tables above there is a change between the pre-test and the post-test for the control group. The participants of the control group seemed to change their minds after the solar lesson (the traditional teaching method). Five participants in the control group changed their minds and changed the self-evaluation to *an expert* on energy issues in the post-test. Yet, there is no change in numbers for the experimental group between the post-test and the post-test. Four participants still think that they are *quite a bit informed* and three participants agreed that they are *somewhat informed* before and after the activity.

In addition to these results, each group's mean for item one in section one can be found in the table below.

Table 8
Self-assessment group means

| | Control Group | | Experimental Group | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| Mean | 3.57 | 4.57 | 3.57 | 3.57 |

The table above shows the means of participants in the control group and the experimental group. There is an increase of *28%* (from 3.57 to 4.57) in the control group, while there is no change in the experimental group for the first item in section one.

Item two asks participants' energy using habits whether or not they think that they consume a lot of energy or save energy.

Table 9
Energy usage habits pre-test

| Pre-test | | | | | | |
|---|---|---|---|---|---|---|
| **1.2** When it comes to energy usage, how would you describe yourself? | Sample Size (N) | High Energy User | Moderately high energy user | Medium energy user | I save energy | Almost always Save energy |
| Control Group | 7 | 0 | 5 | 0 | 2 | 0 |
| Experimental Group | 7 | 0 | 1 | 2 | 2 | 2 |
| **Total** | 14 | 1 | 7 | 2 | 4 | 2 |

Table 10
Energy usage habits post-test

| Post-test | | | | | | |
|---|---|---|---|---|---|---|
| **1.2** When it comes to energy usage, how would you describe yourself? | Sample Size (N) | High Energy User | Moderately high energy user | Medium energy user | I save energy | Almost always Save energy |
| Control Group | 7 | 0 | 3 | 1 | 3 | 0 |
| Experimental Group | 7 | 1 | 2 | 2 | 1 | 1 |
| **Total** | 14 | 1 | 5 | 3 | 4 | 1 |

The tables show participants' energy usage change in the pre-test and the post-test. The control group's two participants changed their minds: one participant changed his or her response from *moderately high user* to *medium energy* user and the other one changed his response from *moderately high user* and to *energy saver*.

Additionally, the mean of participants in groups can be found in the table below for the energy usage question.

Table 11
Energy usage group means

| | Control Group | | Experimental Group | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| Mean | 3.42 | 3.0 | 2.28 | 3.14 |

Since this energy usage item is a reverse coded question, which is “when it comes to energy usage, how would you describe yourself?”, decreases show a positive attitude toward energy saving. The table above shows there is a *decrease* of *12* % in the mean between the pre-test and the post-test for the control group (*n=7*), while the experimental group (*n=7*) has an increase of *37%* in the mean.

Item three identifies which source has contributed the most to participants’ background knowledge about energy issues. In its responses, a fair amount of participants *(n=8; 57%)* indicated that school has the most contribution to their renewable energy knowledge in the post-tests. However, just four of them (*n=4; 28%*) had reported that school has the most contribution to renewable energy awareness in the pre-tests.

These frequencies can be seen in the table below.

Table 12
Most contribution to energy awareness

| | Control | | Experimental | |
|---|---|---|---|---|
| | Students who said YES | | Students who said YES | |
| **1.3** Most contribution to the understanding of energy issues | Pre-test | Post-test | Pre-test | Post-test |
| School | 3 | 5 | 1 | 3 |
| Books, newspapers, or magazines I have read on my own | 0 | 0 | 1 | 0 |
| Friends or family members | 1 | 0 | 3 | 3 |
| Information from the internet | 2 | 2 | 2 | 1 |
| Television programs | 1 | 0 | 0 | 0 |
| **Total** | **7** | **7** | **7** | **7** |

In the post-test, there is a rise in the number of participants who agreed that *school has the most contribution to their energy knowledge* in both groups. Two participants from each group changed their minds and agreed *school has the most contribution to their energy knowledge*.

Item four of section one is about learning whether participants talk about energy saving with their parents. It is important to know whether such conversations occur in between participants and their family members to look into students' awareness of energy.

The results of item four in section one show that one participant in the control group changed his answer *from only a little bit* to *a fair amount* in the post-test. Similarly, in the experimental group, one participant changed his answer from *I have mentioned something once or twice* to *only a little bit.*

Table 13
Energy conversation

| | Control | | Experimental | |
|---|---|---|---|---|
| | Students who said YES | | Students who said YES | |
| **1.4** How often do you talk to your family about ways you can save energy in and around your home? | Pre-test | Post-test | Pre-test | Post-test |
| A lot | 1 | 1 | 1 | 1 |
| A fair amount | 1 | 2 | 3 | 3 |
| Only a little bit | 2 | 1 | 2 | 3 |
| Mentioned once or twice | 3 | 3 | 1 | 0 |
| Not at all | 0 | 0 | 0 | 0 |
| **Total** | **7** | **7** | **7** | **7** |

The mean of participants for item four is also shown in the table below.

Table 14
Energy conversation group means

| | Control Group | | Experimental Group | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| Mean | 3.0 | 3.14 | 3.57 | 3.71 |

Both groups have a positive change in the mean. The control group (*n=7*) has an increase of *4%* and the experimental group (*n=7*) has an increase of *3 %* in the mean.

**Section II**

In section two of the instrument, eight Likert scale questions were asked to students to figure out how they feel about energy issues and concepts. These questions were kept the same in the pre-test and the post-test and participants answered them from strongly agree (5) to strongly disagree (1) with numbers. It was important to know the level at which students are interested in energy issues. Besides, seeing how their opinions change after the activity or/and the solar lesson appeared to be a substantial comparison.

Responses to these questions from 1 to 5 in Likert scale can be found in the table below.

