DEVELOPMENT OF EFFECTIVE STEM EDUCATION MATERIALS

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ABSTRACT

DEVELOPMENT OF EFFECTIVE STEM EDUCATION MATERIALS

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The aim of this study is to develop STEM Project-Based Learning (STEM PBL) activities for 9^{th} grade level by using ASSURE Model. During the literature research, it was found that there was no systematic material development process in the development of existing STEM PBL activities. To fill this gap in the literature, firstly, the characteristics of STEM activities were determined and ASSURE Model was revised to form these characteristics. Subsequently, with this model, 3 STEM PBL activities were developed. In the literature, it is seen that some steps of the methods of implementing STEM activities in a class are missing. To fill this gap, 10-step STEM PBL activity implementation model was developed by integrating some steps from other models. Research and Development (R & D) method was used in the study. With the iteration process, one of the cornerstones of the R & D method, the second activity was revised with the findings obtained with the implementation of the first activity. Afterwards, with the findings obtained with the implementation of the revised second activity, the third activity was revised. During each activity, one physics teacher and 6 students consisting of 2 low, 2 medium and 2 high achievement level were included. The data collection instruments in the study are semi-structured group interviews with students, semi-structured interviews with teacher, and observations made by the researcher in the classroom. Consequently, 3 STEM PBL activities were developed without any problem at the end of the 3 iterations. Lastly, related implications have been proposed.

Keywords: Physics Education, STEM Activities, Development of STEM Activities, STEM Project-Based Learning

ÖZ

ETKİLİ STEM EĞİTİM MATERYALLERİNİN GELİŞTİRİLMESİ

Tomaç, Cemre
Yüksek Lisans, Fen Bilimleri Eğitimi, Fen ve Matematik Alanları Eğitimi
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Bu çalışmanın amacı, bir öğretim materyali geliştirme modeli olan ASSURE Model'i kullanarak lise 9. sınıf seviyesinde FeTeMM Proje Temelli Öğrenme aktiviteleri geliştirmektir. Alan yazın incelendiğinde mevcut FeTeMM Proje Temelli Öğrenme aktivitelerinin geliştirilmesinde sistematik bir materyal geliştirme süreci izlenmediği tespit edilmiştir. Alan yazındaki bu boşluğu doldurmak için, çalışma kapsamında önce FeTeMM aktivitelerinin özellikleri belirlenmiş ve bu özellikleri oluşturacak şekilde ASSURE Model revize edilmiştir. Daha sonra bu model ile 3 adet 9. sınıf FeTeMM Proje Temelli Öğrenme aktivitesi geliştirilmiştir. Alan yazında kullanılan FeTeMM aktivitelerini sınıf içerisinde uygulama yöntemlerinin bazı adımlarının eksik olduğu tespit edilmiştir. Alan yazındaki bu boşluğu doldurmak için, 10 adımlı FeTeMM Proje Temelli Öğrenme aktivite uygulama modeli diğer modellerden bazı adımlar entegre edilerek geliştirilmiştir. Çalışma kapsamında Araştırma ve Geliştirme (AR-GE) yöntemi kullanılmıştır. AR-GE yönteminin temel taşlarından olan yineleme süreci ile birlikte birinci aktivitenin uygulanması ile birlikte elde edilen bulgular ile ikinci aktivite revize edilmiştir. Daha sonra revize edilen ikinci aktivitenin uygulanması ile birlikte elde edilen bulgular ile üçüncü aktivite revize edilmiştir. Her bir aktivite sürecine 2 düşük, 2 orta ve 2 yüksek başarı seviyesine sahip öğrenciden oluşan toplam 6 öğrenci ve 1 fizik öğretmeni dahil edilmiştir. Çalışmadaki veri toplama kaynaklarını, öğrencilerle gerçekleştirilmiş yarı yapılandırılmış grup görüşmeler, öğretmenle gerçekleştirilmiş yarı yapılandırılmış görüşmeler ve araştırmacının sınıf içerisinde yaptığı gözlemler oluşturmaktadır. Araştırma sonucunda, AR-GE yöntemi kapsamında ASSURE Model kullanılarak geliştirilen 3 FeTeMM Proje Temelli Öğrenme aktivitesi önerilen FeTeMM Proje Temelli Öğrenme aktiviteleri uygulama modeli ile uygulanmış ve 3 yineleme sonunda aktiviteler sorunsuz ve anlaşılır bir şekilde geliştirilmiştir. İlgili uygulama değişiklikleri önerilmiştir.

Anahtar Kelimeler: Fizik Eğitimi, STEM Aktiviteleri, STEM Aktivitelerinin Geliştirilmesi, FeTeMM Proje Temelli Öğrenme

To my beloved family

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LIST OF ABBREVIATIONS

ABBREVIATIONS

Dok	Depth of Knowledge
EDP	Engineering Design Process
ESTEM	Entrepreneurship, Science, Technology, Engineering, Mathematics
FeTeMM	Fen, Teknoloji, Mühendislik, Matematik
H-STEM	Hacettepe-STEM
ITEA	International Technology Education Association
ITEEA	International Technology and Engineering Educators Associations
I-STEM	Innovation-STEM
LGS	Lise Giriş Sınavı
MEB	Milli Eğitim Bakanlığı
NAE	National Academy of Engineering
NASA	National Aeronaustics and Space Administration
NGSS	Next Generation Science Standards
NRC	National Research Council
NSES	National Science Education Standards
NSF	National Science Foundations
NSTA	National Science Teaching Association
OECD	Organization for Economic Co-operation and Development
PBL	Project Based Learning

PISA	The Programme for International Student Assessment
PD&I	Purposeful Design and Inquiry
R & D	Research and Development
SMET	Science, Mathematics, Engineering, Technology
STEAM	Science, Technology, Engineering, Art, Mathematics
STEM	Science, Technology, Education, and Mathematics
STEMM	Science, Technology, Education, and Mathematics, Medicine
STEM PBL	STEM Project Based Learning
STEM+C	Science, Technology, Education, and Mathematics, Computing
STEM+E	Science, Technology, Education, and Mathematics, Entrepreneurship
TIMSS	Trends in International Mathematics and Science Study
T-STEM	Texas-STEM

CHAPTER 1

INTRODUCTION

Over time, societies have evolved and their needs have changed accordingly. Understanding the nature, struggling with negativity, and for a livable world, it is necessary to know what science is, how it is learned and taught. In history, primitive human had observed the nature and noticed their necessities. Therefore, they had invented the wheel, which is one of the most basic needs of human life. Thanks to this invention, society had applied the minimum force to carry the goods. At this point, science education plays an important role in preparing the individual for a society and the upcoming future in order to meet the needs.

Needs of society had begun with the wheel and they have lasted until the 21^{st} century. This situation will continue in the 21^{st} century and beyond as needs of society will always exist. Therefore, science, engineering and technologies become prominent (MEB, 2016; MEB, 2017). In addition to that, in the 21^{st} century, students need to dominate technological developments in order to make sense of their environment (Akgündüz, Aydeniz, Çakmakçı, Çavaş, Çorlu, Öner, & Özdemir, 2015; Bybee, 2010). Economic success and technological developments are important for nations because they need a reform to develop within themselves (Akgündüz et al., 2015; Williams, 2011).

With the approach of the twenty-first century, the world of humanity is undergoing a pro-change (NRC, 1995). It leads to a global economy in which market domination is fragmented, widely dispersed, and often short-lived (NRC, 1995). All of these have increased the demands of engineers and engineering (NRC, 1995). This is related to the way of designing, producing and controlling what works have been done and how they have been done (NRC, 1995). The nature and the role of technology can be understood with the engineering (NRC, 1995). In the 21st century, engineering and engineering education will have important place (NRC, 1995). At a point where the change of technology and engineering is so valuable, it is quite important to regulate the education system (NRC, 1995). Moreover, variables affecting engineering are not only related to technology and economy but also they are related to social sciences and culture (NRC, 1995).

When looking at the problems of countries, education system takes part in the front raw. When we consider the results of TIMSS, PISA and the results and the categories of OECD, Turkey takes place in for behind (PISA, 2012; PISA, 2015; TIMSS 2015). PISA 2018 results are on the rise compared to PISA 2015 results, but are still generally below the OECD average in all areas (PISA, 2018). Therefore, it would not be correct to interpret it as a major development. To improve this issue, Turkey's education system needs to be improved. Classical learning methods no longer help to the students that much. Today's generation focuses more on fast, paced, dynamic visual images (NRC, 1995). Instead of giving information directly to students, they should be taught how to access that information and how to use it in real life (Güneş & Karaşah, 2016). Students conduct their learning process with solving problems, inquiry and creating projects within teams.

In fact, all of these necessitates include the accepted 21st century skills. Education systems should be changed according to the qualifications in this rapidly developing period of 21st century skills (MEB, 2018). 21st century skills' definitions can be defined as differently from person to another person, from institution to institution. The most comprehensive ones among these skills are Learning and Innovation Skills, Life and Career Skills, and Information, Media and Technology Skills (Partnership for 21st Century Skills, 2010). The basics of these 3 main subtitles are classified. Learning and Innovation Skills cover critical thinking and problem solving, creativity and innovation, collaboration, and communication. Life and Career Skills cover flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, and leadership and responsibility. Information, Media and Technology Skills cover information literacy, media literacy, and ICT (Information, Communications and Technology) literacy.

In Turkey, 21st century skills can be different according to courses. For example, while in science course there are creativity, critical thinking, decision making are more important, in Turkish course there are social participant, empathy etc. are more important (MEB, 2018). In recent years, the approaches in which students actively take part in the learning-teaching process have increased. It is possible for the students to create their own knowledge by constructivist approach (Güneş & Karaşah, 2016). It should be one of the most important aims of science education to provide creative thinking skills to the students who will be adults of the future at every stage of their education starting from primary education (Güneş & Karaşah, 2016). We need to do all these in the field of physics education.

Developing learning and teaching contain student-based practices and constructivist practices in nature. Problem-based, inquiry or project-based can be given to these practices. This kind of practice gives the students various skills. Thanks to these practices, their economic productivity increases, their knowledge increases about scientific and technological concern and their knowledge about the world increases (NRC, 1997). In the light of all these, one of the changes in education in Turkey started with changing the curriculum in 2007 (MEB, 2007). This curriculum was designed in a way that teachers, students and educators were not used to. There was now a curriculum with more activities. The 2013 and 2018 curriculums that followed were tried to be formed on this basis (MEB, 2013; MEB, 2018). So since 2007, a different approach has been applied. The best feature gained after this date was that it was real-life context-based instruction. In the context-based approach, students were able to make connections between events by making them more active with daily life-based approaches (Yam, n.d.). According to Papert (1993), if learning in mind is associated with a context in the real world, it becomes more meaningful and permanent.

One of these approaches is the STEM. When most people heard the word STEM, they associated it to plants, and others associated it to science and mathematics. Few people have been able to relate this to technology and engineering. As such, this concept began to be accepted before STEM was fully understood. The main aim was to make STEM understandable to everyone and to accept it as an innovation. However, STEM was seen as a slogan, and over time, the slogans became interpreted by people. Therefore, STEM can be interpreted differently by different people. The STEM is a project-based approach based on the integration of the disciplines of science, technology, engineering and mathematics (Akgündüz et al., 2015; Bybee, 2010; Bybee, 2013; Corlu, 2013; Corlu; 2014; Kennedy & Odell, 2014; Milli Eğitim Bakanlığı, 2016; Moore et al., 2014; Morrison, 2006; Sanders, 2009; Williams, 2011; Yıldırım & Altun, 2015). STEM is based on integrated STEM. Integrated STEM is to assimilate the interdisciplinary education and seek a solution to the problems with the obtained knowledge with STEM disciplines (Nadelson & Seifert, 2017; Nite, Capraro, Capraro, & Bicer, 2017). In fact, STEM, which was presented first as SMET (Sanders, 2009) and then changed its name, is based on past times. STEM has an important place in history. Important events such as World War II and Soviet Union's Sputnik are very important indicators for the implementation of STEM education. Both events used STEM to end the search for solutions to the existing needs of societies (White, 2014). Although STEM education is mentioned in the literature with many approaches such as project-based, problem-based, inquiry-based and theme-based learning (Mustafa, Ismail, Tasir, Said, & Haruzuan, 2016), it is based on project based approach (Bybee, 2010; Capraro, Capraro, & Morgan, 2013; Milli Eğitim Bakanlığı, 2017; Moore, Mustafa, Ismail, Tasir, Said, & Haruzuan, 2016; Stohlmann, Wang, Tank, & Roehrig, 2014; National Academy of Engineering and National Research Council, 2014). An important feature that makes the project-based learning (PBL) one of STEM’s cornerstones is the search for solutions to a real-life problem. This gives us the context-based structure associated with everyday life (Moore et al., 2014). Since the search for a solution to a problem in daily life is important for STEM, individuals need components that explain the purpose of STEM education (Bybee, 2013). STEM is needed for the following reasons. According to Zahav and Hazzan (2017), there are two reasons why STEM education is so important. The first important reason is that in the future, many of the current occupations will not remain valid. In addition, occupations covering STEM subjects and contents will be in the forefront. This will have an important role in the success of future generations. Thus, both individual development and development as a society will increase. As a result of this, qualified workforce is expected to increase. Another important reason is that people want to find solutions to the problems they face in daily life (Bybee, 2013; Zahav & Hazzan, 2017). In doing this, they use their knowledge and follow economic strategies. For this, they need basic knowledge of STEM. Therefore, it was aimed to strengthen the education area in order to be understood better by everyone. Thus, change movements started in curricula. Similarly, innovations in education started in our country. A report related to STEM Education was published by Milli Eğitim Bakanlığı (MEB) in 2016. This report supports curriculums renewal (MEB, 2016) because current curriculums are not suitable for STEM education.

In Turkey, science curriculum (High School Physics Course Curriculum (MEB, 2018), High School Chemistry Course Curriculum (MEB, 2018), High School Biology Course Curriculum (MEB, 2018), separately) and High School Mathematics Course Curriculum (MEB, 2018) are available, but there is not any technology or engineering curriculum for high school level. In the current High School Physics Course Curriculum published by Milli Eğitim Bakanlığı in 2018, some features aimed to be gained to individuals are given. With this curriculum, it is aimed that individuals are original and innovative, curious, associater what they have learned with different disciplines, interrogator, interpreter, critically and analytically thinker, wonder, investigator, searcher for solutions to the problems they face. In fact, these are the features that coincide with those required by Milli

Eğitim Bakanlığı for STEM. But more studies need to be done on the curricula, and technology and engineering curricula should be arranged.

In addition to all above, in order to present STEM Project-Based Learning (STEM PBL) as a healthy approach, there are two important elements that have an important place in this field. One of them is the teacher (Şatgeldi, 2017; Zahav & Hazzan, 2017) and the other is the student (Zahav & Hazzan, 2017). When looking at the literature, related to the teachers and students studies are usually the remaining studies in theory. Teachers and students occupy an important place in this field, but the sources related to the trainings given to them are almost never seen as important as among other sources in the literature. Because, while there are studies these are mostly read about the readiness, perceptions or attitudes of teachers and students, the number of practical training studies related to the skills they need to have in the transition to practice and the content provided for them are very few. Also, very few teachers are trained in engineering (NAE, 2009).

Looking at the literature, there are resources about what STEM is, what integrated STEM is and what STEM education is available and these resources have wide areas. These sources are common. However, there are no studies emphasizing what STEM is not, what integrated STEM is not or what STEM education is not. Therefore, most people do a lot of wrong things under the name of STEM, integrated STEM and STEM education. It says STEM, integrated STEM and STEM education by practicing a discipline or doing experiments or doing projects or robotic coding. However, it does not contribute anything in it. There has not seen any study to emphasize them and to study their distinctions.

In addition, the development of instructional materials for STEM has less area than theoretical areas in the literature. The current studies have not provided detailed information about how these materials have been developed and there is no systematic material development method in the development methods. Even if these studies have followed any method of developing activity, they have not presented these methods as a result. Therefore, how these studies have done these instructional material development processes is unknown in literature.

When the literature is examined, it is seen that there are not many studies in high school level in STEM related studies. On the other hand, unit-based and objective-based in the current physics curriculum instructional material development activities, which are shaped within the framework of the high school curriculum-related objectives, are relatively low compared to the number of other study areas. In the studies performed, a systematic approach was taken and the activity samples studied at each grade level were rarely encountered.

Looking at the instructional material development studies in the literature, the materials which will need to be requested by participants in the studies were pre-determined and included in the studies by researchers. However, it was necessary for the participants to determine their own materials according to their chosen solutions in the activity process. Otherwise, it does not create a production process inventively.

The important questions that we should seek the answer from the literature; What are the characteristics of the STEM?, what are the characteristics of the STEM education?, what are the characteristics of the STEM activities?, how do students improve STEM skills when they apply STEM education-based activities to the students?, what steps can be applied to develop an effective STEM education-based activity?, what are the 9th grade physics STEM activities?, and what are the effects of STEM based Instructions on Students' Outcomes? Since the literature includes many different answers to these questions, the literature should be examined and the answers to these questions should be sought.

In this study, STEM instructional materials for 9th grade physics will be developed by following a systematic follow-up. Using the interdisciplinary feature of STEM, the researcher will integrate other disciplinary contents with physics. In doing this, the researcher will develop the instructional materials with the ASSURE Model (Smaldino, Russell, Heinich, & Molenda, 2004). Then, as a result of a detailed literature review, the researcher will create own 10-step implementation cycle from the literature. Then, the researcher will apply these instructional materials in the classroom with these 10 steps. Therefore, this study will fill an important gap in the literature for all mentioned above.

1.1. Purpose of the Study

The purpose of the study is to develop STEM Project-Based Learning activities by using an ASSURE Model for 9th grade students in Turkey.

1.2. Significance of the Study

Today, developments in science and technology are gaining momentum and many innovations are taking place in the world. One of them is the STEM, which is based on a project-based approach. The increase in the number of studies on STEM cannot be ignored. STEM education is spreading rapidly since it is being applied to all levels in schools in our country and clubs are being established in related schools and it is of great importance today. Also, everyone is talking about STEM and STEM-related workplaces are being opened. The concept of STEM, which has emerged abroad, has been shaped by each country in accordance with its needs. However, as the education system, school studies, curriculum contents, class hours, and many other things that each country has, STEM is as diverse as it is. Nevertheless, the increase in mid-level levels in high schools (9th, 10th, 11th grade), especially in project-based learning in recent years, has made most of the work accessible to schools, educators, students and teachers.