Table 15
Results of section two

| | Control | | Experimental | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| **2.1** Energy education | 4.57 | 4.71 | 4.43 | 4.28 |
| **2.2** Working with others | 3.86 | 4.14 | 3.86 | 4.71 |
| **2.3** Saving energy | 2.14 | 1.86 | 2.29 | 2.86 |
| **2.4** Don't worry about energy | 1.86 | 1.86 | 1.71 | 1.86 |
| **2.5** Labels of electrical appliances | 4.0 | 4.0 | 3.43 | 3.57 |
| **2.6** Governmental acts on energy | 4.0 | 4.0 | 3.43 | 3.43 |
| **2.7** Making electricity from RES | 4.57 | 4.71 | 4.57 | 4.57 |
| **2.8** Efforts to develop RE technologies | 4.43 | 4.57 | 3.71 | 4.29 |

As seen in the table above, after the activity, the experimental group has an increase of *22%* points in Likert scale (from 3.86 to 4.71), while the control group has an increase of *7% (from 3.86 to 4.14)*in the survey item 2.2 which is about *working together to solve energy problems*. Likewise, the experimental group has an increase of 15% on the survey item 2.8, which is about *whether efforts should increase to develop renewable energy technologies*, while the control group has an increase of 3% in the mean for the same item.

In addition, for the experimental group, there were three additional questions in section two so as to see whether they are satisfied by the activity and its process. The results of these three questions were presented in the first research question of this chapter.

## Section III

In section three, there are four multiple choice questions in order to see participants' renewable energy concept knowledge. Only one question was kept the same in order to see if they learned about scientists' common opinion about renewable energy technologies. The other three questions were changed in the post-test to avoid memorization in assessing the change accurately, but the replaced questions in the post-test are comparable to the previous ones. The data obtained from the pre-test and the post-test can be found in the table below.

Table 16
Results of section three

| | Control | | Experimental | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| **3.1** Source of energy | 7 | 7 | 6 | 7 |
| **3.2** Forms of energy | 7 | 6 | 4 | 6 |
| **3.3** Renewable energy sources | 7 | 7 | 6 | 7 |
| **3.4** What scientists say about RES | 0 | 1 | 1 | 2 |
| **Total** | **21** | **21** | **17** | **22** |
| **Mean** | **3** | **3** | **2.42** | **3.14** |

In the table above, the change in the frequencies by groups can be seen. Since these are knowledge questions, each correct answer gets one point and wrong ones get nothing. Along with this calculation, participants' renewable energy concept knowledge can be evaluated by the total frequency of each group.

Apparently, the control group was better than the experimental group in the pre-test which is not necessarily important since the researcher looks into the comparison of the groups in the change of total frequencies.

The control group has exactly the same total (21) points in the pre-test and the pots-test which can be concluded that there is no change in their understanding of renewable energy concepts. However, the experimental group's score improved from 17 to 22 which refer to an increase of *29%*.

The qualitative data collected from the interviews confirms that students agreed that the activity supported their appreciation of renewable energy. They stressed that using a renewable energy to move a car in light of physics concepts made them feel they are learning physics truly. Interestingly, one of the interviewees said that "I want to be an engineer and the activity made me think that I could contribute to the energy problems of the world in the future." One student stated that "Before the activity, the concepts we learned were like imaginary but now they are like for real. I think renewable energy sources and their applications have a great importance for our future." Therefore, the reason for the experimental group to have a better result in the post-test may seem as the impression of the hands-on which is addressing the research question one and is to be discussed further in chapter five.

**4) Does a lesson about building solar cars support teachers' efforts to integrate RE concepts into a physics curriculum?**

The researcher used the results of the interview

with the expert teacher to address this research question. He confirmed that many physics topics could be covered through this activity. For example, the topic of heat could be covered during the activity by stressing the relationship between friction and heat. The expert teacher pointed out that hands-on experience must be part of physics classes. Since the intense curriculum to cover, he cannot spare so much time for extracurricular activities. Thus, he tends to conduct similar activities in his lessons but he does it once or twice in a semester. He finished his sentence with stressing the importance of implementation of this activity into a lesson. Moreover, he reported that he leans towards trying this activity in his lessons in the future.

He pointed out that the context was not new to him. He conducted some solar energy activities before but he has not combined them with physical concepts. He added that this activity could be adjusted with regard to student profile. For example, it could be more challenging for top-set students.

He pointed out that this activity and STEM activities have a common background. As STEM activities are becoming popular, this activity also could be combined with STEM activities. For these reasons, the teacher could utilize these experiences to provide students with some opportunities to contribute their creativity and understanding. In addition, the expert teacher stressed that observing students in a hands-on activity is very important to be able to see what is going on in their minds during the learning process since exams do not show students' learning processes, they just show what students know at that point.

## Summary

This chapter introduced the results of the study. The researcher was expecting a bigger change from the experimental group in between the pre-test and the post-test due to the influence of the activity. As expected, the experimental group showed an improvement in physics concept questions and energy concept questions. However, this change could not be considered a significant finding because of the small sample size that was not randomly selected. Therefore, the researcher was aware of the fact that these results, while promising, need further and more extensive study. Nevertheless, the results were meaningful to the researcher. His action research and reflections on the outcome of the study are shared in the next chapter.

# CHAPTER 5: DISCUSSION

## Introduction

The purpose of this study was to adapt a hands-on activity by combining renewable energy and physics concepts and then integrate it into a physics lesson. The researcher investigated if the activity made any contribution to students' understanding of physics concepts and awareness of RES. The main aim of the study was to ensure the activity could be implemented successfully. The researcher did find indications that the activity may have contributed to a change in participants' awareness of RES and related physics concepts.

## Overview

This study involved students putting their theoretical knowledge of physics into practice. The resource for this implementation was a popular activity, Junior Solar Sprint, where students design, build and test a model solar power car. The researcher enhanced the activity by identifying and highlighting selected physics concepts. To ensure the activity could be successfully implemented, the researcher conducted the study and investigated outcomes of students' learning. Through simple statistics and descriptive information, this study provided evidence that a popular hands-on activity related to model solar car design could enhance students' understanding of selected physics concepts. Furthermore, the researcher learned that the activity helped the participants become more aware of renewable energy.

Throughout the process, the researcher aimed at facilitating students' learning with scientific inquiry. This required encouraging them to make predictions and test their designs and then come to conclusions on how physics and renewable energy can work together.

Another aim of this study was to be useful for the researcher, who is a pre-service teacher, in gaining knowledge and building experience of integrating hands-on activities into physics lessons. That is why action research was the crucial feature of the study. There might be some subjective conclusions in interpreting the data as the researcher tends to use such activities in his classroom in the future.

The study used quasi-experimental research design that includes a control group and an experimental group. This research design was used to inspect the effect of an intervention which is only applied to the experimental group. The traditional teaching method which is a solar energy lesson was applied to both groups; it was just a period lesson which lasted 40 minutes. Before the solar energy lesson, the pre-test was applied to each participant to see their awareness of renewable energy issues and knowledge of related physics concepts.

Then the experimental group received the activity and it lasted two weeks. These two weeks started just after the solar energy lesson for the experimental group. They were gradually constructing a solar car in the lens of physics concepts. After the activity, both groups took the post-test so the participants of the control group waited for two weeks to take the post-test at the same time with the experimental group.

Instruments of the study, the energy survey and physics concepts questions, were distributed and collected by the researcher. The energy survey and physics concepts questions targeted to see the change in participants' understanding, awareness, or attitudes towards energy issues and related physics concepts. The data collected through the energy survey and physics concepts questions were used to address the following research questions:

- What steps can be taken to ensure that a lesson on building solar car works as designed?
- Does a hands-on renewable energy activity involving solar cars promote students' understanding of physics concepts?
- What evidence is there that building a model solar car increases students' awareness of renewable energy concepts?
- Does a lesson about building solar cars support teachers' efforts to integrate RE concepts into a physics curriculum?

**Major findings**

The study examined whether a hands-on activity related to renewable energy can be integrated into physics lessons and it also explored if selected physics concepts related to RES can be covered together. The findings showed that the activity which is a hands-on solar model car design activity could be integrated into a physics lesson and it could work smoothly. The qualitative data coming from the interviews also supported the quantitative data coming from surveys.

**The steps can be taken to ensure that a lesson on building solar car works as designed**

The qualitative data obtained from interviews showed that the solar car design activity could work as designed in a physics lesson. Participants reported that this experience is different than any practical work they did in the laboratory or their regular physics lessons. As part of a physics lesson, the participants enjoyed applying their theoretical knowledge into practice, especially physical concepts related to building a solar car. Although some of the participants reported that extra instructions would have been better, the majority of interviewees agreed that open-ended format of the activity let them design, build, and test their cars by themselves. In this way, they had the chance to apply their knowledge to a real world problem and see how physics concepts work to move a solar car. In addition, the expert teacher also noticed that there are more physics concepts could have been covered than the researcher has covered such as coding with physics concepts through the instrument of Arduino.

Renewable energy education in science courses could be a useful part of lessons since traditional ways of raising awareness of RES may not be enough (DeWaters & Powers, 2011). For this reason, this activity also could work as a combined activity with renewable energy topics like solar energy. Since the study showed students improved their awareness of RES through the activity, it could be considered a way of covering energy issues and renewable energy fundamentals.

The findings of the study also revealed that a solar car activity combined with physics concepts could be meaningful for multiple purposes in a physics lesson. For example, it could be useful for covering renewable energy topics or for implementing STEM components into the classroom environment, and also for having students familiar with scientific inquiry process. On the other hand, traditional ways of teaching science might not be as effective as the ways of letting students be in the active role in their learning process (Volpe, 1984). As the study showed that building a solar car activity worked as designed in a physics lesson, it also could be adapted to different formats with regard to student profile. Therefore, this study could be a sign of a new learning process in which students could shape their own understanding by means of hands-on activities combined with physics concepts within a classroom environment.

**The influence of building a solar car on students' understanding of physics topics**

This study also intended to gain insights into whether a hands-on activity about renewable energy concepts could contribute participants' understanding of related physics concepts. Because building solar cars requires knowing physics concepts at a certain level, it might be important to investigate whether it aids the participants to consolidate these concepts.

As expected, the post-test results of the participants of the experimental group have a notable improvement of the mean score in the physics concept questions. While the control group has a decrease of *2%*, the experimental group has an increase of *23%* in the frequencies of the post-test.

The reason behind this improvement could be the inquiry process the experimental group underwent. It was some sort of scientific inquiry process in which they asked questions, discussed with peers, developed an enduring understanding of related physics concepts. As discussed in the literature review, these findings may refer to many studies in the literature that showed hands-on activities promote students' with a better understanding of the concepts rather than the traditional methods do (Bredderman, 1985; Freedman, 1997; Glasson, 1989; Shymansky, Kyle, Alport, 1983; Turpin, 2000).

As Campbell and Neilson (2009) found, students begin to see the connections between different concepts and use evidence to come up with a conclusion. In this way, they develop a solid understanding of the science concepts in a holistic manner (p. 15). Similarly, the findings of this study, especially for the physics concept questions, indicated that the experimental group's participants who participated in the activity showed a better grasp on the concepts. Nonetheless, because of the small sample size, this study could not claim any statistical conclusions; however, it still may hold important information that could lead to a further study which would be extended over a long period of time with a bigger sample size.

**The effect of building a solar car activity on students' awareness of RES**

The study also perused differences between the control group and the experimental group in the pre-test and the post-test. The acknowledged presumption of the researcher was there might be a bigger change in the experimental group because of the fact that they were involved in a hands-on activity.

The participants were asked to assess themselves in terms of their energy knowledge in the first item of section one. The experimental group did not show any change in the post-test, the participants of this group revealed the same results in both tests.