Among this diversity, a lot of activities are being developed under the name of STEM activities. But when the literature is examined in detail, there are some missing points. In these circumstances, it is very difficult to balance STEM. After the correct understanding of what STEM is, when it comes to developing STEM materials, there are many missing parts in the literature. First of all, there are certain characteristics that STEM activities must possess. Researchers developed STEM activities, but did not elaborate on them by emphasizing the characteristics that STEM activities should have. In this study, since STEM activity was desired to be developed, a detailed literature review did not reveal any source in which these features were presented as features that should be possessed in a STEM activity. In this study, after a comprehensive literature review, I will identify the features that STEM activities should have and clarify the subject and include them in this study. Thus, I will be able to integrate these features into STEM activities. Thus, I will present the features that a STEM activity should possess to those who will study after me and those who wish to develop a STEM activity.

Second, integration of STEM disciplines is the main feature of STEM activities. It is very important that STEM activities are lesson and objective-based, because it involves reform movements to the curriculum. When the literature was examined, researchers developed STEM activities, but they did not present that they integrate curriculum objectives in detail in these activities. Through this study, you will see how STEM activities are presented with integrated objectives.

Third, correct development and implementation of STEM activities is very important. Researchers developed STEM activity, but how these activities were developed in the literature was not clearly explained. I want to develop STEM instructional materials, but I cannot develop it because other researchers who state to have done this work before do not have a systematic material development process. I will clarify these situations from the literature and use them in my own work and develop STEM activities. I'm going to look at whether these activities work or not, and I'm going to offer a method to develop STEM activity for those who come after me.

Fourth, it is also very important that a developed STEM activity is implemented correctly in the classroom. Within the literature there are various cycles of the implementation of STEM activities in the classroom. These loops contain similarities and differences. These loops have overlapping and non-overlapping steps. In some cycles there is no iterative path in engineering and technology design cycles. There is not a single correct way to implement the activities, but what is important is that steps do not work in the activities are identified and revised to achieve the desired result. The steps to be followed in these cycles are very important. I will examine these cycles in detail and present my cycle of specific steps that I propose for the effective implementation of an effective STEM activity in the classroom.

Fifth, it is useful to emphasize that STEM activities are lesson and objective based. When the literature was reviewed, researchers and teachers developed STEM activity and put it into practice. However, the planned times for the activities they developed were not presented in detail during the implementation of the activity. This detailed schedule has a very important place in terms of lesson planning. I will present the study by making detailed time plans with revisions of the activities developed through this study.

Sixth, it is very important to provide a creative working environment to produce authentic products in STEM activity. In order for students to develop their authentic prototypes, they should determine the materials they will use. When the literature was examined, teachers implemented STEM activities, but they did not enable students to determine the materials. In these studies, materials predetermined by teachers were given to students in the process of the activity. Through this study, you will see how STEM activities are applied with the material choice of students in the activity process.

Briefly, therefore, while integrating a project to the course, it should include the objectives and skills that should be transferred to the students in the course. In addition to this, I decided to do such a study since I observed serious problems in combining the 4 disciplines in the content of the studies. With this study, I will develop several materials for STEM Project Based Education for 9th grade physics subjects by using ASSURE Model which is an instructional material development model. While searching for solutions to a problem, students will develop their research skills, problem solving skills and questioning skills. Thus, instead of directly acquiring information and content, the students will conduct research by themselves and obtain information and content. While doing these, I have created my own implementation cycle so that STEM activities can be implemented correctly in the classroom. In doing so, I will prepare a project education cycle that

I deem appropriate. This cycle can be used by every teacher, educator, student and school.

1.3. Assumptions of the Study

In the study, instructional materials were revised according to the interviews of the students and teacher, and observations of the researcher; therefore, it was assumed that the students, the teacher and the researcher were honest in this process.

1.4. Limitations of the Study

There are four limitations in this study. First, this study covers the students from high schools in Karadeniz Ereğli. The contribution of students to work together with the return of having education from different schools and having different backgrounds may change. Second limitation of the study is to have one teacher and one researcher as guidance for the students throughout the study. Both teacher and researcher worked together with different students in different activities and guided them according to their own knowledge and methods. This can affect the results of the study. Third limitation is that we developed activities with students, but do not look at the readiness of students and how much knowledge they have about the STEM. If there are people who have already participated in these and similar studies, they can foresee and influence the results of the study. The fourth limitation is the characteristics of the researcher. The researcher graduated from mathematics and science education in major of physics education of a state university that has the 2nd highest admission score among all universities that have major of physics education in Turkey in 2015. The undergraduate graduation average is 2.48. The researcher is doing her master's degree in Mathematics and Science Education Department. Cumulative GPA in master program is 3.30. The researcher does not have any experience in STEM or Research and Development (R & D) field prior to this study. In order to do this study, the researcher conducted a literature research on STEM for 9 months. The researcher encountered the STEM field while studying on graduate courses. On the one hand, while studying on the graduate courses, the researcher made preliminary research for STEM field. In addition, the researcher studied on the outline that forms the skeleton of this study for 3 months. Then, the researcher completed the literature study. In addition, the researcher examined R & D process for 3 months. At the end of the literature study, the researcher developed STEM PBL instructional materials. This development process lasted 3 months. This process covers expert opinions, supervisor's opinions, and then the revision of the instructional materials. The development of the data collection instruments to be used in the study lasted 2 weeks. The researcher has researched on STEM areas and improved herself during her graduate study. The researcher worked as a student assistant in the applied science museum of the university because of her interest in science. During undergraduate and graduate study, the researcher participated in various national congresses and workshops in the field of physics education. The researcher has 4 years of teaching experience in high school physics. The researcher is working as a physics teacher at one of Turkey's prestigious and institutional private high schools. The researcher takes part in national projects related to STEM at high school where she works.

1.5. Definitions of Important Terms

Main terms used in the study are defined as follows:

STEM: STEM has emerged with the abbreviation of science, technology, engineering and mathematics (Bybee, 2010; Bybee, 2013; Kennedy & Odell, 2014; Milli Eğitim Bakanlığı, 2016; Sanders, 2009; Yıldırım & Altun, 2015) and a course, an activity and an education and this brings the integrated approach (Akgündüz et al., 2015; Corlu, 2014; Moore, Stohlmann, Wang, Tank, Glancy, & Roehrig, 2014; Morrison, 2006; Williams, 2011) and also contains real world problems (Moore et al., 2014). Also, according to Breiner et al. (2012), Güneş and Karaşah (2016), and Kennedy and Odell (2014), STEM is an interdisciplinary approach. In addition, STEM is a student-centered way of teaching with the inquiry-based approach that includes steps of method of project-based learning with guided-inquiry by teachers. In detail, it offers a combination of four disciplines with an integrated approach. In doing so, it presents a problem in daily life. This problem is ill-defined (Johannes, 1997). This ill-defined problem must be produced with a well-defined result. In trying to ensure this integrity, STEM adopts a project-based method. The aim is to reach a product-based conclusion with an ill-defined daily life problem and a well-defined solution (Sahin, 2013). In here, students are expected to develop a prototype and test it, and if necessary redevelop the prototype.

Integrated STEM: Integrated STEM education combines with science and math education theories with the applicability of technology and engineering (Satchwell & Loepp, 2002). According to STEM Task Force Report (2014), STEM is much more than the integration of four disciplines. It covers the real world problem and their problem based learning situation, their active teaching and learning process. In integrated STEM applications, many areas such as health, transportation, climate, and mining are used besides STEM components (Nadelson & Seifert, 2017). However, in education, integrated STEM is generally related to project based learning or problem based learning in schools. However, in its base, integrated STEM is to assimilate the interdisciplinary education and seek a solution to the problems with the obtained knowledge with STEM disciplines (Nadelson & Seifert, 2017; Nite, Capraro, Capraro, & Bicer, 2017). According to National Academies Press Report, Honey and colleagues mentioned that STEM integration has to work in the context of tasks that require students to use knowledge and skills from different disciplines (Honey, Pearson, & Schweingruber, 2014).

STEM Education: STEM education has project-based education approach and this provides producers and students inventors without any discrimination between the disciplines (science, technology, engineering, mathematics) of STEM (Bybee, 2010; Capraro, Capraro, & Morgan, 2013; Milli Eğitim Bakanlığı, 2017; Moore, Stohlmann, Wang, Tank, & Roehrig, 2014; National Academy of Engineering and National Research Council, 2014).

STEM Education Based Activities: STEM education based activities are project based activities. They have four disciplines and are from the real life and interdisciplinary, multidisciplinary activities. It provides students with a problem from real-life that they need to produce solutions. According to Bybee (2013), STEM education based activities differ from other ones because they focus on global challenges, change the environmental and related problems' perception, identify the 21st century workforce skills and keep going national security topics. Also, they are context-based. They are integrated to the lesson and so, many interdisciplinary objectives are gained. These activities have disciplinary curriculum integration. Thanks to these activities, students learn time management and budget determination. These activities bring together different disciplines and at the same time develop social skills.

CHAPTER 2

LITERATURE REVIEW

Today, the need for thinking, producing, questioning and creative individuals in the fields of science, technology, engineering and mathematics is increasing day by day (Yıldırım & Altun, 2015). New and different programs have to be implemented for the teaching-learning process in these areas. The most recent of these programs are STEM learning and applications (Yıldırım & Altun, 2015).

One of the methods that will be utilized in order to make education applicable for enriching education today is STEM. Well, has the STEM actually always existed, or is it a new term? In this chapter, what the STEM is, what the integrated STEM is, what the STEM education is, the role of teacher on STEM education, the role of students in STEM education, what features STEM education-based activities should have, how STEM education-based activities differ from other types of activities, what the positive and negative sides of STEM education are, examples of STEM education-based activities, what the skills that STEM develops in teachers and students are, how a STEM education-based activity should be developed, how a STEM activity is applied in the classes, effects of STEM based instructions on students' outcomes, and summaries of the literature review are examined, respectively.

2.1. What is STEM?

First official encounter with STEM is based on recent history. When looking at the background of STEM, according to Sanders (2009), in the 1990, SMET (science, mathematics, engineering, technology) was used by National Science Foundation (NSF) but this word was thought to be rude. Therefore, it had been changed as STEM (Sanders, 2009). After that, STEM has been crucial important since 2001 (Breiner, Harkness, Johnson, & Koehler, 2012) and Judith A. Ramaley from the National Science Foundation constituted the STEM in 2001 (Daugherty, 2013; Watson & Watson, 2013). Ramaley defined STEM as an educational inquiry where context was integrated to learning, where students solved real-world problems by opportunities with pursuit of innovations (Daugherty, 2013; Watson & Watson, 2013). Finally, STEM has continued to gain speed so far.

Every country has different political, social and technological history. Therefore, their education and technological systems are also different. As a result of this, STEM is not suitable to happen for each country (Williams, 2011). According to Elmalı and Balkan-Kıyıcı (2008), the studies of STEM have started in 2013 and in recent years, the studies about STEM have been increasing year by year (Elmalı & Balkan-Kıyıcı, 2008; Güneş & Karaşah, 2016; Herdem & Ünal, 2017; Kennedy & Odell, 2014; Williams, 2011). Science, technology, engineering and mathematics are important topics in STEM studies (Güneş & Karaşah, 2016; Kuenzi, 2008; Williams, 2011).

Turkey's orientation to STEM education has started with the poor performance shown in PISA and TIMSS exams and attempt of private sector (Herdem & Ünal, 2017). Turkey's efforts to improve science education in the OECD which has begun with the adoption of the principle of learning by doing and experiencing implemented in 1955, in Europe in 1960 with the support (Güneş & Karaşah, 2016). The interdisciplinary relationship between science education thesis and articles has been tried to be studied with STEM education, but since it is a new preferred method, the number of data is quite low (Güneş & Karaşah, 2016).

In literature, there are many definitions about what STEM means. In generally, there is a fact that it has 4 main component rules. STEM has emerged with the abbreviation of science, technology, engineering and mathematics (Bybee, 2010; Bybee, 2013; Kennedy & Odell, 2014; Milli Eğitim Bakanlığı, 2016; Sanders, 2009; Yıldırım & Altun, 2015) and it is also a course, an activity, an education and these topics bring the integrated approach to STEM (Akgündüz et al., 2015; Corlu, 2013; Corlu; 2014; Moore et al., 2014; Morrison, 2006, Williams,

2011) and it also contains real-world problems (Moore et al., 2014). This can be acceptable but actually there is no certain definition about what kind of course, activity or education it is. At this point, real-life features of this course, activity or education should be exactly stressed in its definition. Also, STEM is an interdisciplinary approach (Breiner, 2012; Güneş & Karaşah, 2016; Kennedy & Odell, 2014) because; it covers the teaching methods in education system. At this point, there is another definition of STEM. According to Corlu, Capraro, and Capraro, (2014); and Green (2007), STEM does not only contain the science, technology, engineering and mathematics but also it contains a social and behavioral sciences such as psychology, economics, sociology and political science by NSF (National Science Foundation). After this definition, it shows us STEM has an interdisciplinary approach.

In addition to this, there are various meanings of STEM. However, different audiences can identify it with different words; but in fact, most of them have the same meanings. However, if it is needed to analyze and group them for better understanding this diversity, only a few can be obtained. In this respect, Bybee (2013) makes our work easy. According to Bybee (2013), after many articles, discussions, projects and reports have been examined; definitions of STEM and actually STEM education can be grouped in 9 categories or named as different perspectives. The names of these categories are:

STEM Equals Science (or Mathematics): In here, STEM is thought as science. This shows that it means single discipline instead of multidisciplinary approach.

STEM Means Both Science and Mathematics: In here, STEM is thought as both science and mathematics. This situation has continued for a long time because this situation is based on science-and-mathematics based curriculum.

STEM Means Science and Incorporates Technology, Engineering, or Math: In here, teachers in schools give place to the technology and engineering in their lessons. However, they consult the science part while they are explaining.

Actually, they notice the different disciplines but they give great importance to science.

STEM Equals a Quartet of Separate Disciplines**:** In here, there are four different and separate disciplines. Their contents include in school curriculum.

STEM Means Science and Math Are Connected by One Technology or Engineering Program: In here, science and mathematics are independent disciplines for engineering and technology. That means engineering and technology can be thought as a bridge between science and mathematics.

STEM Means Coordination across Disciplines: In here, teachers ask others branch concepts in their own lesson because some concepts are processes can be presented and implemented. That means disciplines interact with each other.

STEM Means Combining Two or Three Disciplines: In here, two or three disciplines are integrated.

STEM Means Complementary Overlapping across Disciplines: In here, disciplines in the lectures, units, courses can integrate STEM.

STEM Means a Transdisciplinary Course or Program: In here, there are different programs or courses such as use of resources for energy, global climate change, etc.

STEM still has insufficient research on its use about the integration part, and there is little intervention in this situation by researchers, teachers, anyone interested in STEM (Honey et al., 2014). So, what is the importance of these concepts for the STEM?

In recent years, the integration of STEM is based on more science and math (Breiner et al., 2012; Sanders, 2009; Wang et al., 2011), less technology and engineering (Bybee, 2010). When looking at science and its education, although they mainly cover science, it also includes mathematics and mathematics education (Honey, Pearson, & Schweingruber, 2014). Recently in school, there has more time for mathematics with science (Blank, 2012). Another point of view is that difference between science and mathematics is invalid according to STEM education because their relationship provides to understanding STEM education (Corlu, Capraro, & Capraro, 2014). Application of STEM education is depend on school level, type in Turkey (Corlu, Capraro, & Capraro, 2014). Also, there should be curriculum reform in K-12 level in Turkey and teachers should adopt this change (Corlu, Capraro, & Capraro, 2014). In addition to these necessary changes in education, the place of disciplines is also important. At this point, first of all the disciplines should be understood, then necessary changes should be made in the curriculum and courses.

Science and mathematics are more widely accepted, but technology and engineering are also important. Technology is a key for problem based learning model to utilize math, science, and engineering principle. However, mostly, the definition of technology can be perceived as computers or internet. According to many dictionaries, technology is application of methods and tools. According to many people or places in education, technology is mentioned as computer whose meaning is a technological tool. Computer is a tool but in technology it provides narrow perspectives as a whole. Computers are absolutely as a form of technology but technology is much more than computers (White, 2014). Technology is included in these areas such as engineering and manufacturing technologies, electronics, energy and power etc. (White, 2014). To give an example for technology, if we think of multimedia as a technology tool, it also offers learners something related to the real world. In doing so, multimedia provides children with a learning and information environment (Bransford et al., 1992). But, eventually, a pencil can be accepted as a technology. Therefore, technology is considered as an area with different perspectives for the STEM. Also, it is a bridge between science and technology in STEM (Sanders, 2009). In the 1980s industry and handicrafts, known as technology, were replaced with business skills. Then, technical education, vocational education and materials began to replace them. Computers, film strips, internet, TV and derivatives can be seen as other technology communication. Computers, soft wares and others are included in their components of the STEM's science, engineering and mathematics (Honey et al., 2014). Engineering plays an active role in helping to solve real-life problems, while science, technology and mathematics are at this point a tool that helps in engineering. In addition to this, in order to understand the work, our literacy plays an important role to shed light on the work done in the past. They have conversation that allows us to communicate with other people. The engineering component is a new developing area according to other areas in the STEM. It is directly related to the real world. Therefore, an engineering-oriented curriculum is more designed for the first and second school.

On the assimilation and understanding of all 4 disciplines, 21st century skills, science and mathematics skills, technology and engineering skills and interdisciplinary cooperation come into prominence with objective-based STEM applications (MEB, 2019). Therefore, right after, concept of STEAM has emerged (Watson & Watson, 2013). According to Yakman, STEAM is a science and technology which are based on mathematics with engineering and art. Art provides different perspectives to look at the world with STEM (Watson & Watson, 2013; Storksdieck, 2011). Also, when we look at the engineering dimension, the design part gets a lot of space and the creativity innovation comes to the fore. All of these are quite important but 21st century skills are looking for innovation and creative design (Meyrick, 2011). The design in engineering comes into the preeminence. For this, specific limitations and criteria must be determined (Honey et al., 2014). This is a kind of derivation of STEM. Except this, some sources can mention their description as a kind of STEM branch. However, they are not the STEM branch. For example, I-STEM (Innovation-STEM) or STEMM (STEM+Medicine) are a few of the examples encountered in the literature review. The meaning of I-STEM is Innovation+STEM. Innovation's meaning is discovery, invention or alteration/modification. It can be included in the definition of STEM. Therefore, it is not a derivative of STEM. Another example is STEMM (Bequette & Bequette, 2012). STEM+Medicine can be included in biology which is included science part or it should be investigated deeply whether it is a derivation of STEM or not.

STEM+C (STEM+COMPUTING) and STEM+E (STEM+ENTREPRENEURSHIP) (Akgündüz et al., 2015) or ESTEM (ENTREPRENEURSHIP+STEM) (Herdem & Ünal, 2017) are not also a branch or acronym of STEM. Also, NSF supports the basic sciences and engineering, so it does not include Medicine as a discipline in STEM. Therefore, they are not a new derivation.

Also, some universities have started to study about STEM. Hacettepe University, Bahçeşehir University and Istanbul Aydın University have some attempts of this issue (MEB, 2018). Also, some institution or university can use STEM as their name such as T-STEM (Texas-STEM) (https://tea.texas.gov/T-STEM/) or H-STEM (Hacettepe-STEM) (http://www.hstem.hacettepe.edu.tr/) (Akgündüz et al., 2015). They are just a name for institution or university, not derivatives of STEM (Akgündüz et al., 2015). Especially among these, T-STEM put together all STEM disciplines (Kennedy & Odell, 2014).

STEM is the reason why we encounter different approaches and explanations when we think about it are due to various perspectives. These are, for example, the non-integration of the science, technology, engineering, mathematics sections of the traditional education system for NSF and places with educational perspectives. Therefore, the integration part of the STEM is very important in solving real life problems (Labov, Reid, & Yamamoto, 2010; Sanders, 2009; Williams, 2011) and project-based studies of engineers and scientists (Williams, 2011). This part is really important because what STEM is and what integrated STEM is are highly linked, and this highly linked situation allows us to recognize what STEM is not. For example, when people heard first STEM in education, they supposed that STEM is related to do something about science and/or computer. People could not understand the meaning of STEM correctly when memorizing the classification of Bybee. Actually, science and computer are also parts of STEM. They are tools to create STEM but they have not a place for definition of STEM (White, 2014).

When mentioning the integrated approach of STEM, to solve the global difficulties about energy, health and environment, integrated curriculum approach can be used (Bybee, 2010). Moreover, according to Meyrick (2011), STEM has an important place to add science and technology, engineering and mathematics into the curriculum. That means their integration of each one to the curriculum is necessary because thanks to integration of curriculum, STEM education has theoretical framework (Corlu, Capraro, & Capraro, 2014). Curriculum integration provides strong connection to the life (Corlu, Capraro, & Capraro, 2014). It should be but when looking at Turkey's Education System, there are no separate curriculums for STEM, or there is not a curriculum related to STEM separate disciplines, specially. STEM has four disciplines but many people accept that science and math are pioneers (Bybee, 2010; Nite, Capraro, Capraro, & Bicer, 2017). Technology and engineering are represented less in STEM education, and technology and engineering provide insufficient resources in K-12 education area, especially (Miaoulis, 2011). We can participate in this inference for Turkish Education System because in Turkey there is a truth like a compulsory education which is from beginning of primary school to end of high school. Actually, we can add kindergarten to this process because many schools try to give the integrated STEM in kindergarten. Therefore, there should be related curriculum about STEM. Also, the information on curriculum is related to daily life (MEB, 2018). Technology should be integrated to the curriculums, lessons, teaching strategies, culture for improving learning (Kennedy & Odell, 2014). Looking at the curriculum, courses are done separately and they should be handled together with STEM (Corlu, 2014).

Integrated STEM education is really important; therefore the separate areas should be integrated (Yıldırım & Altun, 2015). When looking at education in Turkey, there are some curriculums for every lesson for every education level like primary, middle and high school. In primary and middle school, there are related curriculums about each lesson. In these curriculums, there are science curriculum that can be applied for integration of STEM (Milli Eğitim Bakanlığı, 2018) and math curriculum that can be applied for integration of STEM (Milli Eğitim Bakanlığı, 2018) separately. However, there are not separate technology and engineering curriculum for integration of STEM. There is just an information technologies and software curriculum but it is not suitable for technology definition exactly, because a pencil can be accepted as a technology. Therefore, it supplies the part of the definition of technology. In high school, there is a High School Physics Course Curriculum (Milli Eğitim Bakanlığı, 2018), High School Chemistry Course Curriculum (Milli Eğitim Bakanlığı, 2018) and High School Biology Course Curriculum separately instead of science curriculum in primary and middle school. It can be acceptable for science curriculum for integration. Also, there is a math curriculum in high school but there have not any technology and engineering curriculum specially. Therefore, studies included with science and math can be accepted as a part of STEM integration and they can be in the foreground. However, in order to fully evaluate them, we should examine whether the objectives of science and math curriculum are appropriate for the integration of STEM activities.

If STEM is seen a practical solution for future, design and technology should be integrated to the STEM curriculum (Roberts & Cantu, 2012).

In order to include students in a high quality STEM education process, integration of requirements such as integrating technology and engineering to the science and math curriculum, assessment, developing scientific inquiry and design process, and strict curriculum into STEM education is required (Kennedy & Odell, 2014). According to Roberts and Cantu (2012), there are 3 approaches of STEM education; silo, embedded, and integrated. In silo approach, every STEM subject is isolated (Dugger, 2010). If every subject is studied separately, students can understand the lesson better. However, at this point, students may not understand real life STEM subjects without application (Breiner, Harkness, Johnson, & Koehler, 2012). In embedded approach, there are important parts such as problem solving and real life situations. While being interested in them, they are related to the social, functional and cultural contexts (Chen, 2001)**.** The key point of this approach is that foreknown subject and suitable class level knowledge are really important (Novack, 2002). In integrated approach, there is a holistic approach which removes the walls of the each stem discipline. Therefore, it can be taught as one subject (Breiner et al., 2012; Morrison & Bartlett, 2009). According to Wang, Moore, Roehrig, and Park (2011), students can be concentric on STEM subjects about real life problem solving. It has two separate integrated parts. One of them is multidisciplinary integrated approach and other one is disciplinary integrated approach (Wang et al., 2011). In multidisciplinary, students combine various topics in different classroom (Wang et al., 2011). According to Wang et al., (2011) there is a problem from real World in disciplinary integrated approach. To reach a solution, problem solving skills, critical thinking and curriculums are combined. Therefore, integration can be taught as the best approach for STEM education (Laboy-Rush, 2011; Wang et al., 2011).

The most important part is real life for STEM but our curriculums have not been designed for it. Actually in Turkey's education curriculum has some life-based skills (MEB, 2018) but STEM is directly related to the real life. Our curriculum must have the skills to cover four disciplines in STEM, or a separate curriculum should be developed for this because STEM should be considered as a whole.

Well, then how can we apply STEM? This point is related to STEM education. There are several teaching methods applied in the education system. Some of them are cooperative learning, project based learning, inquiry learning, problem based learning etc. According to Breiner et al., (2012), STEM is more appropriate to application with project-based approach instead of the traditional teaching method. Because, disciplines can be come together with the project based learning with STEM (Watson & Watson, 2013). Also, main common point for project based learning and STEM is student-centered learning for this, the role of teacher should be a guide for students. However, when applying, there have been some troubles since previous time because, in the first time, there were science and math parts, not technology and engineering parts. Therefore, the connection between science and math was taken in consideration. This situation still remains a bit valid today. Thus, students who see science as part of the world should also see mathematics as part of the world. These situations lead to a new way of looking at the world (Davison, Miller, & Metheny, 1995). Combining mathematics with science allows students to connect with the real world and interpret it in their own way (Davison et al., 1995). When science is mentioned with mathematics, it is a condition that science can include other disciplines because they are intertwined. Technology and engineering are also included in these other disciplines. Moreover, the reasons why science and math are more prominent than technology and engineering, according to White (2014), here are 5 explanation items. First reason is that science and mathematics are most familiar area and many educators feel comfortable when teaching these areas. Second, educators which are not from engineering and/or technology are afraid of the process of related to engineering and technology. Third, nevertheless, engineering is familiar word and many educators are related to it, many people who are not from this area are not sure what the engineers do in education area. Fourth, many people think that technology is an area about computers. The last one is that many educators feel comfortable in their areas (White, 2014). All this talk brings us to the compulsory education point and missing suitable curriculums. Therefore, White's 5 explanations should be based on compulsory education and missing separate curriculums. Actually, reform efforts in science and mathematics are really important for STEM education (Kennedy & Odell, 2014). Also, according to Kennedy and Odell (2014), there can be a curriculum to combine all 4 disciplines instead of improving science lessons and current curriculum.

When looking at what is STEM and what is not STEM, it is observed that robotic applications are generally used in out-of-school activities in our country. The fact that robotic applications address science, technology, engineering, mathematics disciplines both in hardware and software, which the programs used in this field are easily accessible, and that sufficient algorithms are sufficient for secondary and high school level in terms of teaching of simple algorithms caused STEM education to become dominant in this field (Herdem & Ünal, 2017).

STEM education requires changes of education system and education methods (Portz, 2015). Therefore, we should understand the meaning of STEM. According to Portz (2015), what is STEM and what it is not is the first and most important issue and challenge. The aim of the STEM is to integrate critical issues in industry with real-life applications (Portz, 2015) and increase the current generation to the innovative mindsets (Corlu, Capraro, & Capraro, 2014). Therefore, if people do not understand the aim of the STEM, the application of it is difficult.

2.2. What is Integrated STEM?

In this part, integrated STEM is detailed. This is highly relevant to what STEM is and is not. For deeply expression, this part is necessary. In this part, integration of science, integration of technology, integration of engineering and integration of mathematics are detailed. Actually, all of these are the basis of context-based approach.

Integrated STEM education combines with science and math education theories with the applicability of technology and engineering (Satchwell & Loepp, 2002). In integrated STEM applications, many areas such as health, transportation, climate, mining are used besides STEM components (Nadelson & Seifert, 2017). However, in education, integrated STEM is generally related to project based learning or problem based learning in schools. However, in its base, integrated STEM is to assimilate the interdisciplinary education and seek a solution to the problems with the obtained knowledge with STEM disciplines (Nadelson & Seifert, 2017; Nite, Capraro, Capraro, & Bicer, 2017). According to National Academies Press Report, Honey and colleagues mentioned that STEM integration has to work in the context of tasks that require students to use knowledge and skills from different disciplines (Honey, Pearson, & Schweingruber, 2014). At this point, a context-based approach emerges. Context-based approach can be expressed in many ways. According to Whitelegg and Parry (1999), it is a cultural and social environment with teachers, students and corporations. In this context, at first, students can identify the contexts in real life. Therefore, they can get information about context and physics concepts relationship and their application steps that can be examined (Whitelegg & Parry, 1999). This shows that learning can be associated with the implementation from the real life (Whitelegg & Parry, 1999). Context based approach aims to teach directly events from real life and make it necessary to learn the physical concepts and laws (Tekbıyık & Akdeniz, 2010).

As most of people know that physics is everywhere and so physics explains how the world works. According to Whitelegg and Parry (1999), this increases the motivation of students because students can notice that one unit of physics can be related with another one. Therefore, this approach gives opportunites because students can look from different sides to reinforce their knowledge. Actually at this point, context based learning defines the concepts with the traditional physics subjects' applications with the real world situations (Whitelegg & Parry, 1999). Therefore, context based learning forms the basis of integrated STEM.

All in line, when looking at the K-12 level STEM in foreign schools, it is suitable a more segregated STEM spectrum. Whereas, integrated STEM education supports students to develop solutions to problems and projects they experience. Therefore, focusing on integrated STEM requires students and teachers to determine when and how the STEM will be applied (Nadelson & Seifert, 2017). Including students in the integrated STEM is one of the requirements of our age and it is necessary to teach them how to apply the STEM disciplines (Nadelson & Seifert, 2017). However, in Turkish education system, science and math does not provide applicability of technology and engineering because there is no separate curriculum for how to apply technology and engineering. Therefore, there is a fact that STEM still has insufficient research on its use about integration part, especially in Turkey, and there is little intervention in this situation (Honey et al., 2014).

Apart from all of these, here are some difficulties about integrated STEM. One of the difficulties in the implementation of integrated STEM education is to bring an integrated STEM instead of existing and applied STEM education. Except for some applications, the education system is not problem based. Therefore, the existing STEM education should be replaced with the integrated one. Therefore, things like how to integrate, what kind of assessment should be determined for correct integration (Nadelson & Seifert, 2017). Another difficulty is the knowledge of teachers on this subject. Because integrated STEM teaching requires basic knowledge about the use and requirement of contexts (Nadelson & Seifert, 2017).

In addition to these, it is very important for teachers to understand how to use integration in different ways (Underhill, 1994). As I mentioned in the section of what STEM is, there are some reasons for the basis of why science and math are at the forefront. According to Miller, Davidson and Metheny (1993), here are five integration types for science and math. They are discipline specific, content, process, methodological, and thematic. For discipline specific integration, students should differentiate the science and mathematics when using them together because in their base they are different units (Davison, Miller, & Metheny, 1995). Therefore, in integration, science integration, mathematics integration and others should be examined deeply in themselves, and then they should come together comprehensively. Also, for discipline specific integration, there should be a problem which is based on all disciplines, critical thinking and problem solving skills. For content specific integration, it transfers goals from each discipline. To give an example, students combined mathematics and science, in fact physics, and they did a simple machine study. For this, using the materials to create the mechanism; while using mathematics in proportion, they used science, physics, to create leverage. They combined with these disciplines and work on simple machine part of leverage. The teachers also guide them, thus the students worked by them. Then, they tested the device whether it is working or not (Davison et al., 1995). Thanks to these studies, students can start to see the differences and associations between mathematics and science, especially physics, together (Davison et al., 1995). Also, the integration of science and mathematics provide us with a basic learning (Davison et al., 1995). Therefore, students can learn the information and integrate them to their studies. In process integration, another usage area is to use the daily life activities in the lessons (Davison et al., 1995). Generally, to answer the real world problems, mathematics calculations are important (Davison et al., 1995). In this process, students do experiments and collect data. Then, they analyze them and get a result. Therefore, they experience this process and approach between math and science (Davison et al., 1995). Moreover, while students are studying this, they can use their information with the integration of engineering to the real world. When mentioning the methodological integration, while students are using mathematics and science together, they should also use the discovery, inquiry and learning cycle parts (Davison et al., 1995). According to Davison et al, (1995), thematic integration is a theme that has become an environment in which all disciplines interact. To give an example, when looking at the oil spills, volume, surface area and etc. should be included in mathematics but environmental parts and density and etc. should be considered in science part.

Integrated STEM is used seldom because disciplines of STEM are rarely integrated in schools. Generally in education system of the world, discipline based approach is used. Moreover, students can take some courses focusing one content (Marrero, Gunning, & Germain-Williams, 2014). This can be applicable but while doing this, at first we must integrate the integration of each discipline within itself, then thus, integration with other disciplines can be provided as a whole.

When looking at the importance of integrated STEM, we can notice how it is necessary. The students will be able to understand and make sense their knowledge. According to Perkins (2008), when looking at the Bloom-Old Version (1956), Bloom-New Version (1990's) and Webb's Dok (Depth of Knowledge) (2002), students make sense of what they have learnt and use them in new way with creation. Therefore, the availability of knowledge teaches student to deeper understand and relate the STEM disciplines and integration process.

2.3. What is STEM Education?

In this part, what STEM education is, the role of teacher on STEM education and the role of student on STEM education are examined.

History has a crucial role in STEM education (White, 2014). STEM education was first used in making of engineering firms such as light bulb, automobiles, etc. In history, Thomas Edison, Henry Ford used STEM in their studies (Butz, 2004). This actually shows us a way in the field of application of STEM education. In addition to these, two important events, World War II and Soviet Union's Sputnik, contributed to develop the STEM education (White, 2014). During the World War II, many developments occurred from the standpoint of human history. Atomic bomb and various transportation tools were also included these developments. Scientists, mathematicians, academic engineers worked together and produced new products to help win the war for STEM education (Judy, 2011). The importance of these studies is that it is a pioneer for technological studies on the future space and discovery in human life (White, 2014). Also, NASA was a pioneer for STEM education innovations. It was Sputnik's effect for STEM education (White, 2014). So, how do all these study provide us an inference? STEM education has project-based education approach and this provides inventors, producers, educators, teachers and students without discrimination between the disciplines (science, technology, engineering, mathematics) of STEM (Bybee, 2010; Capraro, Capraro, & Morgan, 2013; Milli Eğitim Bakanlığı, 2017; Moore, Stohlmann, Wang, Tank, & Roehrig, 2014; National Academy of Engineering and National Research Council, 2014).

Additionally, STEM education is based on project-based, problem-based, inquiry-based and theme-based learning. Among these, project-based learning is the most featured on STEM education. After that, there is design-based learning that follows the project-based learning as a kind of project-based learning because, these types of learning methods is based on the real world situations and create and design solutions to problems from real world. Other followers of project based learning are problem-based learning and inquiry-based learning (Mustafa, Ismail, Tasir, Said, & Haruzuan, 2016).

In the meantime, while talking about project based learning which is the most overlapping learning method with STEM education, this can be said that project-based learning is a process that has existed for many years. Daily life and disciplines come into prominence by project-based learning. When looking at real life and the world, most things are a combination of many disciplines and integration in the project based learning. Such examples include physiology, biomedical engineering. All are examples of interdisciplinary project based work of education (Honey et al., 2014).

With all these information, there is also the dimension of STEM education in schools, where some problems may arise. Science and mathematics disciplines are separated from other disciplines and engineering discipline could not be seen almost in many schools (English, 2016). All have separate duties. Curriculum documents emphasize that interdisciplinary study process of basic knowledge of STEM is limited (English, 2016). At this point, interdisciplinary study should be more active. However, it is not an easy task to follow the students' personal and unity processes (Honey, et al., 2014; Moore, et al., 2014). Therefore, students and teachers play a very important role. Lately, the number of students who study STEM has been decreasing because the number of qualified math and science teachers also less (Sanders, 2009).

2.3.1. The Role of Teacher on STEM Education

While integrated STEM education study increases, there are some difficulties about implementation of integrated approach of teachers (Zubrowski, 2002). Their approaches depend on national curricula, educational trends, etc. (Zubrowski, 2002). For successful implementation, there should be collaboration between STEM teachers, their interest to integrative approach and administrative support (Zubrowski, 2002).

Here, the classical learning methods are went out and the roles of teachers and students differ. The teacher guides the student in the process. STEM education is a student-centered approach. Therefore, in here teachers' role in student-centered approach is mentioned.

According to Sanders (2009), the mission of teachers is to guide the students and they should be expert about all subjects in STEM and STEM education. The STEM teachers should have field knowledge and knowledge of field education at expert level. Also, they should develop their knowledge share with others (Corlu, 2014). Teacher's role is very important for STEM area. Teachers do not have enough information about this area (Herdem & Ünal, 2017).