However, the control group had a notable change in the post-test: there was an increase of one point (3.57 to 4.57) in the mean. The researcher had expected to have a bigger change in the experimental group but during the interviews, he noticed that the participants of the experimental group seemed very cautious about energy concepts. It is possible that they may have realized there are many things to learn just as one of them stated, "I'm amazed by the extensiveness of the energy concepts and how they could be useful."

It appears that the activity did not help the participants of the experimental group change their *energy usage habits* toward being an energy saver. When participants were asked to assess their energy usage, the experimental group showed an increase in the mean which is a negative attitude because it was a reverse coded question. But, the control group has a decrease in the post-test which is a positive attitude after the solar lesson. However, this may because of the fact that experimental group's participants may have realized that they consume energy carelessly and this awareness might have led them to a negative attitude in this section of the survey.

There is an indication that the activity helped students recognize the school as a resource for renewable energy education.  However, both groups have the same increase in the number of participants who agreed on *the school is the place that has the most contribution to their energy awareness and knowledge*. For the control group, it may because of the fact that they learned about RES in the solar energy lesson even though they did not participate in the activity. But, for the experimental group, perhaps more participants than the control group might be expected to report the school is the place that has the most contribution to their understanding, but it did not turn out to be as expected.

Maybe the most interesting finding of the study is that almost all participants in the experimental group expressed more positive attitude towards renewable energy. It is about the second item of section two which talks about *working together to solve energy issues*. The increase of the experimental group was *22%* in the mean which is relatively higher than the increase of the control group on the same question, which is only *7%* in the mean. Since the activity required group work, they worked together on their designs. Therefore, they may have realized that even with a little amount of time they created an alternative design to the traditional cars. It might have them think that if people work together to solve energy issues of the world, they can achieve this goal, which exactly addresses one of the research questions in this study.

There is also evidence that the activity supported energy knowledge of the experimental group's members. For the energy knowledge section, the experimental group scored better than their previous score, while the control group had the same score in both tests.

Throughout two weeks period of time, the experimental group searched, investigated, and brainstormed about renewable energy to come up with a successful design. That could be the reason why they developed a better understanding of the energy concepts and scored better compared to their previous time. Another point is that both groups took part in the solar energy lesson so a little bit change might have been expected even for the control group. But, it seems the solar energy lesson did not make a difference for the control group in renewable energy concepts. Otherwise, as Haury and Rillero (1994) pointed out, students could understand the concepts better when they are involved. It is possible to think that the hands-on experience helped the participants of the experimental group to develop a better understanding of the concepts compared to the control group.

## Conclusion and reflections of the researcher

The related research question to this section was: Does a lesson about building solar cars support teachers' efforts to integrate RE concepts into a physics curriculum? To this end, I tried to address this question and benefit from the experience for my future career.

One of the purposes of the study is to encourage teachers in conducting and implementing hands-on activities into their classrooms, especially for science teachers. To be able to this, I integrated a hands-on about solar energy into a regular physics lesson to ensure that it could be useful in the lessons.

The problem with conducting hands-on activities in lessons is considering them as extracurricular activities and then searching for extra-time to conduct. Nevertheless, my supervisor and I thought these activities can be merged with the concepts of science and then they could become part of regular lessons. As a consequence, I attempted to deal with that matter and searched for an activity that can be combined with some of the physics concepts. During this period, I reflected on this experience in order to become accustomed to the problems that I may encounter and then thrive on accordingly.

My supervisor provided me an activity guide of which there are many hands-on activities. While I was examining this guide and trying to use its activities during my internship lessons, I came across Junior Solar Sprint (JSS) activity. At first glance, it looked like just a hands-on. But, it includes building a solar car so I thought there must be quite a few physics concepts need to take into consideration while building the solar car. That is how my supervisor and I decided to combine JSS with the selected physics concepts. After this point, I needed to devise the activity in a way that it could be integrated into a lesson so I consulted experienced teachers and sought possible ways to actualize this project.

My original plan was to conduct this study with a bigger sample size and it was going to be longer like 5 weeks or so. Yet, the schools available at that time did not provide me that amount of students and that much time. I was obliged to conduct the study with 14 students from an international school, but I thought that the results of the study could still offer important information.

To reflect on my experience and efforts, I need to explain why I chose to perform this project. Practical work in physics goes beyond the meaning for me. Since childhood, I question the things around me: their nature, mechanism, and structure. As I started to discover the functions of scientific principles, I developed the tendency to see things in a holistic manner. For this reason, when I learned something in school, I tried to test it by myself, even the theoretical concepts. I grew up and studied physics at the University and I carried this manner with me. After a while, I decided to be a physics teacher. During this process, the most I heard from students was how hard physics is. In spite of teaching them physics in a traditional way, I preferred to show them there is a different way to learn physics: learning by doing. I even came up with a motto and said it whenever students were about to say that physics is hard to understand; that was, *do not just learn physics, do physics*. Then I found myself embarking on a thesis project that can display students could learn the nature of physics and its connections with the other concepts by themselves.

Eventually, I was able to conduct my project in an international school in which students were very responsive and accustomed to hands-on activities. As soon as they committed to participate in the activity, I explained its steps and how I was going to do it. I let them be creative and I never set limitations except for using solar energy to move the car. They were surprised in the first place because they got used to being told many instructions and limitations in the exams and in the activities before. In the beginning, they did not know what to do about their designs. Yet, I encouraged them to create any design they like to see and tried to trigger their imagination by showing them solar cars around the world. Although they were going to design a miniature solar car, I wanted them to feel like engineers or scientists. Now that they confronted an issue, they had to find a way to solve the problem. They started asking questions about how to make a good design and I did not answer their questions completely, I just guided them through their design process. Hence, they came up with a design and I saw them holding their solar cars as they are treasures. However, only one group managed to have a working car on the road. It was nice to see how they were happy about their success. Yet, during the race day, I did not let the other group members feel frustrated just because they did not manage to have a working car. I helped them fix their cars, by connecting the right cables, inserting the shafts tightly, or doing anything to make their car work. In my opinion, it is crucial to support the students who could not create a working solar car to not let turn this experience a disappointment for them.

Overall, I learned many things during the process but fixing inactive cars was the most important exercise to me because I did not have a plan about it. It was a spontaneous act from me at that time. If I ever conduct this activity again, I am going to make a preparation for making unsuccessful cars work to deliver all students a good experience. Thus, they could learn from their mistakes as well.

## Implications for practice

As part of the study, the researcher also aims at investigating how this activity can be conducted more efficiently and successfully. As a result of the results, the researcher developed an activity plan for guidance (Appendix A) in order for teachers can apply this activity. It indicates that students' understanding of RES and related physics concepts are enhanced along with a hands-on. All interviewed participants stated that the activity helped their understanding of the concepts. One of the comments that participants made in the interview as follows: "Trying to use a concept was different than just learning it. I truly grasp the concepts by applying them." Thus, spreading out the activity and make it useful for more physics teachers was one of the researchers' intentions. However, some of the students reported that the instructions were clear and adequate, but a few of them stated that they needed more guidance, Therefore, if a teacher wants to apply this activity with the guide in Appendix A, the researcher suggests to consider the fact that there might be some students who need more guidance, while some of them might need open-ended format.

Time limitation could restrict the implementation process of the activity as the researcher experienced. Nonetheless, extending it over an enough period of time in order for students to internalize the activity can be meaningful. For instance, a teacher from the USA, who was giving advice to the researcher during the process, conducts the activity for five weeks. She covers the topic Newton's Laws of Motion along with the activity. This is a good example of how a hands-on could become part of a science lesson, in spite of considering it an extracurricular activity. In addition, not only force and motion could be covered with this activity, also electrical circuits, work, and energy may comply with the concepts students applying into practice. For this reason, the activity could be changed according to the teacher's intention.

After allocating enough time, the teacher can require students to make a list of thoughts, while they are building their cars. By this way, they could see their designs flourish step by step on their notebooks. This could also give students the chance to reflect on and be aware of what they are doing. International Baccalaureate Organization (IBO) values metacognitive and self-regulation skills, integrating the activity into their lessons may be a way of meeting these objectives for the IB teachers (IBO, 2013, p. 5).  Likewise, this activity could be considered as an inquiry-based learning process in science lessons since providing inquiry-based learning is a common goal of many curricula regardless of country or education type.

Each group can present their design to the others before racing their cars. Explaining their rationale, how they came up with the design, what they thought, what they did well, and what the challenge was for them. It could create a platform where students give feedback to each other and learn from each other. In addition, students might explain the physics concepts they applied to create a design. It is important to be aware of which physics concepts had a bigger impact in their design or what the concept was they failed to apply.

If the school has some equipment like Logger Pro, students could track their cars' data on a laptop. They also might be able to draw graphs and analyze the car's success in terms of the factors like displacement, velocity, speed, etc. In fact, they could measure the cars' data and compare them so as to see each car's strengths and weaknesses on the race day.

This activity could be converted into a Science, Technology, Engineering, and Mathematics (STEM) activity as well and investigate different factors that contribute students' learning. Herein, using software based tools may ensure the activity go beyond the renewable energy and physics concepts. In this way, it also could make students develop some skills in programming.

Overall, this activity may be considered a way of creating a window through the scientific inquiry within which teachers could enhance their teaching about physics topics and renewable energy concepts holistically.

## Implications for further research

Although the present study had a very little sample size, it may hold an important indication that a hands-on activity can be integrated into physics lessons and could work for covering quite a few topics. For this reason, this study showed a glimpse of promising results in a larger study which may provide statistically meaningful results to generalize them to the entire population.

Applying a quasi-experimental study might take over a semester or a systematic continuous approach in claiming cause and effect between the intervention and the positive or negative achievement of the participants.

A more extensive guide could be developed by experienced teachers in the field so as to provide a standard pattern about the activity. Moreover, a resource trunk which is a mobile container full with required materials for such activities could be performed. This resource trunk could offer a ready-to-go material set for hands-on activities in order to encourage teachers in conducting hands-on activities.

## Limitations

The sample size of the study was 14 since they were the only students available for the researcher to conduct the activity at that time. The control group and the experimental group are quite small for quasi-experimental research since there are two classes in the study that each includes 7 students who were in International Baccalaureate Diploma Programme (IBDP). Therefore, the student outcomes were not statistically analyzed so that the findings of the study are not generalizable to other populations and regions throughout Turkey.

Time limitation was restrictive for this study. It took two weeks which is a very short period of time to apply a new teaching program or activity to see its effects compared to the traditional one.

The sample of the study comes from a private school which cannot represent the whole student profile of Turkey. In addition, it is an international school that contains many extracurricular activities and freedom to create any activity within the classroom environment so its students were accustomed to hands-on activities. Therefore, conducting a solar-powered car design activity in a different school environment may not cause the same results.

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# APPENDICES

## APPENDIX A: A Guide for Integrating a Hands-on Solar Model Car Design Activity into a Physics Lesson

### BUILDING A SOLAR CAR

An activity presented by the Bilkent University

Graduate School of Education

### Overview

In this activity, students will learn about how to create a solar car on their own. At the beginning, they will be introduced to the key concepts of solar energy and its importance for our future. Based on the Junior Solar Sprint activity developed by the National Renewable Energy Laboratory, students will be guided in the process of designing, building, and testing a car that is powered by solar energy. Their main aim is to successfully apply a solar cell that converts solar energy into an electrical current.

They need to design their car so that this energy is conveyed from the motor to the wheels of the car (mechanical energy). Accordingly, students will be examining a number of few physical principles that underpin or hinder the car movement.

## Summary and purpose

The purpose of this solar car design activity is to provide students with the opportunity to apply concepts they have learned in class. There are many studies in the literature that students develop more solid understanding of science concepts through first-hand experiences. These experiences involve hypothesizing, testing, trial and error, and revision that are all part of the scientific process.