Teachers design projects studies and while doing these, they share their knowledge and meet together with other teachers. Also, teachers determined the interested students about these projects and be a guiding (Milli Eğitim Bakanlığı, 2017; Watson & Watson, 2013). Also, teachers should be superior in communication of knowledge, skills and beliefs (Corlu, Capraro, & Capraro, 2014). Also, teachers should provide strong connection between science and mathematics (Corlu, Capraro, & Capraro, 2014). Teachers should design a measurable instructional focus (Basham & Marino, 2013). Teachers have impact on classrooms and this feeds the students' team skills with the collaborative learning practices by teachers (Nite, Capraro, Capraro, & Bicer, 2017).

When teachers teach how to create a project, collaborate and learn by using suitable technology to students, they actually teach not only content of the subject interestingly but also the subjects related to real world to the students (Portz, 2015; Watson & Watson, 2013). According to Portz (2015), science teachers are not enough to teach engineering. According to Basham and Marino (2013), teachers should know how to integrate STEM learning experiences. According to Balsam and Marino (2013), teachers should consider motivation, weakness and strength of people and individuals, abilities when planning the learner's variabilities. They should watch the students. Also, they should keep students' learning at maximum level.

There is an expectation for effective STEM education program. Integration of four components of STEM to curriculum and apply with various teaching methods is not easy to evaluate. Some teaching methods used in the course (problem solving, cooperative learning, subject integration) encourages students to work together to solve real life problems (Meyrick, 2011). Students need to be encouraged to produce new productive connections in two or more disciplines (English, 2016).

In addition to all these, the stress in the components of STEM should be done more for teachers and by teachers. According to Moore et al. (2014), integrated STEM can be less clear in learning. Likewise, according to Shaughnessy (2013) mathematics in STEM should need more transparent and clear because all students cannot see the math in nature of problem. Therefore, many studies should be necessary for transparent and meaningful of connections of STEM in disciplinary ways. Also, when suitable curriculum borders and resources are lacking, new ways should be investigated for teachers to develop these connections.

While teachers meet the STEM concepts to students, they can apply the integration and /or collaboration STEM education (Barakos, Lujan, & Strang 2012; Brown, Brown, Reardon, & Merrill, 2011). Teachers support the engineering designs of K-12 courses that should be developed and understood to develop the studies for better integration (Rockland et al., 2010). That means the most common role of teachers in here is being a guide for students. Also, this can be a guide for all teachers, educators, curriculum developers.

2.3.2. The Role of Students in STEM Education

The student's role in STEM education is not just a listener, as in the classical learning model. Here it is also important to have a good listener. But they also need to play a variety of roles in the process. These are sometimes like engineers, sometimes theater, sometimes designer, sometimes project manager because the basis of the STEM is to assume a role in daily life and to find a solution to the problem.

The roles defined for the students with the guidance of their teacher are as follows; discussion of the given problem with team members and brainstorming on it, searching for new solutions in the process, working in collaboration with the team members, being in contact with the team members, questioning, designing a product that meet the need of the problem in daily life.

2.4. What Features should STEM Education-Based Activities have?

STEM activities are not applied with one discipline. Different disciplines and lessons are put together for STEM activities (Milli Eğitim Bakanlığı, 2017). Also, STEM is not an experiment (Milli Eğitim Bakanlığı, 2017) STEM education based activities should be created by being aware of all of these. Therefore, the characteristics, positive and negative sides, and examples of STEM activities should be emphasized. In following sub-sections, how STEM Education-Based activities differ from other types of activities, what the positive and negative sides of STEM education are, and examples of STEM Education-Based activities are examined, respectively.

2.4.1. How do STEM Education-Based Activities differ from Other Types of Activities?

According to Bybee (2013), STEM Education-Based activities differ from other ones because they focus on global challenges, change the environmental and related problems' perception, identify the 21st century workforce skills and keep going national security topics.

STEM activities are funny, helpful and useful, more enjoyable with group work, enjoyable, more remarkable to be applied, research-oriented, intriguing and attractive, practical, able to study as group, communication-based and collaboration-based, product-solution associated, remarkable, multi-disciplinary approach, creative (MEB, 2018). Also, STEM activities improve visual, auditory intelligence, provide the ability to study by touch, embody abstract problems, add different information, and provide students thinking (MEB, 2018).

According to Thibaut et al., (2018), STEM education and STEM activities have some characteristics. These are integration of STEM content, focusing on problems, inquiry-based, designing, team-work, student-centered, hands-on, assessment, 21st century skills. First one is integration of STEM content. STEM activities are such activities that combine all STEM components. This integration contains multidisciplinary-interdisciplinary approach and content-context integration. There should be curriculum integration focused on related content. It contains many disciplines. It merges two or more content fields (Thibaut et al., 2018). Another characteristic of STEM activities is focusing on problems. It supports problem-based and project-based learning. This project-based learning has some steps as characteristics. They are focusing on problems, using interesting definition and context. Also, problems are from real world and open ended and authentic (Thibaut et al., 2018). Another one is being inquiry-based. At the beginning of the process, there should ask a question. This question is related to daily life problem. Then, doing investigations, collecting and analyzing information follow the process. Therefore, learning with discovery and scientific inquiry is included in the process (Thibaut et al., 2018). Another one is designing a product. This keyword says learning through design-based. In here, engineering design needs designing solutions. Therefore, this presents improving models, opportunity of redesign (Thibaut et al., 2018). Another one is teamwork. Thanks to teamwork, students study with cooperative and collaborative and are also responsible for each other. They develop their communication skills (Thibaut et al., 2018). Another one is student-centered (Thibaut et al., 2018). Another one is hands-on. STEM requires hands on activities and learning process (Thibaut et al., 2018). Another one is assessment. Thanks to assessment, misconceptions and capabilities of students can be determined. Also, their prototypes are analyzed and controlled, therefore; their learning process is controlled (Thibaut et al., 2018). Another one is 21st century skills. Students develop 21st century skills with the STEM activities (Thibaut et al., 2018).

Also, the context in STEM education should be relevant and motivating. Therefore, students can relate it with their personal connections. Students have some roles in the problem and they need to solve this. It develops students' creativity and higher order thinking skills in design process. Students can fail, relearn and redesign. The main points of the lesson should be both math and science also engineering and technology. There should be reading or social studies for STEM lessons at the same time. The lessons contain teamwork and communication skills (Moore, Tank, Glancy, Siverling, & Mathis, 2014a). Also, there are no definite results in STEM activities. STEM activities always have the idea of getting new. Improvisation is at the forefront of STEM activities (MEB, 2019). Students' prototypes are not the final product and are always open to improvement. All these features are presented in Table 2.1.

Table 2.1. *Characteristics of STEM Education-Based Activity*

Characteristics of STEM Education-Based Activity
Integration of STEM dimensions (integration of disciplines), (integration of curriculum) (integration of content-context) (Capraro & Slough, 2013;MEB, 2017; Sahin, 2013; Thibaut, 2018; Wang, Moore, Roehrig & Park, 2011)
Problem-based centered (disciplinary approach (interdisciplinary, multidisciplinary, transdisciplinary)) (open-ended problem) (real-world problem) (Bybee,2013; Capraro & Slough, 2013; Çepni, 2018; Jonassen, 1997; MEB, 2018; Sahin, 2013; Sanders, 2009; Shahali, Halim, Rasul, Osman, & Zulkifeli, 2017; Slough & Milam, 2013; Thibaut, 2018; Wang, Moore, Roehrig, & Park, 2011)
Project-based centered (design-based centered) (product-solution) (hands-on learning &activities) (active learning) (Asghar, Ellington, Rice, Johnson & Prime, 2012; Clark & Ernst, 2006; Çepni, 2018; MEB, 2018; Sahin, 2013; Shahali, Halim, Rasul, Osman, & Zulkifeli, 2017; Slough & Milam, 2013; Thibaut, 2018)
Inquiry-based instruction (Thibaut, 2018; Wells, 2016)
Teamwork (collaborative & cooperative) (communication-based) (Capraro & Slough, 2013; MEB, 2018; Shahali, Halim, Rasul, Osman & Zulkifeli, 2017; Thibaut, 2018)
Student-centered (Guzey, Moore & Harwell, 2016; Thibaut, 2018)
Assessment (Thibaut, 2018)
Research-Oriented (MEB, 2018)
21st century skills (Bybee, 2013; Capraro & Slough, 2013; Thibaut, 2018)

2.4.2. What are the Positive and Negative Sides of STEM Education?

STEM education and STEM activity, like any activity, have both positive and negative aspects.

For positive sides, STEM education is integrated with daily life. STEM provides students to understand the world (Morrison, 2006). Thanks to STEM education, individual can get a chance to relate real world problems and different disciplines (Yıldırım & Altun, 2015). Also, it provides permanent learning because it connects the information met in real life and information learnt previous. Teaching science and mathematics through design prepares the students the challenges of life (Haury, 2002). This brings more memorable knowledge and they start thinking solution-oriented (MEB, 2018). Also, STEM education overlaps with one’s personal curiosity, has model, experiment, etc. construction processes and has theoretical and practical coexistence (MEB, 2018).

According to Portz (2015), integrated STEM education benefits for all students who are not only low level students but also high level students. This side brings students from all levels of learning together. Thanks to STEM education, students can learn the lesson easier (MEB, 2018). STEM education makes information permanent and students learn the subjects with fun (Yıldırım & Altun, 2015).

For negative sides, design is an example of solving problems in real-world but it is a representation (Fortus et al., 2004).

According to MEB (2018), STEM education has some negative sides like having trouble finding ideas, having difficulty in productivity, taking time to do research and reporting findings. Also, it has more verbal knowledge; it has problems finding in problems, returning to hypothesis (MEB, 2018). Also, when integrating the disciplines, all disciplines could not have the same integration density (Thibaut et. al., 2018). Also, some do not using context-based challenge. T (technology) and E (engineering) are not applied correctly in STEM education.

Therefore, problems turn to activities focused on mathematics and science. Thus, people see STEM as a slogan and when applying it in education, there is difficulty (Bybee, 2013). Besides all these, where teachers and students have the most problem is implementation of STEM activity (MEB, 2018). Also, as an indication of this problem, students have difficulty while producing solutions and creating ideas to the problems (MEB, 2018).

The negative sides of STEM can be said as challenges at the same time. For example, many believe that when they give an IPAD to the students, the technology discipline of STEM is actualized (Portz, 2017). This is a situation where precautions and awareness should be created. Except this, there is another handicap as a challenge. Engineers understand the science and math because they learn them in their education. However, scientists and mathematicians could not be the same as engineers because their programs do not have engineering discipline (Portz, 2015). Also, negative side of STEM education is that how to apply STEM integration is unknown by educators, teachers, etc. (Thibaut et al., 2018).

STEM can be easily misunderstood because the reason of this is misinterpretation. That is where some misconceptions occur. Therefore, we can say that these misconceptions create negative sides of STEM. According to Morrison (2006), people think that technology and engineering are separate parts and learnt separately and also, technology means like computers in schools and students. Actually, technology is a product of engineering. Another misconception is that hands on means active learning with the official rules (Morrison, 2006). Actually, STEM requires freedom and re-experience. In the process, students should choose their materials that will be used in the STEM activity unlike other activities. Another one is that laboratory works and scientific method are ignored with STEM (Morrison, 2006). However, according to studied area, laboratory works and scientific method are included in STEM. Another misconception is that all students with STEM educated should choose technical departments because they could not choose other things like liberal art departments (Morrison, 2006). Another one is that math education is separated from science education. Actually, they are complementary fields. Other one is STEM solves only labor problems (Morrison, 2006). Actually, STEM is interested in every real-world problems. Another is that technology education and engineering are different and demanding (Morrison, 2006). Other one is that science and math are not taught by technology education teachers and science and math are not taught by engineers (Morrison, 2006).

2.4.3. Examples of STEM Education-Based Activities

According to Tekbıyık and Akdeniz (2010), in literature, there are some studies about context-based physics problems activities but there is no problem preparation process in them. According to Benckert (1997), there should be some requirements to develop context-based problems. Every problem has a story with a student who should be subject in this problem. Problem should be logical and include a situation that needs to be solved. Every object in problems should be from real life. Problem should not be solved with just one step. More information than needed can give to solve the problem. The variable in problem should not be determined clearly.

Situations encountered from real life, solutions which are different from calculations, organizing data, classifying, noticing relationships and performing some activities in succession of context-based problems are necessary. They are features of context-based problems (Tekbıyık & Akdeniz, 2010).

To create a good context-based problem for STEM activity, there are some requirements. According to Tekbıyık and Akdeniz (2010), appropriate contexts should be determined for students. Then, problem makes feel the relationship between principles of physics and real life. Every problem has a story or scenario with students. In the problem, students should be confronted with a problem that can be solved by using mental skills. The problem should be in real life. Then, the problem should be ended with a qualitative question, but it should be felt that the qualitative problem should be proved quantitatively.

In the line with all these, in order to call an activity as STEM activity, it must have some characteristics. To give some examples of STEM activities we can examine the following context-based situations:

"There are many famous dams throughout the world: the Hoover Dam in Nevada, the Three Gorges Dam in China, and the Aswan Dam in Egypt. Dams have also been constructed since ancient times, some dating back to circa 3000 B.C.! During this project you will design and build a dam that can stand up to the pressure of three gallons of water. You may choose what materials you think would best contain the water, whether you use mud and rocks, as were used in ancient times, or bricks and cement, as are used in modern dams. You will also research and learn the purpose of building a dam, including, but not limited to, positive and negative effects to nature and society, practical uses, and cost. With your research information and the details on how you built your dam and what materials you used, you will put together a short slideshow to present with your finished dam, and we will test the projects together as a class. After testing all of the dams, the class will look at the effectiveness of the materials used in each dam. (DAM Will It Hold?, Lance & Etchells, 2016, p. 81-87)"

The problem gives us *integration of STEM connections*: "Science: Apply the scientific method, Understand hydrostatic pressure, Water conservation, Fluid mechanics; Technology: Proper use of the Internet, Use of presentation technology, Understand ancient and modern dam technology, Technology used to minimize environmental impact; Engineering: Dam construction; Mathematics: Find unknown scientific values, Building a budget" (Lance & Etchells, 2016). Also, there is a real world situation to be expected to be solved. This gives us *problem-based centered* and *project-based centered* situation. How much this dam can withstand the pressure and try to find a solution of this question gives us *inquiry-based instruction* situation. Students can work as a team in this project. This gives us *teamwork* situation. Students can design a dam, therefore, they need to search how to do a dam. This gives us *research-oriented* situation. Also, while searching the information and developing a dam, all these process will be *student-centered*.

In addition, students make use of *21st century skills* (learning and innovation skills, life and career skills, and information and media and technology skills) in doing so. In the process, there is an *assessment* part that students are evaluated under the guidance of the teacher accordance to their work and at the end of the process; students are evaluated in terms of whether their prototypes meet the requirements of the need.

Another example of STEM activity is:

"You and your friends are on a senior trip to Big Bend National Park. After a huge storm hits, you and your friends are left with very few supplies. Knowing that you can only survive three days without water, you begin to dig through your backpack and find random supplies that you brought from home. You realize that you must make a water filter with these supplies in order to make the 45 mile hike to the nearest ranger station. We see it all over the news. Drinking water has become an ever-pressing issue throughout the world. It's important that people are aware of the different techniques that can be used to filter water. Without water, the human body will cease to function. Without clean water, the human body is susceptible to various viruses, bacteria, and diseases. (HEALTHY WATER IS WELL WATER Homemade Water Filtration, Szutkowski, 2016, p. 103-109)"

The problem gives us *integration of STEM connections*: "Science: Understand the chemistry behind water and be able to explain why those properties make it the universal solvent and the molecule of life, The importance of water in biological functions, Understand the effects that potable water versus non-potable water has on eukaryotes, Understand the effects bacteria can have on eukaryotes, Identify the term potable, Identify and quantify causes and effects of uncertainties of measure data, Effectively communicate data to an audience, Use the steps of the scientific method to create a three-dimensional product; Engineering: Use engineering design methodology to understand the different limits of a system, Use decision making in construction of a water filter, Develop skills to manage and assist in the project; Mathematics: Students will use geometry skills to construct their filters by matching up angles and ensuring that all samples of water are required to pass through the filter, Understand relationship between surface area and filter efficiency.” (Szutkowski, 2016). Also, there is a technology discipline that students analyze the given conditions and find a product by searching for different solutions. This is a *technology dimension of integration of STEM connections*. Also, there is a real world situation to be expected to be solved. An event given that happened to the students is analyzed in the context, and this creates a need to solve the problem with a prototype. This gives us *problem-based centered* and *project-based centered* situation. To reach the place 45 miles away, students need to build a water filter because people can stop drinking for up to 3 days. For this, they try to develop a water filter with their limited materials. How a water filter can be done with these limited materials and try to find a solution of this question gives us *inquiry-based instruction* situation. Students can work as a team in this project. This gives us *teamwork* situation. Students can design a water filter; therefore, they need to search how to make a water filter. This gives us *research-oriented* situation. Also, while searching the information and developing a water filter, all these process will be *student-centered*. In addition, students make use of *21st century skills* (learning and innovation skills, life and career skills, and information and media and technology skills) in doing so. In the process, there is an *assessment* part that students are evaluated under the guidance of the teacher accordance to their work and at the end of the process; students are evaluated in terms of whether their prototypes meet the requirements of the need.

2.5. What are the Skills that STEM develops in Teachers and Students?

During the process of STEM, teachers and students gain some new skills and develop existing ones. In here, questioning is center of learning (Morrison, 2006). According to Morrison (2006), students with K-12 STEM educated goes on their education in the line with the world view. Their powers of comprehension are supported with the knowledge, reality and vocabulary (Morrison, 2006). Therefore, the attributes of STEM educated students are problem-solvers, innovators, discoverer, self-reliant, logical thinkers, technologically literate, a STEM bridge between STEM education in school and in workplace, able to connect their own history and culture to their education (Morrison, 2006). According to Yıldırım and Altun (2015), STEM education increase students' critical thinking and creativity. They can get an interdisciplinary perspective. They can relate the pre-knowledge and new ones. They bring them senior thinking. It gives individuals opportunities of designing and creating prototype.