In this activity student will learn about solar energy and the mechanism of a car. In addition to that, to move a solar car there are lots of things that must be under consideration such as, drag coefficient, where to insert the motor into the body, power, current and voltage of the motor, the balance of the car, the angle of the solar panels, friction etc. Furthermore, students also will think of a light body in order to move the car smoothly on the road. Overall, the ultimate purpose of the activity is to have students comprehend basic laws of physics with just one activity.

For further information about the similarities between the objectives of the IBO and the activity, please refer to chapter five and the following resource:

https://ibpublishing.ibo.org/server2/rest/app/tsm.xql?doc=d_4_physi_gui_1402_1_e&part=1&chapter=5

## Objectives

Through this activity, students will be able to:

- design, build and test a model car that is powered by solar energy
- describe the transmission of a vehicle, which transfers energy from the motor to the wheels
- illustrate how a solar cell transfers solar energy into electricity
- explain how physics concepts such as Newton's laws of motion, electrical power, and torque affect the efficiency and function of their design

## Background

Since the industrial revolution, the world has faced energy consumption problem due to the high demand of petroleum production. As the fossil fuels become insufficient for the demand, the world will face energy scarcity. Hence, technologies and transportation which heavily rely on energy might come to a standstill. Then the transition from fossil fuels to renewable energy sources is gaining ground as an alternative.

Sun is our primary energy source and we benefit from its nuclear process that results in rays of sunlight reaching Earth's surface. The sun provides us with an inexhaustible energy source that sustains the life on the planet. In recent times, humans have developed technologies that convert the sun's light into other forms of energy such as heat and electricity.

Transportation has played a key role throughout the history of humanity. Therefore, the modes of transportation have changed and evolved over time, yet their fuel type was mostly fossil fuels. Especially, along with the proliferation of transportation in the 21st century, fossil fuels became indispensable. However, other energy sources for transportation are also being considered. Among them, solar energy seems a promising one. There are many development designs about solar cars. A few of them only use solar energy to start, move and function, but the most of them are hybrid designs which harness solar energy partially.

- Stella Solar Car is one of the first of its kind because it is meant for carrying people on a road as they call it the world's first solar-powered family car.
- Toyota's the 2010 Prius has a solar-powered cooling system that the ventilation of the car functions separately from the motor.
- ReVision Energy has a mission to combine electrical and solar-powered car technologies.

For further information about energy consumption, renewable energy, and solar cars, please refer to the following resources:

Bailey, S. (2014). *Solar power: Technologies, environmental impacts, and future prospects*. New York, NY: Nova Science Publishers, Inc.

Fink, G. (2014, January 03). Ford Is Making A Concept Car With Solar Panels For A Roof. Retrieved from http://www.huffingtonpost.com/2014/01/03/solar-power-ford_n_4533029.html

Martinez, D. M., & Ebenhack, B. W. (2008). Understanding the role of energy consumption in human development through the use of saturation phenomena. *Energy Policy*, *36*(4), 1430-1435.

Roman, H. T. (2015). Using Solar Energy to Teach STEM. *Tech Directions*, *75*(1), 13-15.

Romm, J. (2017, March 07). Will electric cars soon have solar roofs? Toyota and Tesla say yes. Retrieved from https://thinkprogress.org/prius-solar-roof-breakthrough-2b929f467061

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Stella. (n.d.). Retrieved from https://solarteameindhoven.nl/stella-lux/stella/

## Solar model car design

The solar car design activity requires students share their ideas, make presumptions, and then test them to draw conclusions about the accuracy of their designs. The process starts researching how to build a solar car in light of related physics concepts such as force and motion, electricity, work, and energy. Then students gradually start building their cars. They discuss, change, or progress ideas throughout the process. In a way that students can appreciate renewable energy and physics concepts together and become accustomed to using their theoretical knowledge into a real world problem.

For further and more specific information about how to conduct this activity with students please review the following resources:

- Junior Solar Sprint (designed by the National Renewable Energy Laboratory:

  https://www.nrel.gov/workingwithus/car-competitions.html http://www.nrel.gov/docs/gen/fy01/30825.pdf

- The Wisconsin K-12 Energy Education Program (KEEP), adapted an NREL activity focusing on designing transmissions. https://www.uwsp.edu/cnr-ap/KEEP/Documents/Activities/Doable%20Renewables/SolarTransmissions.pdf

## Materials

Both the above resources identify materials students will need. **The essential materials are the solar panel, motor, conducting wire and clips**. Additional materials listed below can be provided to students or they can be challenged to secure their own supplies using recycled materials.

- Wheels
- Axels (metal or wood sticks)
- Rubber bands
- Wheels
- Glue gun full with silicon
- Sticky tapes
- Craft knife
- Alligator clips
- Gears

## Guidelines for implementation and suggested timeframe

The activity generally involves an introduction to renewable energy and an overview of the mechanics of automobile design. The amount of information provided depends on class time and student learning needs. Following the introduction, students learn about the activity and challenge to design their model cars. Ideally, they should be given some class time to begin their design and the teacher is encouraged to help students relate and apply physics concepts. The addition time students need to design, build and test their cars can be during class, after school, or homework. Teachers are encouraged to support students and provide guidance for testing and trials. The final race can range from a simple class activity to a whole school presentation. Below is one suggested timeframe for this activity.