STEM is a type of project-based learning. Thanks to project-based learning, students learn active listening skills. Therefore, their cooperative working and creativity increase. Also, their communication skills, respect for others, and teamwork skills increase (Bell, 2010) because students learn by talking and experiencing. Also, they learn to create an argument and supply enforcing evidence for it (Morrison, 2006). Moreover, their creativity is active because brainstorm keeps it alive (Bell, 2010). Thanks to project-based learning, students learn to evaluate their motivation, performance, interest, productivity. They improve their interactions with others. They can give and get feedbacks (Bell, 2010). Active learning is a part of science (NRC, 1996) and learning with design is a part of life (Haury, 2002). Solving environmental challenges and being successful on these challenges are also (Haury, 2002). Thanks to learning through design, productivity of students increases (Haury, 2002). Thanks to teaching with design, being connectable with daily life, improving critical thinking skills, problem solving skills and decision making process, simplifying active learning, feeding creative thinking and imagination, being a part of content related to technology and society, touch upon several students' learning styles, relating the art, social studies with other areas, and improving science-related dimensions of jobs are mentioned (Haury, 2002). Students and teachers become more individual learners by watching their cognitive levels and emotional and physical engagement (Basham & Marino, 2013).

All for the above substances, problem-solving skills, inquiry-based learning and exploring are also very important for the use of the STEM education. As students work as a team, they do many things together as they carry out the process of solution to make the application finish the test which they are studying. Students' learning levels rise to the highest level because they share the information they have with their teammates and begin to discover new things to bring it to the top (Meyrick, 2011). That means teamwork is a key to get a successful STEM education.

Rockland and his colleagues state that learning activities make learning better and more relevant and engineers in the real world better associate the order they create with these activities (Rockland et al., 2010). For example, most activities in technology classes have the potential to improve students' mathematical literacy (Litowitz, 2009). While mathematically identifying a problem in technological design, students also create and understand advanced solutions. It provides mathematics learning in contexts for mathematics students supported with a well-designed technology education. Thus, cross-disciplinary connection is established (Silk, Higashi, Shoop, & Schunn, 2010). For example, teaching integrated science and engineering also provides space for different content areas to find the environment (Meyrick, 2011). Only the parts of the STEM do not play an important role in integration (Meyrick, 2011). For STEM, the four disciplines are mentioned but their balance is not equal in the process. In STEM education, each discipline must not be used at the same level. Some parts can be looked more in integration. But, all disciplines support and feed each other (Sanders, 2009). Therefore, sometimes science education may be more in the foreground sometimes technology education may be. It also has important roles in communicating reading, writing and speaking for the curriculum. All this creates a broad frame for the learner, and so the person develops the skills versatile (Meyrick, 2011).

According to Meyrick (2011), the inquiry-based learning model allows students to explore information. Supported by NSES (National Science Education Standards), this form of learning is not only limited to critical thinking and reasoning skills in students, but also provides the child with skills to develop research such as a scientist (Meyrick, 2011). According to Sanders (2009), “purposeful design and inquiry (PD&I)” is vital for integrative STEM education because design and scientific inquiry in the outside of the school is used for the engineering of solution of the real world problems.

Students develop social, artistic and contextual skills and combine them with the disciplines of STEM. It improves students' analytical and critical thinking skills. In addition, it develops communication, problem solving skills in students (Capraro, Capraro, & Morgan, 2013; Çorlu & Aydın, 2016; Honey, Pearson, & Schweingruber, 2014). According to Basham and Marino (2013), higher order thinking skills of students increase with understanding the content. According to Mahoney (2010), student attitudes towards STEM education plays an important role in increasing the individual motivation for the needs of students' affective areas.

STEM develops some skills on teachers as well as students. STEM develops teachers' personal characteristics. Thanks to STEM, teachers are more risk takers, open to change, information seeker (El Nagdi, Leammukda, & Roehrig, 2018). Also, STEM develops communication, collaboration and teamwork skills of teachers (El Nagdi, Leammukda & Roehrig, 2018). Moreover, teachers' content knowledge in STEM increases their self-efficacy (Gardner, Glassmeyer, & Worthy, 2019).

2.6. How should a STEM Education-Based Activity Developed?

When the literature was examined in detail, it was seen that heretofore, very few information was given about how the activities which had been developed as STEM activities was developed, and no information was found about the activities being developed with a systematic approach. There is a gap in the literature on this issue; therefore, I tried to be in search of filling the gap. I thought that ASSURE Model, one of the systematic material development methods, could solve this problem and fill this gap. In this part how "a STEM-Education based activity is developed" is analyzed.

There are some steps in which the activities I have developed. To do this, after literature search and I come across the widely used ASSURE MODEL (Smaldino, Russell, Heinich, & Molenda, 2004). It consists of 6 steps, and this model has the necessary steps to develop a basic activity. These steps are to analyze learners, state objectives, select methods, media and materials, utilize media and materials, require learner participation, evaluate and revise. However, since this is a model that can be applied to improve almost any activity, I need to adapt this model to STEM activity. For this, I have integrated some important characteristics of STEM activities which are missing in the ASSURE Model into this model.

The integrated characteristics of STEM activities in the ASSURE model are problem situation, technology-engineering cycle, objectives which should be stated interdisciplinary, product-based situation. That's why I have tried to integrate them into the ASSURE model since these should be in characteristics of STEM activity. I am going to explain what I have done to improve the activity in the contents of these steps. In each step, the first paragraph describes the definition of the step in the model, and the second paragraph describes the sections with integrations related to STEM.

i. Analyze Learners: This step of ASSURE Model relates between the characteristics of the learners and the content of the model. It basically covers three features. The first is general characteristics, the other is specific entry competencies, and the last one is learning styles. General characteristics comprise to describe the features of learners such as age, grade level, job or position, and cultural or socioeconomic factors. Specific entry competencies comprise knowledge, skills, and attitudes about the topic. Learning styles include how the learning environments are perceived, interacted and emotionally reacted by the individual.

According to this step, participants need to be determined. Before determination of the participants, *a context* is needed because STEM activity should have a context. This context should be related to real life. Therefore, a context is added in this model. Also, to give this context to the participants, a *problem situation* is necessary. This problem situation is from real world. After all of these, the participants should be determined according to context and problem for general characteristics, specific entry competencies, and learning styles.

ii. State Objectives: After analyzing participants, on the basis of determination objectives, it is very important for participants to know what to achieve. Therefore, in this respect, it is very important to determine the objectives both for the correct media and material selection for further step, and to help make the appropriate evaluation.

After the determined context, problem situation, and the participants who can be related with this problem situation in previous step, objectives need to be determined. In here, there are learning outcomes that are expected to be realized by the participants. The overlap of the determined contexts with the related grade level is investigated. At this point, curricula are examined for objectives. The *interdisciplinary* feature of STEM is integrated into this step at this point. This feature does not stress a single discipline. In this way, more than one discipline is included in the material development process.

iii. Select Methods, Media, and Materials: According to this step, the systematically chosen methods, media, and materials need to be determined for a systematic plan to use media and technology. In here, there are 3 steps. First one is to decide appropriate method for learning tasks. Second one is to select a media for fulfilling the method. Third one is to choose materials within this media by selecting, modifying, or designing. All these process establish a connection between the participants and the objectives.

According to context and problem, this is a STEM PBL activity. Therefore, there should be *a prototype* in the process because STEM has *product-based* solution. Therefore, it is very important that the selected materials reflect the activity. Therefore, certain criteria can be set in the process. The materials needed to be used by the students are to be easily accessible from real life, inexpensive materials that could be used for different things. Maybe they are made from recyclable or recycled materials. Then, in order to transfer these product-oriented activities to the students in the lesson, the instructional materials which are lesson plans, teacher activity guide sheets, and student activity guide sheets all based on the activity are developed.

ix. Utilize Media and Materials: In here, a learning environment for instructional materials, and materials which students need were created and teachers were expected to implement them in the classroom. Actually this step is based on 5P in itself. They are preview the materials, prepare the materials, prepare the environment, prepare the learners, and provide the learning experience. In preview the materials, teacher should not use the instructional materials without previewing. In prepare the materials, all materials that students need should be ready previously. In prepare the environment, the environment in which students carry out the process of the activity and use the materials should be ready in advance. In prepare the learners, choosing topics, and examples to include students in the activity process, and providing a remarkable introduction to the course can be used to prepare the learners in the activity. In provide the learning experience, instructional experiences are provided to students.

Prepared computers, materials, books should be made ready for students to use and placed in the learning environment. Teacher should organize the students. STEM instructional materials prepared for teachers and students should be included in the process. Students are provided to follow the process with student activity guide sheet prepared for them. They are expected to continue their efforts to create products by following it. Here, they apply their materials using the proposed model to implement STEM PBL Activity the researcher developed for this study.

v. Require Learner Participation: This step requires active mental participation of students and feedback from the teacher. In this process, students need to participate in the discussions among themselves and with the teacher, and participate in the project processes.

In here, every student in the process should participate in the activity. They create a prototype and they must do this in accordance with the *technology-engineering cycle*. Also, this is a cycle and if the prototype does not work or it is needed to improve, the process begins again because technology-engineering requires this improvement process. The steps of this cycle as general and basic steps in the literature are to define, to develop solutions and to optimize. In define step, criteria and constraints of the problem are determined. In develop solutions step, the problem is handled as minor problems to be solved. Therefore, criteria and constraints can be checked easier. At the same time, with these possible solutions, a prototype is created. In optimize step, criteria and constraints are taken into account their priority and prototype is tested. This process continues until the criteria are met.

vi. Evaluate and Revise: What is expected here is to be able to answer questions whether both the objectives in the process have taken place and the participants have used the materials properly. These are expected to be evaluated and revised. In this study, prototype and process are evaluated.

In STEM activities, prototype and process should be evaluated for this step. Whether the prototype meets the criteria and constraints are really important. If the prototype does not meet the criteria and constraints, it is revised and reassessed. Also, in-class performances of the students are evaluated.

2.7. How is a STEM Activity Applied in the classes?

In this section, I am going to review and summarize how STEM activities are implemented in previous studies, and try to identify an implementation method to use in my own study.

When I have looked at the literature review, I have found that STEM activities are implemented in different ways in the classroom. As a result of all these examinations, I have prepared a summary of how the STEM activities are implemented in the classroom, and I have presented them in Table 2.2. Table 2.2. is in Appendix I.

After examining these cycles, I have noticed some deficiencies in these cycles. Therefore, I have decided to develop my own steps of cycle. I have taken advantage of some ready-made processes and steps in creating all these steps. I have also added some steps myself. The steps of some of the existing processes have overlapped. Therefore, I want to explain which ones intersect while taking them exactly. The first step of proposed model is available in the all ready-made processes. Therefore, I have not changed it and used it directly. The second step of proposed model is matched with STEM Cycle (Corlu, 2017) and EDP 1, 7 and 8. The third step of proposed model is matched with STEM Cycle (Corlu, 2017), STEM PBL (Erdogan, Navruz, Younes, & Capraro, 2016), PIRPOSAL (Wells, 2016), EDP 1, 2, 3 and 4. In step four, for developing a prototype, the relationships between objectives and STEM disciplines should be determined and embedded in the activity. The fifth step of proposed model is composed of step 4 (limitations) of STEM Cycle (Corlu, 2017), step 4 (Identifying criteria and specifying restraints) of EDP 1 (ITEA Standards for Technological Literacy 2000/2002/2007), step 4 (Identify Necessary Materials, Resources, and Tools) of EDP 8 (Dankenbring, Capobianco, & Eichinger, 2014). The sixth step of proposed model is matched with Improvisation Process Cycle (Papert, 1993), PIRPOSAL (Wells, 2016) and EDP 1, 2, 4 and 10. The seventh step of proposed model is matched with Improvisation Process Cycle (Papert, 1993), PIRPOSAL (Wells, 2016) and EDP 1, 2, 3, 4, 9 and 12. They are related to best possible solution. I add “best probable solution” to this “best possible solution”. The eighth step of proposed model is in almost all, but as separate step. Therefore, I combine them develop or redevelop a prototype. The ninth step of proposed model is composed of testing and evaluating part. I add “by individual group” to clarify who should perform this step. PIRPOSAL (Wells,

2016) and EDP 1 and 2 are seen as more comprehensive in detail for this step. The tenth step of proposed model is share step and available in all process.

To summarize the integrations made, a step has been added to realize the integration of objectives and STEM disciplines. Develop and redevelop steps have been combined. "By individual group" has been added to the test and evaluation step to make it clear who will carry out it. These changes show that we need a new implementation model. After all of these examinations, I can say that STEM is related to project based learning (PBL). Therefore, I can say STEM PBL because students do research, design a prototype, etc. However, these are the places to be considered when creating this prototype. For this, we integrate all above in the STEM PBL process. After these, I have developed the proposed model to implement STEM PBL Activity in this study. It has 10 steps. They are identify the need, generate ideas/brainstorm, searching for the answer, associate the disciplines, determine the criteria, materials, restrictions, limitations of the problem, examine possible solutions, choose the best possible/applicable/probable/feasible solution, develop or redevelop a prototype, test and evaluate the prototype by individual group, and share. Each of these steps is described below with a paragraph. I have explained what each step means and what to do in each step one by one. In the study, it was explained how this step was tried to be realized.

The first step is to identify the need. There is a problem situation with context in the activity. It is not completely defined in case of a problem, but we should have some clues in problem that can create solution ideas. Also, problems should be from real life.

In addition to this, problems should be ill-defined. They are uncertain. Questions about what you know, what you need to know or how you find answer are asked by these problems. All of these questions present many solution ways because problem is uncertain (Greenwald, 2000). Also, According to Morgan and Slough (2013), ill-defined tasks improve students' motivation and participation. This ill-defined situation brings a product end and this has real-world application

(Sahin, 2013). Also, there are some elements for this. One of them is final outputs of the students. Another one is restriction-limitations to draw the boundaries of the project. The last one is what they learned when they finished the project (Sahin, 2013). Teachers, like engineers, need to design for a known/common/familiar result. Ill-defined task provides teachers all learning skills and design process (Slough & Milan, 2013).

The problem to be examined in this step is very important. According to Johannes (1997), many educators think that problem solving is one of the most expressive and significant way of learning and thinking. According to Johannes (1997), the problems can be classified as puzzle problems, well-structured problems and ill-structured problems. According to puzzle problems, there is one correct solution. Therefore, this is inconsistent with problem solving in real life (Johannes, 1997). In well-structured problems, there is a preferable and predictable solution. It presents all dimensions of the problem. Also, well-structured problems have limited effect to solve the real world problems (Johannes, 1997). Ill-structured problems are the problems that are met in real life. They can integrate many contents. There can be many alternative solutions. Students should describe the problem and determine what information and ability are needed to solve the problem. Therefore, it makes more sense for them. It does not offer a clear path to an appropriate solution (Johannes, 1997).

To give the problem in context-based with the subjects from the curriculum, scenarios are prepared in this study. Scenarios are shared with the students by teachers. Students are expected to examine the scenario and define the need. Then, to solve the problem, they are expected to specify the need.

Actually, since the problem will be an ill-defined problem, the problem should be thoroughly examined. Students are expected to ask themselves the following questions:

-How is the problem defined clearly?

-What are the definitions within the problem?

-What information does the problem give us?

-What are the minimum requirements and criteria in the problem?

Students are expected to answer these questions.

In this step, teacher is a guide. If there are any questions from students, they should be guided by teachers.

The second step is to generate ideas/to brainstorm. Students are expected to generate ideas by sharing ideas with their teammates. This step provides them to share their thoughts about the problem and need by brainstorming. Therefore, during the exchange of ideas, they have the opportunity to learn if they have encountered such a situation before, what they can do if they have met, and each other's experiences and opinions about the problem. Also, they can generate an idea about a solution for this problem. In this step, teacher is a guide.

The third step is searching for the answer. In this step, students are expected to search about the problem and need with Internet in laptops and their grade level MEB physics books. Therefore, they are expected to search the problem and its derivatives with research environments. They are expected to investigate whether the problem has been encounter before and what kinds of solutions and precautions have been taken. They are expected to share their personal idea and then, review common ideas. In this step, teacher is a guide.

The fourth step is to associate the disciplines. Students are expected to associate the disciplines (science, technology, engineering and mathematics). Therefore, they are expected to notice that the problem has not one dimension. Students are expected to determine the concepts of the subjects according to their grade level. Therefore, they are expected to notice how they can follow a solution way. They are expected to detail the problem and subject.

For examples; if the subject in the problem is electric circuits in electricity and magnetism unit (which is an example of 10^{th} grade level unit), students are expected to comprehend the concepts of series circuits and parallel circuits. In this example, the main discipline is science, physics. However, students are expected to specify other disciplines which can be related to this subject. They are expected to associate the science disciplines with technology, engineering and mathematics disciplines.

Here, the teacher makes students aware of the interdisciplinary relationships. Teacher guides the students through the activity process because students may have difficulty in associating different disciplines. For example, if the students have difficulty in interpreting the associations what they find, teacher can suggest that they can draw a mathematical graph to see the relationship. Therefore, teacher guides about the disciplines.

The fifth step is to determine the criteria, materials, restrictions, limitations of the problem. Criteria and restrictions-limitations are necessary to analyze the need and predict what materials are foreseen to the study by students.

To create a prototype, materials, restrictions and limitations of the problem are expected to be determined. Criteria are related to what characteristics the product will have at the end of the design. As an example is how the product looks aesthetically or how many goals have been achieved.

According to Morgan, Moon and Barroso (2013), constraint usually concentrates on limited resources for the project when planning a solution. Restrictions should be met on a simple level and, if not, set to a minimum.

When looking at the materials in here, these materials are just based on research about which materials had been used for related prototype and predictions about foresight of the students in the previous steps. That means that these mentioned materials are not the materials what students will want in later step for their prototype.

The sixth step is to examine possible solutions**.** Students are expected to develop possible solutions through their search and necessitates in step 5. In this step, they are expected to develop solution more than one because the problem is ill-defined that means there is no single correct solution. Therefore, multiple solutions should be developed and examined. Then, students are expected to examine these possible solutions.

The teacher is a guide for students, and if students have difficulty about finding possible solutions, the teacher asks them some questions about features of the prototypes. Thus, students can produce possible solutions.

The seventh step is to choose the best possible/applicable/probable/feasible solution. Students are expected to be able to interpret and analyze the possible solutions they produce under the guidance of teachers. Therefore, among the solutions produced, the one that is most likely to lead them to the result is chosen and is expected to concentrate on it.

After determining the solution, the students are expected to determine dependent, independent, and control-constant variables in the problem. After determination of the variables, students are expected to determine the materials they need according to size and scope of the project (Wells, 1999). After these, students choose their materials and teacher brings the materials to the next lesson.