<table>
<tr><th colspan="3">Suggested timeframe</th></tr>
<tr><td>Time</td><td>Activity</td><td>Content</td></tr>
<tr><td>30 to 40 minutes</td><td>Part 1- Teacher Introduction</td><td>Background on energy issues such as consumption and depletion. Introduction to renewable energy and photovoltaics</td></tr>
<tr><td>20 minutes</td><td>Part 2- How to build a solar car</td><td>Introduce students to the principles of car design and the role of the solar panel; introduce key physics concepts.</td></tr>
<tr><td>10 minutes</td><td>Part 3- Divide students into working groups and explain the materials and resources available to them</td><td rowspan="2">Allow students time to design and test their cars</td></tr>
<tr><td>One-week Break</td><td>Part 4- Designing, building, and testing the cars</td></tr>
<tr><td>Next week</td><td>Part 5- Racing the solar cars to see which design works best</td><td>Race</td></tr>
</table>

## Assessment ideas

The teacher can use these following methods to assess whether students meet the objectives.

**Before the race**

- Students could explain their designs' features and their rationale with a presentation.
- Each group could deliver paperwork to the teacher. Then students adjust their designs to be better at the race.
- Each group could make a list of thoughts to keep track their mind map. The teacher could check that list and make sure they are on the right track while monitoring.

**After the race**

- Each group could reflect on what went right or wrong in the process and how they could manage to be better.
- The teacher could give a written feedback to each group with regard to the design's performance in the race.
- A discussion session could be conducted as a closure. Students can express how they felt during the activity and what they learned from each other.

**APPENDIX B: Pre-test**

**BILKENT UNIVERSITY**

**GRADUATE SCHOOL OF EDUCATION**

**ENERGY LITERACY SURVEY**

**A BROAD ASSESSMENT OF**

**ENERGY-RELATED KNOWLEDGE,**

**ATTITUDES AND BEHAVIORS**

**HIGH SCHOOL ISSUE**

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Developed by researchers at

**Clarkson University**, Potsdam NY

with funding by the National Science Foundation

**Section I.** Fill in the circle on your answer sheet for the letter of the answer that best indicates your

response to the following questions. Be honest, remember - this is not a test!

**1.** How much do you feel you know about energy? (rate yourself as “expert” to “novice” or less, as described below)

A. A lot – expert

B. Quite a bit – informed

C. A “medium” amount – somewhat informed

D. Not much – novice

E. Nothing – not in the running

**2.** When it comes to energy use, how would you describe yourself?

A. High energy user

B. Moderately high energy user

C. Medium energy user

D. I try to save energy sometimes

E. I almost always try to save energy

**3.** Of the following choices, which **one** thing has contributed **most** to your understanding of energy issues and problems?

A. School

B. Books, newspapers, or magazines I have read on my own

C. Friends or family members (including parents)

D. Information from the internet

E. Television programs

**4.** How often do you talk to your family about ways you can save energy in and around your home? (for example, shutting off lights when they are not in use, turning down the heat, closing doors and windows)

A. A lot

B. A fair amount

C. Only a little bit

D. I may have mentioned something once or twice

E. Not at alş

**Section II.** Please indicate **how you feel** about each statement below. There are no right or wrong

answers. Read each statement carefully, then fill in the circle on your answer sheet for the letter that best describes how much you agree or disagree, using the following key:

“A” represents “strongly agree”

“B” represents “agree moderately”

“C” represents “neither agree nor disagree”

“D” represents “disagree moderately”

“E” represents “strongly disagree”

**5.** Energy education should be an important part of every school’s curriculum.

**6.** I would do more to save energy if I knew how.

**7.** I don’t need to worry about turning the lights or computers off in the classroom because the school pays for the electricity.

**8.** We don’t have to worry about conserving energy because new technologies will be developed to solve the energy problems for future generations.

**9.** All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and operating costs.

**10.** The government should have stronger restrictions about the gas mileage of new cars.

**11.** We should make more of our electricity from renewable resources.

**12.** Efforts to develop renewable energy technologies are more important than efforts to find and develop new sources of fossil fuels.

**Section III.** For each of the following questions, choose the **one best** answer. Fill in the circle for the letter of the answer on your answer sheet.

**13.** Each and every action on Earth involves…

A. Food

B. Energy

C. Sun

D. Water

E. Motion

**14.** Which of the following statements best **DEFINES** energy?

A. A force that moves something

B. Potential and kinetic

C. The rate at which work is done

D. The ability to do work

E. Fossil fuels

**15.** The term “renewable energy resources” means …

A. Resources that are free and convenient to use

B. Resources that can be converted directly into heat and electricity

C. Resources that do not produce air pollution

D. Resources that are very efficient to use for producing energy

E. Resources that can be replenished by nature in a short period of time

**16.** Scientists say the single fastest and most cost-effective way to address our energy needs is to…

A. Develop all possible domestic sources of oil and gas

B. Build nuclear power plants

C. Develop more power plants that use renewable energy sources

D. Promote energy conservation

E. Develop alternative fuel vehicles

**BILKENT UNIVERSITY**

**GRADUATE SCHOOL OF EDUCATION**

**PHYSICS CONCEPT CHECK QUESTIONS**

**PRE-TEST**

**1)** A book is at rest on top of a table. Which of the following is correct?

A. There is no force acting on the book.

B. The book has no inertia.

C. There is no force acting on the table.

D. The book is in equilibrium.

E. The inertia of the book is equal to the inertia of the table.

**2)** If an object is moving, then the magnitude of its ____ cannot be zero.

A. speed

B. velocity

C. acceleration

D. A and B

E. A, B, and C

**3)** Which of the following is true?

A. A body with zero velocity cannot have any potential energy.

B. A body with zero acceleration cannot have any kinetic energy.

C. A body with zero acceleration cannot have any potential energy.

D. A body with zero velocity cannot have any kinetic energy.

E. A body with zero potential energy cannot have any velocity.

**4)** When a car rounds a curve at high speed,

A. the tires exert a centripetal force on the road.

B. the road exerts a centripetal force on the tires.

C. the car exerts a centripetal force on the road.

D. the car body exerts a centripetal force on the tires.

E. there are no centripetal forces involved.

**5)** The speedometer in your car tells you the ____ of your car.

A. acceleration

B. average speed

C. instantaneous speed

D. velocity

E. inertia

**6)** Real machines are not 100% efficient because

A. some of the energy input is always transformed into thermal energy.

B. some of the energy input is always transformed into gravitational potential energy.

C. the energy input is always less than the energy output.

D. that would require the work output to be 100 times the work input, which is impossible.

E. that would require the work input to be 100 times the work output, which is impossible.

**7)** If light bulb A has four times the resistance of light bulb B and the same current passes through each bulb, the voltage across bulb A will be ___ the voltage across bulb B.

A. two times

B. equal to

C. one-half of

D. one-fourth of

E. four

**APPENDIX C: Post-test**

**BILKENT UNIVERSITY**

**GRADUATE SCHOOL OF EDUCATION**

**POST-TEST**

**ENERGY LITERACY SURVEY**

**A BROAD ASSESSMENT OF**

**ENERGY-RELATED KNOWLEDGE,**

**ATTITUDES AND BEHAVIORS**

**HIGH SCHOOL ISSUE**

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Developed by researchers at

**Clarkson University**, Potsdam NY

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**Section I.** Fill in the circle on your answer sheet for the letter of the answer that best indicates your response to the following questions. Be honest, remember - this is not a test!

**1.** How much do you feel you know about energy? (Rate yourself as “expert” to “novice” or less, as described below)

A. A lot – expert

B. Quite a bit – informed

C. A “medium” amount – somewhat informed

D. Not much – novice

E. Nothing – not in the running

**2.** When it comes to energy use, how would you describe yourself?

A. High energy user

B. Moderately high energy user

C. Medium energy user

D. I try to save energy sometimes

E. I almost always try to save energy

**3.** Of the following choices, which **one** thing has contributed **most** to your understanding of energy issues and problems?

A. School

B. Books, newspapers, or magazines I have read on my own

C. Friends or family members (including parents)

D. Information from the internet

E. Television programs

**4.** How often do you talk to your family about ways you can save energy in and around your home? (For example, shutting off lights when they are not in use, turning down the heat, closing doors and windows)

A. A lot

B. A fair amount

C. Only a little bit

D. I may have mentioned something once or twice

E. Not at all

**Section II.** Please indicate **how you feel** about each statement below. There are no right or wrong answers. Read each statement carefully, then fill in the circle on your answer sheet for the letter that best describes how much you agree or disagree, using the following key:

“A” represents “strongly agree”

“B” represents “agree moderately”

“C” represents “neither agree nor disagree”

“D” represents “disagree moderately”

“E” represents “strongly disagree”

**5.** Energy education should be an important part of every school’s curriculum.

**6.** I believe that I can contribute to solving energy problems by working with others.

**7.** I don’t need to worry about turning the lights or computers off in the classroom because the school pays for the electricity.

**8.** We don’t have to worry about conserving energy because new technologies will be developed to solve the energy problems for future generations.

**9.** All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and operating costs.

**10.** The government should have stronger restrictions about the gas mileage of new cars.

**11.** We should make more of our electricity from renewable resources.

**12.** Efforts to develop renewable energy technologies are more important than efforts to find and develop new sources of fossil fuels.

**13.** I enjoyed this activity a lot.

**14.** I learned a lot from this activity.

15. This activity was worthwhile.

**Section III.** For each of the following questions, choose the **one best** answer. Fill in the circle for the letter of the answer on your answer sheet.

**16.** The original source of energy for almost all living things is…

A. Sun

B. Water

C. Soil

D. Plant life

E. Wind

**17.** All of the following are forms of energy EXCEPT…

A. Chemical

B. Heat

C. Mechanical

D. Electromagnetic

E. Coal

**18.** Which of the following energy resources is NOT renewable?

A. Solar

B. Biomass (wood, waste, plants, alcohol fuels)

C. Coal

D. Water (hydro) power

E. Geothermal

**19.** Scientists say the single fastest and most cost-effective way to address our energy needs is to…

A. Develop all possible domestic sources of oil and gas

B. Build nuclear power plants

C. Develop more power plants that use renewable energy sources

D. Promote energy conservation

E. Develop alternative fuel vehicles

**BILKENT UNIVERSITY**

**GRADUATE SCHOOL OF EDUCATION**

**PHYSICS CONCEPT CHECK QUESTIONS**

**POST-TEST**

**1)** The property of a moving object to continue moving is what Galileo called

A. velocity.

B. speed.

C. acceleration.

D. inertia.

E. direction.

**2)** According to Newton's First Law of Motion,

A. an object in motion eventually comes to a halt.

B. an object at rest eventually begins to move.

C. an object in motion moves in a parabolic trajectory unless acted upon by a net force.

D. an object at rest always remains at rest.

E. an object at rest remains at rest unless acted upon by a net force.

**3)** If two objects of different mass have the same non-zero momentum,

A. the one with less mass will have the greater kinetic energy.

B. the one with more mass will have the greater kinetic energy.

C. they will have the same kinetic energy.

D. the one with the higher speed will have the greater mass.

E. the one with the lower speed will have the greater kinetic energy.

**4)** When you stand in equilibrium on only one foot,

A. your center of mass will be directly above that foot.

B. your center of mass will be directly above the other foot.

C. your center of mass will be directly above a point equidistant between your feet.

D. your rotational inertia will be zero.

E. you will always fall over.

**5)** To report the ____ of an object, we must specify both its speed and its direction.

A. acceleration

B. mass

C. velocity

D. length

E. position

**6)** A physicist does 100 joules of work on a simple machine that raises a box of books through a height of 0.2 meters. If the efficiency of the machine is 60%, how much work is converted to thermal energy by this process?

A. 40 joules

B. 60 joules

C. 80 joules

D. 20 joules

E. 100 joules

**7)** If three light bulbs of different wattage are connected in series to a battery,

A. the voltage drop across each bulb will be the same.

B. the current in each light bulb will be the same.

C. the resistance in each light bulb will be the same.

D. the power consumed by each light bulb will be the same.

E. the light output of each bulb will be the same.