The eighth step is to develop or redevelop a prototype. Teacher brings the wanted materials by students. After that, students do some inquiry experiments to control and check the dependent, independent and control-constant variables in the problem they were identified in the previous step and the need before developing prototypes. The purpose of doing this is to develop the most possible prototype by observing the effects of the variables on the prototype beforehand rather than creating a direct prototype. Then, students are expected to develop a prototype through chosen most probable solution. Here are the reasons why they are referred to as prototypes. Students may never make the real product. At the same time, whatever the students do, it will always be a prototype, because they will always have a design that can be developed. They are expected to design this prototype in line with their previous thinking and findings, in line with their search, with the materials specified for the students. Here, students are not only provided with the materials determined by students, but also if they want extra materials in process, they are supported by providing them with the materials they want. The redevelop part of this step is that if the prototypes tested and evaluated in the next step do not work, the non-working parts are identified and redeveloped in this step.

The ninth step is to test and evaluate the prototype by individual group. At first, it is checked whether the prototypes meet the minimum requirements and criteria in the problem. If the prototype is working, they can proceed to step 10, share. If they decide to make a correction or add-on without having to investigate the prototype, they should go back the step 8 for redevelop the prototype. If the product does not work, they should go back to determine and correct where the prototype does not work. Therefore, they should go back the step 8 for redevelop the prototype.

The tenth step is to share. Here the prototype is now working and ready to be shared after the prototype meets the minimum requirements and the criteria. This means that the prototype meets the expectations after testing and evaluating. Students are expected to present the prototype to everyone. Also, here, the students will be evaluated according to whether the criteria are met or not. Whether their prototype works or not are taken into account. For this, the criteria used in develop or redevelop, test and evaluate section will be used. Then, teacher determines the first and second group, and explains the reasons why they are the first and the second. These reasons are based on how much the prototypes met the expectations.

2.8. Effects of STEM based Instructions on Students' Outcomes

In Turkey, there is not enough study about STEM activities which are studied with K-12 students so attitudes and behaviors of students on STEM activities should be studied more detailed (MEB, 2018) but when the existing studies in Turkey and abroad were examined, the following results appeared.

“Effects of integrative approaches among science, technology, engineering and mathematics (STEM) subjects on students’ learning” is a meta-analysis (Becker & Park, 2011). This meta-analysis study includes 28 studies. According to Becker and Park (2011), integrative approaches develop students’ learning and interest in STEM. Becker’s and Park’s study (2011) focuses on four questions; “What is the effect of an integrative approach among STEM subjects?”, “How does the effect of integrative approaches among STEM subjects differ by grade levels?”, “What type of integrative approaches is more likely than others to lead to the improvement of students’ achievement?”, “What achievement score among STEM subjects is most improved through integrative approaches?” One of the results from these questions is that integrative efforts in technology education provide learning and teaching context to students (Becker & Park, 2011). Integrative approaches between STEM subjects affect students’ achievement positively (Becker & Park, 2011). Also, according to Becker and Park (2011), the integration types affect the effect of integrated STEM approaches. For example, integrative approaches increase the students’ STEM literacy success with the large effect size. However, there is a medium effect size for science achievement, large effect size for technology achievement and a small effect size for mathematics achievement. According to Becker and Park (2011), integrative approaches between STEM disciplines make STEM education more effective. Also, integrative approaches among STEM subjects have high effect for elementary school level. In another meta-analysis study, according to Nite, Capraro, Capraro and Bicer (2017), the attitudes and perceptions of students who participate inquiry-based activities on STEM are in positive direction. As well as this information, for disabled students, they have more self-efficacy on hands-on STEM activities (Nite, Capraro, Capraro, & Bicer 2017). According to Nite, Capraro, Capraro and Bicer (2017), their purpose is to increase the level of content knowledge of students. For this, their studies show that their enginering design based activities feeds the students’ content knowledge positively. The meta-analysis study of Herdem and Ünal (2017) has different sample groups by using 38 studies. In the study of Herdem and Ünal

(2017), which was formed by teachers in the sample group made to examine the opinions about STEM, they stated that they associate STEM-based activities from the fields of science especially with physics and that they experienced shortage of time and material during the application process. In addition, in some studies, it is seen that teachers do not have enough knowledge about engineering, design and technology (Herdem & Ünal, 2017). According to sample group made by students, STEM education has positive effects on students' academic achievement, attitude, scientific process skills, career awareness and understanding of engineering processes (Herdem & Ünal, 2017). In addition, the attitudes of student and teacher candidates towards STEM were generally positive (Herdem & Ünal, 2017).

Another study is related to measure the attitude of students towards STEM. This is the aim of the Mahoney (2010)'s study. In this empirical study, self-identified STEM based high school program and a conventional college-preparatory program were compared. According to Mahoney (2010), when looking at the gender variable, male students have more positive attitude on content areas of technology and engineering than female students. Another result is that 9th grade students have more positive attitude with mathematics area meaningful than 11th grade students. Also, in another empirical study, according to Yıldırım and Altun (2015), STEM education and engineering application increase the academic achievement. Also, STEM education creates positive attitude about mathematics achievement and mathematics. It has positive impact on scientific process skills and attitude. Also, engineering design based teaching develops teachers' decision making and cognitive process skills.

In STEM activities, according to MEB (2018), students state that the implementation and realization of their ideas make learning easier and they feel free. Students want to study more on STEM activities because they think that STEM activities are more memorable, funny and more lesson-understanding (MEB, 2018). When looking at the attitudes of students about STEM activities (MEB, 2018), students find making design to develop their creativity in lessons, they find STEM activities useful. Also, attitudes towards STEM activities are positive. In particular, students express positive opinion about the design activities in the lessons, technology-based education, STEM activities are beneficial and enjoyable (MEB, 2018). Also, STEM practices improve students' attitudes towards science and self-efficacy (Güneş & Karaşah, 2016). Active participation in science education increased student achievement and positively improved attitudes towards science education (Güneş & Karaşah, 2016). Moreover, according to MEB (2018), students want to apply STEM activities more, they learn the lesson more easily and they want to choose a profession related to STEM in the future. Students are pleased to improve visual, auditory intelligence and provide the ability to study by touch thanks to STEM (MEB, 2018). Students' learning deepens with the real world projects (Bell, 2010). Also, individual strengths and talents of people are used in their works in real world (Bell, 2010).

2.9. Summaries of the Literature Review

STEM, which was introduced as SMET (Sanders, 2009) when it first appeared, has a project-based approach. Although it has different definitions from person to person, from institution to institution, the following definition can be used for it. The STEM is a project-based approach based on the integration of the disciplines of science, technology, engineering and mathematics (Akgündüz et al., 2015; Bybee, 2010; Bybee, 2013; Corlu, 2013; Corlu; 2014; Kennedy & Odell, 2014; Milli Eğitim Bakanlığı, 2016; Moore et al., 2014; Morrison, 2006; Sanders, 2009; Williams, 2011; Yıldırım & Altun, 2015).

STEM, which has an important place in history, actually has the same purpose from the past to nowadays. Its main purpose is to produce a product-oriented solution to a problem encountered in daily life. Basically, there is a search for solutions to the needs of people. STEM is considered important for two reasons today (Zahav & Hazzan, 2017). First, professions based on STEM will be in the forefront in the future. The other reason is that people have to find solutions to the problems they face in daily life (Bybee, 2013; Zahav & Hazzan, 2017). For these purposes, important changes have been made in the education system. This situation was also valid in our country, and a step was taken by publishing a report by MEB in 2016. According to this report, curricula should be renewed.

When we examine the literature, we find resources about what STEM is, what integrated STEM is, and what STEM education is. These resources have a wide area. However, many people, institutions and organizations are doing wrong practices under the name of STEM. In addition to these studies, material development studies related to STEM education has very little area in the literature. There are various deficiencies in existing studies. These deficiencies can be mentioned as follows. There are many features that STEM activities should have. The basis of these is that it contains a context from daily life and is focused on objectives. STEM activities in the literature do not have the features and curriculum integration required in these studies. However, most studies state that STEM provides four basic disciplines. However, while our country has science and mathematics curriculum in high school level, there is no technology or engineering curriculum. Therefore, these activities contain deficiencies and inaccuracies in terms of integration of four disciplines. That is, when it is desired to reach a resource about how the STEM activities have been developed, it is noticed that they have not been developed with a systematic approach. In addition, there are many different implementation cycles having similar and different steps in literature for implementation of existing activities. However, there are deficiencies about the integrations associated with the features of STEM in these implementation cycles.

CHAPTER 3

METHODOLOGY

In this chapter, research design, subject of the study, procedure, instructional materials, context-based problems, lesson plans, teacher activity guide sheets, student activity guide sheets, data collection instruments, interviews, observation form, validity and reliability, validity and reliability of the research design, and validity and reliability of data collection instruments are discussed.

3.1. Research Design

The aim of the study is to identify and revise the problems in understanding and implementing the 3 STEM Project-Based Learning activities by providing training to participants that the researcher developed these activities. Research and Development (R & D) is chosen for the aim in this study. In the definitions of the terms in R & D, research is a process that provides new information, and development is a process of obtaining new products using the information obtained (Bock, 2001). This research type contains systematic and creative work with the knowledge to develop new applications by following human needs, culture and public (OECD, 2015). R & D activities should have the following characteristics: novel, creative, uncertain, systematic, transferable and/or reproducible. In R & D activities, these five criteria are met, at least in principle, continuously or occasionally.

In order for a R & D activity to be novel, new knowledge adapted to different contexts is required. In order for a R & D activity to be creative, it must have objective new concepts and opinions that develop existing knowledge. In order for a R & D activity to be uncertain, time, cost, kind of outcome of a R & D project cannot be exactly concluded. In order for a R & D activity to be systematic, process of R & D should be carried out in a planned manner. In order for a R & D activity to be transferable and/or reproducible, R & D transfers and uses of new information and uses of the results of the studies by other researchers in their own studies, and if the hypothesis does not work or the product does not work as intended, R & D should include processes such as redevelopment. In here, if the prototype fails, a feedback loop can be used to further develop this prototype. This means that R & D enters into an iterative process (OECD, 2015).

According to OECD (2015), R & D contains three types of activity which are basic research, applied research and experimental development. Basic research is to gain new knowledge about the fundamentals of observable facts and to make experimental work without using them in an application or use. Applied research is a research conducted to obtain new information especially for a specific purpose and objective. Experimental development is a systematic study aiming to produce new products and processes by using the information obtained from the researches and experiences, or to improve existing products and processes. This study is an experimental development study. The experimental development is not clearly a product development study. It refers to a process through which various processes and trials are conducted to successfully develop the desired product.

3.2. Subject of the Study

Participants in the study were 18 9^{th} grade high school students. These participants were from KDZ. Ereğli district of Zonguldak, and they were selected from 93 applicants. The following describes how the researcher selected participants.

A form was created on the Internet to identify the applicants (Appendix E). This form included basic information of applicants (name-surname, school name, age, telephone number) to reach the applicants. It also included other information LGS "Lise Giriş Sınavı (High School Entrance Exam)" success ranking, middle school graduation average, grade of middle school science lesson in report card which included their success in order to select participants. This form was made available to the applicants via Internet.

In order to deliver this application form to the applicants, the teachers who are district physics department heads were first reached via an Internet platform were present. Therefore, every public school and private school in Kdz. Ereğli could have knowledge about this study. In this platform, an announcement text and a link about the application form (Appendix E) which was shared with the teachers. Therefore, students could reach this form link via their teachers. Then, the teachers shared this announcement and the link with the students. Following this, student applications started to come. This phase lasted approximately 1 month. The researcher was able to view and evaluate the applications via this form on the Internet. Subsequently, the researcher began to analyze the information of the applicants. Then, the researcher reached the chosen the participants for the study. The researcher telephoned with the chosen participants. The researcher gave pre-information to participants about who the researcher is, what the study is related to, the process of the study, timing of the study (2 days), place of the study, starting time.

Three activities were developed in the study. For every activity, there were two groups. Every group has 3 participants. Therefore, the number of students participating in each activity was 6. Therefore, the participants of the study were 18. Each participant took part in only one activity. The researcher formed the groups by trying to create a heterogeneous distribution. These participants were selected according to the LGS achievement ranking in the application form (according to the achievement score they stated when completing the form). Apart from this score type, middle school graduation average and grade of middle school science lesson in report card information was requested from the applicants; however, since the notes written on the application form and not corresponding with the relevant scores type were encountered, the researcher preferred to use LGS achievement ranking instead of these score types. Groups were formed with one low, one medium and one high successful participant in each group. Based on the distribution of the applicants, the success score range could be acceptable between 250-350 low, 350-450 medium and 450-500 high.

Thereafter, for each activity two high-successful, two medium-successful and two low-successful participants were selected according to the specified range of points. The characteristics of the applicants and the participants are explained detail in the following parts.

Gender Distribution of the Applicants by Number and Percentage, Age Distribution of the Applicants by Number and Percentage, and LGS Success Score Distribution of the Applicants (analysis of these sections lasted for 1 week) are as follows. The number of the applicants was ninety-three. Fifty-two of them were male and its percentage was 56%. Forty-one of them were female and its percentage was 44%. Gender Distribution of the Applicants by Number and Percentage is shown in Figure 3.1. Particular attention was paid to the distribution of gender of the participants. The distribution was balanced to include 3 female and 3 male participants in each activity. Therefore, for three activities, there were 9 female and 9 male participants. Their percentage is equal to each other. The Gender Distribution of the Participants by Number and Percentage is shown in Figure 3.2. The researcher tried to balance the number of private and public school students in groups. In study, there were 15 applicants from private schools and 78 applicants from public schools. There were 8 participants from private schools, 10 participants from public schools.

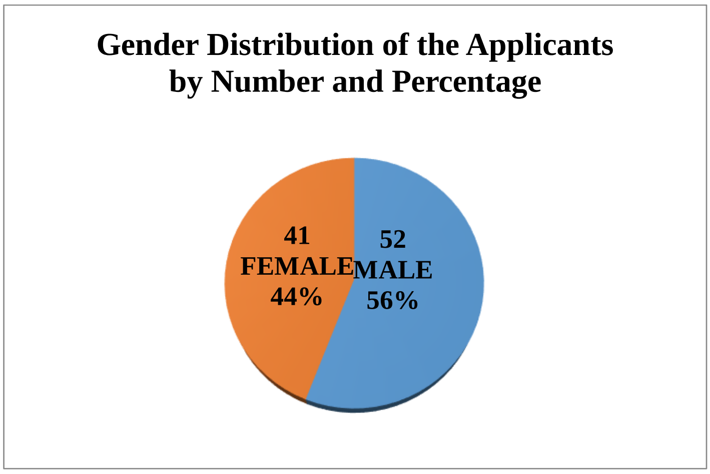

Figure 3.1. Gender Distribution of the Applicants by Number and Percentage

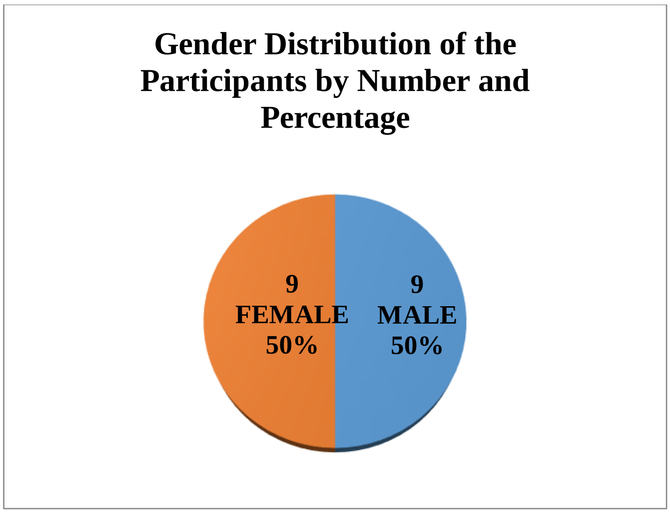

Figure 3.2. Gender Distribution of the Participants by Number and Percentage

The ages of the applicants were 14 and 15. There were 73 applicants whose age was 14, and its percentage was 78%. There were 20 applicants whose age was 15 and its percentage was 22%. Age Distribution of the Applicants by Number and Percentage is shown in Figure 3.3. The ages of the participants were 14 and 15. There were 16 participants whose age was 14 and its percentage was 89%. There were 2 participants whose age was 15 and its percentage was 11%. The Age Distribution of the Participants by Number and Percentage is shown in Figure 3.4.

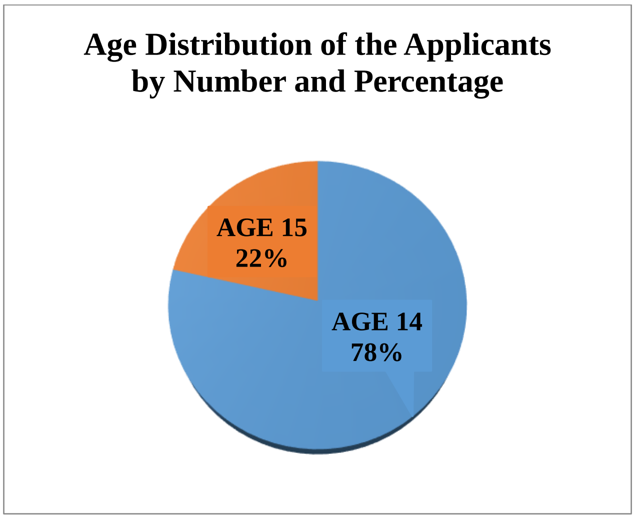

Figure 3.3. Age Distribution of the Applicants by Number and Percentage

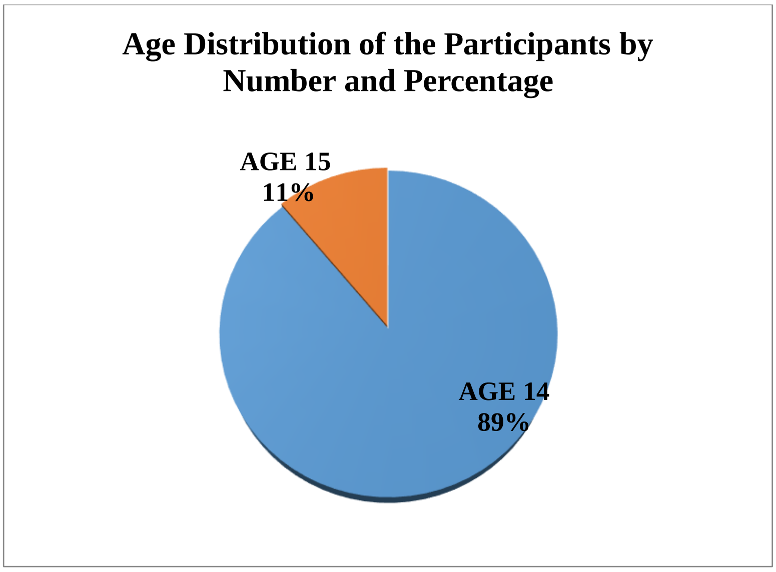

Figure 3.4. Age Distribution of the Participants by Number and Percentage

According to the 2019 LGS Success Scores, the range of points that applicants can take is between 0 (zero) and 500 (five hundred). LGS Success Score Distribution of the Applicants to this study is shown in Figure 3.5. Standard deviation value of LGS Success Score of the applicants was 63.36. According to the 2019 LGS Success Scores, LGS success score distribution of the participants to this study is shown in Figure 3.6. Standard deviation value of LGS success score of the participants was 72.48. Although the ranges in the sample and in the population are approximately the same, few numbers of students in the sample may have caused this difference.

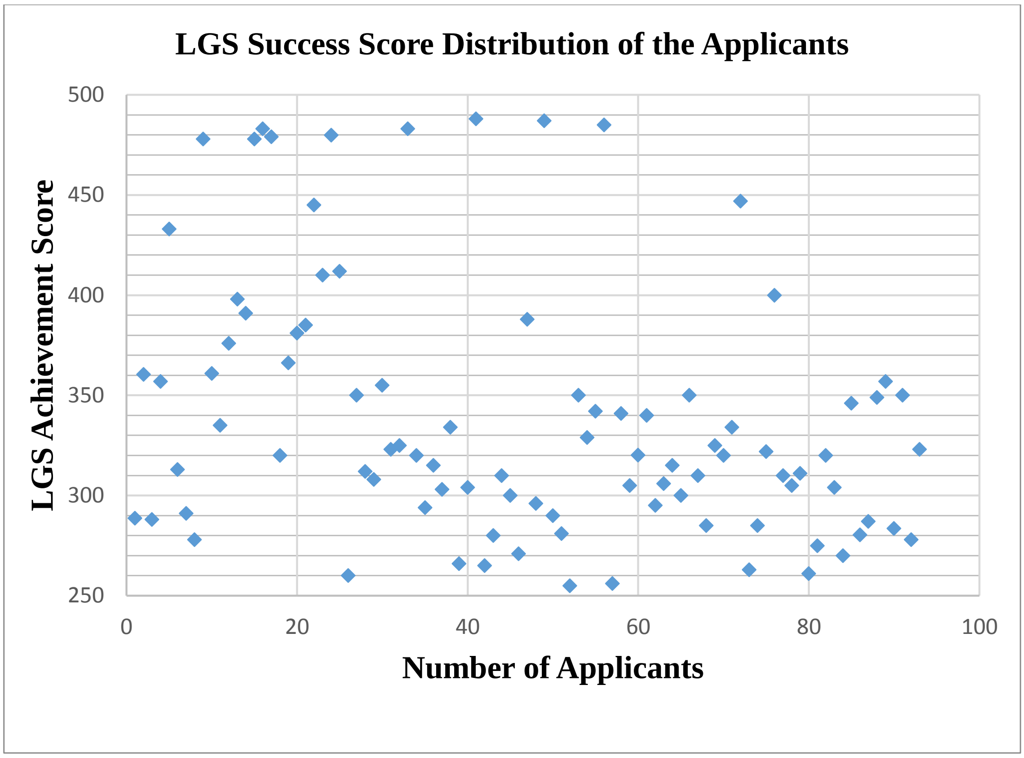

Figure 3.5. LGS Success Scores Distribution of the Applicants

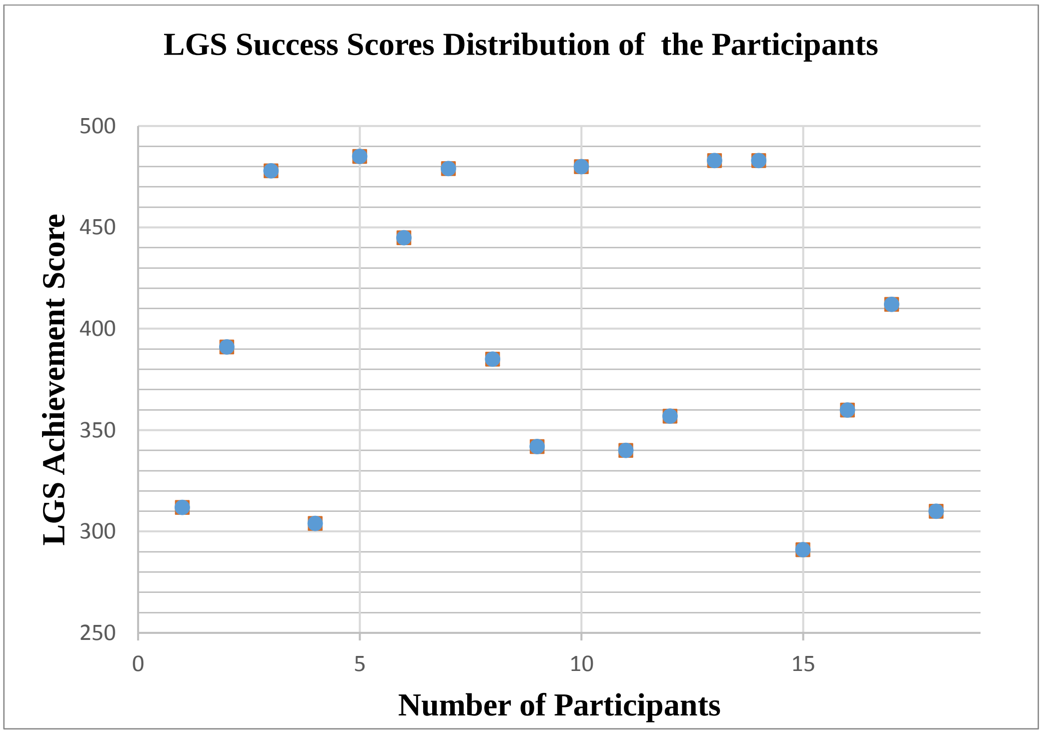

Figure 3.6. LGS Success Scores Distribution of the Participants

After all of these rationales, the groups were formed. Then, a physics teacher was needed as a guide to this study. The researcher talked to two physics teachers in KDZ. Ereğli. Then, the researcher decided the physics teacher according to their interest and leisure time. Also, the characteristics of this teacher were important. One physics teacher from a public high school participated in the study and instructed the both groups in the activities. The teacher was male. He has 16 years of work experience and a master's degree in high energy and plasma physics. Teacher teaches at all high school levels in a school. Also, the researcher was an observer in the activities, but, when appropriate, the researcher guided and directed the students in support of the teacher. All students in the group were taught with a project - based learning (PBL) method with STEM education.

3.3. Procedure

The procedure followed beginning of the research study to the end of the thesis writing is explained below. The process was planned with timing-scale. The following steps in the process are below.

- Determination of the research problem
- Determination of key words
- Literature review through the key words
- Reading the hardcopy and softcopy sources from the literature review
- Preparation of outline
- Determination of population and sample
- Determination of objectives through curriculums
- Writing the context-based problems
- Development of instructional materials (lesson plans, teacher activity guide sheets, student activity guide sheets)
- Development of data collection instruments (semi-structured interviews with the teacher, semi-structured interview with the students, observation form)
- Pre-pilot study of instructional materials (just thermos activity)

- Teacher training
- Application of instructional materials (Pilot study)
- Implementation of data collection instruments
- Revision of instructional materials
- Writing thesis

The steps are explained in the following paragraphs. After the research problem was determined, the researcher determined the keywords. The keywords are STEM, Integrated STEM, STEM Education, STEM Activities, STEM Project-Based Education Activities. The keywords were searched in literature review. The databases which were used in the research are Web of Science, Google Scholar, ERIC, METU Library Theses and Dissertations, ProQuest.

After literature search, the sources were examined in detailed. Every source in literature was examined throughout in terms of its contribution to this study. This literature search of the study lasted approximately 9 months. Development process of an STEM education material involves some steps. After that, the researcher prepared the outline which is a skeleton of this thesis. This preparing outline of the study lasted approximately 3 months. First of all, a comprehensive literature review was sought to answer the following questions:

-What is STEM?

-What is Integrated STEM?

-What is STEM Education? (The Role of Teacher in STEM Education and The Role of Student in STEM Education)

-What Features should STEM Education-Based Activities have? (How do STEM Education-Based Activities Differ from Other Types of Activities? What are the Positive and Negative Sides of STEM Education? and Examples of STEM Education-Based Activities)

-What are the Skills that STEM Develops in Teachers and Students?

-How should a STEM Education-Based Activity Developed?

-How is a STEM Activity Applied in the classes?

-Effect of STEM based Instructions on Students' Outcomes

These questions are answered in Chapter 2 underneath a separate title. Participants in the study were chosen according to the problem. They were 18 9th grade high school students. The distribution among the number of the participants was chosen so that the number of female and male was equal to each other. They were from the public and private high schools in Karadeniz Ereğli. Three activities were developed in the study. For each activity, there were two groups. Each group has 3 participants. Therefore, the number of students participating in each activity was 6. The groups were as heterogeneous as possible. The application process of the participants and selection process for the study took approximately 5 weeks.

The objectives related to the problem were determined. For this, at first, High School Physics Course Curriculum (MEB, 2018) was examined. Related objectives were chosen. Then, mathematics objectives from the High School Mathematics Course Curriculum (MEB, 2018) were examined. In high school level, there were not enough objectives related to the problem, so the researcher examined the Primary and Middle School Mathematics Course Curriculum (MEB, 2018). The related objectives were chosen. After, for technology and engineering, there is no separate curriculum. Therefore, the researcher examined the technology-engineering cycles. The researcher determined technology and engineering objectives from the Engineering Design Cycle of NGSS Lead States (2013). In addition, the researcher chose some of the objectives from the High School Visual Art Course Curriculum (MEB, 2018). Also, 21st century skills (Partnership for 21st Century Skills, 2010) were determined. This section was conducted in detail for each of the 3 activities in the study and lasted approximately 2 weeks in total.

After all this process, for instructional materials' development, the researcher wrote a context-based problem for each lesson plan. These context-based problems were related to real-life and ill-defined, and were supported by a visual related to the problems. In this process, the researcher prepared a lesson plan for each activity. Then, the researcher developed teacher activity guide sheets to guide the teacher, and student activity guide sheets to guide the students in the classroom. Then, in addition to these, expert opinion was received by at least one expert for each instructional material of each activity. These views were analyzed between the researcher and the supervisor, and all lesson plans (see Appendix A.1. for the Pilot Study of Heat and Temperature Activity), teacher activity guide sheets (see Appendix A.2. for the Pilot Study of Heat and Temperature Activity), and student activity guide sheets (see Appendix A.3. for the Pilot Study of Heat and Temperature Activity) were revised. This section of the study took approximately 3 months in total for each context-based problem, lesson plan, teacher activity guide sheet and student activity guide sheet to be written (see Section 3.4. in this Chapter).

Then, the researcher developed semi-structured interviews for teacher and students, and observation form as data collection instruments. This section of the study took approximately 2 weeks (see Section 3.5. in this Chapter).

After that, the researcher made a preliminary implementation (pre-pilot study of instructional materials) before the actual implementation of the activity (Pilot study). This study was done for only thermos activity. This study went on for four days. For this, the implementation place was the researcher's workplace, a private high school. Thus, the researcher tried to identify problems in other activities in advance. Later, thanks to the observations and feedback in the applied activity, the researcher revised the applied activity (thermos activity) and fore coming activities (toy car activity and table activity). This section of the study took approximately 2 weeks.

Then, teacher training was done. For each activity, hand-out all materials were given to the teacher. However, the basic material here was the lesson plan because it has more detail information than the teacher activity guide sheet and the student activity guide sheet. When the teacher started to examine the lesson plan, the researcher told the teacher what the teacher should do in the process, and they analyzed the lesson plan together. Therefore, how the teacher would benefit from the lesson plan and which order the teacher would follow were examined. The researcher and teacher studied on the activity together for approximately 1 hour for each activity. In this section, the views and sharing of the teacher for the activity were taken into consideration.

Subsequently, the researcher carried out the pilot study. This process was carried out with 6 students and 1 physics teacher for each activity. In here, every participant attended only one activity, but the teacher attended all activities. The purpose of this process was to identify and analyze the problems in the process of applying materials, and then revise the materials. The researcher planned the timing of the studies according to objectives in curriculum and interdisciplinary characteristic of STEM. Also, the researcher divided the activities to be concluded in 2 days. The toy car and table activity had been divided into two consecutive days and completed; the thermos activity had been divided into two days with one day apart and completed. The researcher prepared one lesson plan, one teacher activity guide sheet, and one student activity guide sheet for each activity. During the implementation, the researcher made observation for each activity. The execution of each pilot study is divided into two days and a detailed timing is available in the lesson plans. The iteration process of Research and Development (R & D), which started with the implementation of thermos, toy car and table activities respectively, had been carried out in this study. Points where problems were detected with the implementation of thermos activity were revised in toy car activity. The points where the problem was detected with the implementation of the toy car activity were revised in the table activity.

In each activity, the researcher was a guide to students. According to Martin-Hansen (2002) form NSTA, there are four types of inquiry. They are open or full inquiry, guided inquiry, coupled inquiry, and structured inquiry. This study was based on guided inquiry because the researcher and the teacher directed the students with questions. The researcher led the way through their research.

After implementation of each activity, the researcher did an interview with the teacher and an interview with the students. Each interview was conducted separately with the teacher and the students separately. The interview with the teacher lasted approximately 30 minutes for each activity. The interview with the students lasted approximately 20 minutes for each activity. Interviews with the students were done in focus groups.

After the implementation of instructional materials and implementation of data collection instruments, the researcher revised the instructional materials (activities) according to observations, feedbacks, comments, interviews in this process. This part of the study lasted 2 weeks. After that, the researcher wrote the results of the study and concluded the thesis. This part of the study lasted 2 weeks.

3.4. Instructional Materials

Context-based problems, lesson plans, teacher activity guide sheets, and student activity guide sheets are explained in this section. All of these had been developed according to ASSURE Model (Smaldino, Russell, Heinich, & Molenda, 2004). ASSURE Model is an instructional material development model. Assure Model has 6 steps. They are analyze learners, state objectives, select methods, media, and material, utilize media and materials, require learner participation, and evaluate and revise. Some characteristics of STEM PBL activities were added into this model (see Section 2.6 in Chapter 2). The researcher developed STEM Project-Based Learning activities by using ASSURE Model revised for this study and followed this order.

The first step of ASSURE Model is analyze learners. In here, participants need to be determined. Before determination of the participants, a context and a problem should be determined. STEM activity should have a context. Therefore, the researcher had chosen a context from real-life. There was a problem situation in this context the researcher had chosen. When choosing this context, the researcher thought that 9^{th} grade students might be interested in this context. The researcher had tried to make sure that the students the researcher would choose for the activities were 9^{th} grade and from all success levels.

The second step of ASSURE Model is state objectives. In here, objectives related to the participants need to be determined. Since the researcher knew the 9^{th} grade content of High School Physics Course Curriculum (MEB, 2018), the researcher thought that this context could overlap with 9^{th} grade subjects.

Therefore, the researcher had specifically examined and determined objectives in the 9th grade current High School Physics Course Curriculum (MEB, 2018). But since the problem the researcher had identified must be interdisciplinary, the researcher had also examined the curricula of other disciplines that the researcher could relate to the problem. As a result of these studies, the researcher had chosen some objectives from 9th grade content of High School Mathematics Course Curriculum (MEB, 2018) and 7th and 8th grade content of Elementary Mathematics Course Curriculum (MEB, 2018). Also, the researcher had chosen some objectives from the technology-engineering cycle (NGSS Lead States, 2013). In addition, the researcher had chosen some of the objectives from the High School Visual Art Course Curriculum (MEB, 2018). The researcher had determined 21st century skills (Partnership for 21st Century Skills, 2010). Since these objects should be integrated as much as possible, the researcher had tried to relate the objectives to each other.

The third step of ASSURE Model is select methods, media and material. In this step, there is a material determination section in order to establish a connection between the participants and the objectives. According to the context and the problem, this was a STEM PBL activity. Therefore, there should be a prototype in the process because STEM has product-based solution. For this, the researcher had made sure that the materials the researcher had chosen were the ones that reflect the activity. Therefore, the researcher had tried to set certain criteria. The materials needed to be used by the students were to be easily accessible from real life, inexpensive materials that could be used for different things. Maybe they were made from recyclable or recycled materials. Then, in order to transfer these product-oriented activities to the students in the lesson, the researcher developed instructional materials all based on the activity; lesson plan, teacher activity guide sheet and student activity guide sheet.

The fourth step of ASSURE Model is utilize media and materials. In here, a learning environment for instructional materials, and materials which students need were created and teachers were expected to implement them in the classroom. In this study, the researcher had ready my classes and materials. The researcher had placed 2 laptops and 2 MEB 9^{th} grade physics books for 2 groups in the class. In this way, the students could do research if needed. After preliminary search and preparation of materials, the researcher had placed them in the classroom. The researcher had organized the class where the students would work. Thus, the researcher had provided the students with a learning experience. In addition, student activity guide sheet was given as an instructional material to students, and they were expected to continue their efforts to create products by following it. Here, they applied their materials using the proposed model to implement STEM PBL Activity the researcher developed for this study.

The fifth step of ASSURE Model is require learner participation. This step requires active mental participation of students and feedback from the teacher. Therefore, the technology-engineering cycle was included in the process in order to provide both mental and physical activity of the students. In here, every student in the process should participate in the activity. They create a prototype and they must do this in accordance with the technology-engineering cycle.

The sixth step of ASSURE Model is evaluate and revise. What is expected here is to be able to answer questions whether both the objectives in the process have taken place and the participants have used the materials properly. These are expected to be evaluated and revised. In this study, prototype and process were evaluated. Whether the prototype met the criteria and constraints were really important. If the prototype did not meet the criteria and constraints, it was revised and reassessed. Also, in-class performances of the students were evaluated. Also, the problems identified in the instructional materials were revised.

The context based problems, the teacher activity guide sheets and the student activity guide sheets are detailed in sub-sections.

3.4.1. Context-Based Problems

The researcher determined the objectives and sample of this study. Then, the researcher focused on the selected objectives, subjects and examples encountered in daily life. In this process, an attempt was made to develop an activity from almost three physics unit of 9^{th} grade.

Later, the researcher wrote a context based on daily life for these problems. All these problems should be ill-defined (Greenwald, 2000). While writing context-based problems, the researcher first attempted to draw attention to the search for solutions to a problem from everyday life. In doing so, the researcher tried to define the context-based problem quite well. The researcher gave information that could help the participants in the problem. In doing so, the researcher drew a framework for the problem by mentioning certain requirements. However, the participants were not given a single correct path to the solution sought. Their solution to the problem has created a different and acceptable situation for everyone. The problem was ambiguous and the researcher did not accept the solution as the only correct way. In here, problem has many solution ways, not just one correct solution. All problems were prepared accordingly. All problems were integrated into the lesson plans by expert opinions (see Appendix B.1, Appendix C.1, Appendix D.1 for the revised context-based problems).

3.4.2. Lesson Plans

After the context-based problems developed, the researcher prepared lesson plans related to these problems. Within the lesson plan, the objectives were integrated depending on the problems. In addition, after a comprehensive literature review of what steps this lesson plan would be applied in the classroom, the researcher developed the proposed model to implement STEM PBL Activity in this study and integrated the lesson plan into it (see Section 2.7 and 2.7.1. in Chapter 2 for these steps). This model has 10 steps. Thus, in each step, it was stated what the teacher should say and do in the classroom. In addition, the questions to be asked during the lesson and the answers expected by the students were detailed (see Appendix B.1., Appendix C.1., Appendix D.1. for revised lesson plans).

3.4.3. Teacher Activity Guide Sheets

After developing lesson plans, the researcher developed teacher activity guide sheets for each lesson plan. In addition to the lesson plans, there are instructions to help the teacher during the application in class in these sheets (see Appendix B.2, Appendix C.2, Appendix D.2 for revised teacher activity guide sheets). These instructions do not include the answers expected from students as in the lesson plan. The teacher activity guide sheet can be said as a brief summary of the lesson plan, but its content is adequately prepared so that a teacher can carry out the activity during the lesson. These sheets include the questions asked by the teacher during the lesson and the steps to be followed.

3.4.4. Student Activity Guide Sheets

After developing lesson plans and teacher activity guide sheets, the researcher developed student activity guide sheets for each lesson plan and teacher activity guide sheet. These sheets contain instructions for students to follow the course easily in class (see Appendix A.3, Appendix B.3, Appendix C.3 for revised student activity guide sheets). These student activity guide sheets do not include objectives, implementation steps, and answers expected from students. This sheet contains the situations which are expected to do by the students in order and the questions asked by the teacher.

3.5. Data Collection Instruments

According to Creswell (2009), there are 4 types of qualitative data collection. They are observations, interviews, documents and audio-visual materials. According to Yin (2011), there are 4 types of data collection methods. They are interviewing, observing, collecting and examining, and feeling.

In this research, semi-structured interviews and classroom observation form were used. Details of these instruments are discussed in the following sub-sections.

3.5.1. Interviews

Semi-structured interviews were conducted with the students and the teacher in order to analyze the perception and experiences of students and teacher. Seven questions were asked to the students about the content of the activity and their experiences in the process. Because of time limitation, it was decided to conduct a group interview with the students after each activity. Semi-structured interviews were done with 18 students. Interviews with students were done place after the activities they attended with their own activity study groups. The teacher was asked 11 questions about teaching methods used in his own lessons, the content of the activities, the revisions of the activities and his experiences in the process. The interview with the teacher was made after the activities finished. Both interviews were held once separately after each activity finished. The interview with the teacher lasted approximately 30 minutes for each activity. The interview with the students lasted approximately 20 minutes for each activity. Interview questions for both students and teacher are given in Appendix F and Appendix G, respectively. The results obtained from these interviews are presented in Chapter 4.

3.5.2. Observation Form

In this study, there was one observer. Observer was the researcher of this study. Classroom observation form had 15 items which were 4 items for at the beginning of the lesson, 8 items for during the lesson, and 3 items for at the end of the lesson to observe the dynamics between the lesson, the teacher and the students. These items were related to guidance of teacher, directing questions, objectives which were achieved or not correctly. If these items are realized, the researcher puts tick the items; if these items are non-realized, the researcher puts cross the items. Also, in this form, there is a “Situations for your Observations” section. In this section, there is an area where the researcher can write what the researcher observes about the realized and non-realized situations, and unplanned and/or unforeseen situations. This form is completed once for each activity, and since the activities are divided into two days, the rest of the form after the first day is completed on the second day. Classroom observation form is given in Appendix H. The results obtained from this form are presented in Chapter 4.

3.6. Validity and Reliability

According to Frankel, Wallen and Hyun (2011), validity mentions the appropriateness, meaningfulness, and usefulness of the inferences based on researchers' collecting data. Reliability mentions the consistency of these inferences on location, conditions and time.

3.6.1. Validity and Reliability of the Research Design

According to Lincoln and Guba (1985), there are 4 criteria of trustworthiness. They are credibility for internal validity, transferability for external validity, dependability for reliability, confirmability for objectivity. All these criteria have some techniques inside. The techniques of credibility are prolonged engagement, persistent engagement, triangulation (sources, methods, and investigators), peer debriefing, negative case analysis, referential adequacy (archiving of data) and member checks. The technique of transferability is thick description. The techniques of dependability are overlap methods (triangulation of methods), dependability audit. The technique of confirmability is confirmability audit. In this research, for credibility (internal validity), prolonged engagement, permanent engagement, triangulation were used. For transferability (external validity), thick description was used. For dependability (reliability), dependability audit was used. For confirmability (objectivity), confirmability audit was used.

According to Sullivan (2013), to figure out a problem, there are various ways, in engineering. One of them is the iterative design process. Iterative design process is one of various ways utilized in new product development. Iterative design is better for little R & D studies. Design and prototyping are integrated to each other thanks to the iterative model. Describing requirements, developing a prototype, testing the prototype, getting feedback and then heal the requirements and redevelop the prototype are parts of the iterative model. The purpose of these steps is to determine the problems and corrections that may be encountered and to make corrections by verifying the design.

3.6.2. Validity and Reliability of Data Collection Instruments

According to Frascati Manuel (OECD, 1994), Research and Experimental Development (R & D) involves systematic progress to ensure that the knowledge and culture of people and society is used to develop new applications. According to García-Valderrama and Mulero-Mendigorri (2005), the high level of uncertainty in R & D studies does not allow accurate measurement which can be done completely.

According to García-Valderrama and Mulero-Mendigorri (2005), content validation provides a measurement of validity of a study. Content validity has 4 steps. First one is to determine the area of acceptable observations, determine the experts related to the area, taking expert opinions related to this area, apply a procedure to summarize the previous step (García-Valderrama & Mulero-Mendigorri, 2005).

Validity is very important for data collection instrument. The literature review was conducted as the beginning of all these processes, after development of data collection instruments, expert opinions were obtained for each instrument. Then, each instrument was revised. In our study, these processes were tried to be followed.

CHAPTER 4

RESULTS

In the first section, the results of the first activity (thermos activity) are given. The next section contains the second iteration with second activity, which is related to the results of the toy car activity. Following these, the third iteration with third activity, which is related to the results of the table activity is detailed. Then, the summaries of the results are detailed.

The purpose of following this order in this way is to be able to answer the problem sentence. The aim is to determine where the activities do not work and where they work, and to revise the non-working parts. For this purpose, in all 3 activities, the researcher elaborated the first activity step by step using the proposed model to implement STEM PBL Activity in this study (see Section 2.7 in Chapter 2 for these steps), which is developed by the researcher in this study, and consists of 10 steps. What is expected and what is encountered in these steps are detailed. These evaluations and examinations were based on the opinions of the students and teacher based on interviews (see Appendix E and Appendix F), observations (see Appendix G), and evaluations of the researcher based on the activity processes. In this section, the parts that the points with problems and without problems encountered in each step have been examined in detail. In other words, if the problem is not observed in one step of an activity and the problem is observed in the same step of the next activity, it explains why the problem was observed in the same step of this activity and how it was revised. Also, if the problem is observed and revised in one step of an activity and the problem is not observed in the same step of the next activity, it is explained why the problem is not observed in the same step of this activity. In other words, the problems observed in the activities were identified, the reasons of these problems were detailed, and these problems were revised for the next activity. This section, which was revised in the next activity, is mentioned and it is detailed whether it works together with the revision.

Each activity was carried out in two groups of three with a total of 6 students. Six different students took part in each activity. Student attending an activity did not attend another activity. The total number of students participating in the three activities is eighteen. A physics teacher who had not previously involved in any STEM activity participated in the study. The same physics teacher took part in all activities. The teacher guided the students in whole activity processes. The researcher took part in the study as an observer. Throughout the study, the researcher provided support to the teacher and guided the students from time to time, especially if the teacher needed help in the process. After implementation of each activity, the researcher did an interview with the teacher and an interview with the students. Each interview was conducted separately with the teacher and the students separately. The interview with the teacher lasted approximately 30 minutes for each activity. The interview with the students lasted approximately 20 minutes for each activity. Interviews with the students were done in groups. The data that emerges according to the results of the observations of the researcher, the results of the interviews with the students, the results of the interviews with the teacher is integrated into the relevant steps. While integrating, these expressions "as a result of the classroom observation of the researcher", "as a result of the interview with the students" and "as a result of the interview with the teacher" are used in relevant steps.

4.1. First Activity (Thermos Activity)

This activity is detailed according to 10 steps of the proposed model to implement STEM PBL Activity. The steps of this model are identify the need, generate ideas/brainstorm, searching for the answer, associate the disciplines, determine the criteria, materials, restrictions, limitations of the problem, examine possible solutions, choose the best possible/applicable/probable/feasible solution, develop or redevelop a prototype, test and evaluate the prototype by individual group, and share. In each step, what was expected, what had been observed and if necessary, revision and non-revision parts with reasons are detailed.

Day 1

1. Identify the need

In this step, the students are expected to analyze the given problem and determine the need. To do this, they need to be able to determine what the problem gives and what the problem does not give. Also, the students and the teacher are expected to be able to comprehend the integration of the problem with daily life.

The context-based problem presented in this section is as follows.

Problem: In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95 ° C to 60 ° C (ideal coffee drinking temperature) within 1 hour. The size of broken thermos was 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter of thermos, and 0.2 cm ± 0.1 cm in thickness of materials. Also, the broken thermos was very good in terms of health and taste and you could bring with it wherever you went. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60 ° C and above up to 15 minutes before the end of your study like as your old thermos?

The teacher had divided the students into groups and had started discussions for problem analysis. The teacher had asked them what they had thought of the problem. The researcher asked also "Did you have difficulty in connecting the problem situation given during STEM education with daily life?" at the end of the activity. In this part, a male student had stated that he had difficulty in associating the problem with daily life as a result of the classroom observation of the researcher and as a result of the interview with the students. When the teacher had asked why the student had difficulty, the student had expressed that the student had difficulty in visualization because he had never experienced anything like this before. The student had stated that he had not seen a broken thermos in real life, so he could not relate the problem situation to daily life. At this point, the teacher and the researcher had showed a broken thermos photograph to the student. Thus, the student was able to visualize it and relate with the problem. As a result of the interview with the students, he mentioned this difficulty with the same reason.

The researcher asked "Did you have difficulty in associating the problem situation given during STEM education with daily life?" As a result of the interview with the teacher, he stated that he did not have difficulty in associating the problem situation given during STEM education with daily life and at this point.

After the implementation of the activity, as a result of the interview with teacher, the teacher had also expressed that the visuals would be useful, and had emphasized that the full understanding of the problem was important to ensure the continuity of the instructional material. The researcher had decided to add visuals to the problems, thinking that it would be beneficial for the students to match the visual memory with the problem. The visual is a visual of broken thermos mentioned in the problem. As a solution to this, the researcher added visuals into the instructional materials (revised lesson plans, revised teacher activity guide sheet, revised student activity guide sheet) that refer to the need for the problem. The visual added to the revised instructional materials is as follows. Figure 4.1. is the visual reflecting the broken thermos.

Figure 4.1. Broken thermos as visual for revised instructional materials

Then, the teacher has asked "What are the minimum requirements and evaluation criteria that this thermos should have?” to the students. The students had stated that the minimum requirements had been time, desired temperature, quantity of water, length of thermos, width/diameter of thermos, and thickness of materials. Also, they had stated that evaluation criteria had been minimum heat loss with these sizes, carrying for 15 minutes with bare hands, health and taste, and efficacy. In addition, the first group had summarized by saying that the properties of the thermos had been given in the problem. Second group had stated that the most important features given in addition to the properties of the thermos had been how long the thermos should keep the coffee warm and what the temperature of the outer cup of the thermos was. After that, the teacher had asked “What is the need?” The first group had stated that the need was a thermos with a length of 25 cm, a diameter of 8 cm, efficient, healthy, cost - effective and designed by recyclable materials. The second group had stated that the need was a thermos with 25 cm in length, 8 cm in diameter, 2 cm in thickness, 750 mL liquid capacity, and maximum capacity at minimum cost. In addition, the students had stated that they had no difficulty in problem analysis because everything was given in the problem, minimum requirement table and evaluation table. The researcher had realized thanks to this feedback as a result of the classroom observation of the researcher that there had been an inefficient study system at this point because a question-answer-based approach that drives students to think had not been observed in this section. Then, the researcher had left the minimum requirement and evaluation table empty in revised instructional materials so that the teacher could carry out the problem analysis with the students more efficiently with the help of question and answer. In the revised materials, these parts had been left empty to be filled by the students. In addition, as a result of the classroom observation of the researcher, no problems had been observed in the teacher's guidance to the students.

The allocated time for this step before the activity had been administered was 3 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 10 minutes during the activity. Therefore, the allocated time had been revised.

2. Generate ideas/Brainstorm

In this step, the students are expected to discuss the situation and produce ideas by seeking answers to questions such as whether they have developed such a thermos before or what they would have done if they had faced such a situation.

In this step, the students had exchanged their ideas with their group friends and had shared their previous experiences. Some had expressed that they made a thermos before. Some had expressed that they had not encountered such a situation. Those who had made thermos before told their friends about how they had made this thermos. As a result of the classroom observation of the researcher, as a result of the interview with the students and as a result of the interview with the teacher, problem had not been observed here. In addition, as a result of the classroom observation of the researcher, it had been close to each other between male and female students to produce ideas about characteristics and design of the prototype in the thermos activity. These ideas had been about the shape of the thermos, how the thermos could be made, how the thermos could keep the coffee warm. Also, as a result of the interview with the students, the students had stated that STEM activities had been the activities forcing to think. In this step, according to the feedbacks of the students, teacher, and researcher's observations, there had been no problem. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 7 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 10 minutes during the activity. Therefore, the allocated time had been revised.

3. Searching for the answer

In this step, the students are expected to answer to the following questions; “Did you make a thermos before?” and “Is this previously made thermos like thermos you need?” But before the previous questions, the teacher had also asked to the students "Have you ever tried to keep something hot or cold?" As a result of the classroom observation of the researcher, one female student from the first group had stated that she had tried to keep something cold before. Then, teacher had asked “Did you make a thermos before?” and “Is this previously made thermos like thermos you need?” As a result of the classroom observation of the researcher, one male student from the first group had stated that he had not design a thermos before; when he was in science lesson in middle school, he had designed a solar oven. As a result of the classroom observation of the researcher, other students had stated that they had not made a thermos before. After that, the teacher had asked the following questions to the students “What kind of thermoses has been made so far?”, “What solutions have been found?” and “What information is made use of the design of thermos?” Then, the teacher had given to a 9th grade MEB physics book and computer to each group and the students had been expected to seek answer these questions.

Both groups had stated that they had used MEB Physics book to get information about subjects, and Internet to get detail information about subjects and design. As a result of the interview with the teacher, the most comfortable part of the students had been this step because the teacher had observed and had stated that the students could make correct researches about the problem. The teacher and the researcher had observed that the students had researched the heat-temperature unit, the variables that affect the energy transmission rate, the heat insulation and the heat insulation materials, which would benefit the design of the thermos. In addition, the first group had stated that it was necessary to leave a space between the inner surface and the outer surface of the thermos. When the teacher had asked why, the first group had stated that air had the lower heat transmission coefficient than other substance. The students from the second group had stated that they could provide thermal insulation by using two different materials together. Also, the students had stated after their research that they had reached the information about design a thermos with different materials like plastic cups, cardboard cups, cotton, and aluminum foil. According to the observation of the researcher, the students had proceeded in harmony discussing their research with each other. As a result of the interview with the students, as a result of the interview with the teacher and as a result of the classroom observation of the researcher, no problem had been observed here. Therefore, no revision had required at this step.

The researcher asked “What were the most comfortable parts during STEM education?” As a result of the interview with the teacher, he stated that searching for the answer part was most comfortable part for him and students.

Also, the researcher asked “What were the most comfortable parts during STEM education?” after the activity, and as a result of the interview with the students, students said that the searching the information related to the activity was the most comfortable parts.

The researcher asked “Are there places where you think the activity and its execution need revision? If so, what are these?” As a result of the interview with the teacher, he stated that there were no revision in the activity and added the activities were successful. He stated that only the time reserved for the activities should be revised.

The allocated time for this step before the activity had been administered was 30 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 50 minutes during the activity. Therefore, the allocated time had been revised.

4. Associate the disciplines

In this step, the students are expected to associate disciplines, courses, and subjects needed to solve the problem.

The teacher had asked “Which disciplines do you need for the solution of the problem?” to the students. When the students had been asked the concept of discipline, they had been able to specify other disciplines in STEM activity. The students were able to associate the science, technology, engineering and mathematics disciplines where they were necessary for this activity and why they were necessary for this activity in here. Then, the teacher had asked “Which chapters will you need to know about in these lessons’ content?” Both groups had stated the lesson contents as disciplines were Heat and Temperature in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a thermos. Then, the teacher had asked “Which subtitles of chapters are useful for your problem-solving?” Both groups had said Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate. According to the feedback of the students, teacher, and researcher's observation, no problem was observed here. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 5 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 10 minutes during the activity. Therefore, the allocated time had been revised.

5. Determine the criteria, materials, restrictions, limitations of the problem

In this step, the students are expected to answer the following questions; What information does the problem give us?, Does the problem put restrictions and limitations on us?, What are the criteria of the problem?

The teacher had asked respectively “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?” and “What are the criteria of the problem?" and had waited the students answer. The first group had stated that restrictions and limitations were the thermos being 25 cm in length, the thermos being 8 cm in diameter, the thermos being 750 mL, the thickness of the material used being 2 cm. The second group had stated that restrictions and limitations were keeping the coffee hot, the thermos being 8 cm in diameter and the thermos being 750 mL. Also, both groups stated that the criteria were that the coffee could remain at the desired temperature for 1 hour, the thermos could be carried for 15 minutes with bare hand, thermos was appropriate in terms of health and taste, and thermos could be efficiency in terms of how many times thermos can be reused.

After, the teacher had stated that designing a thermos that managed to keep coffee hot, minimum heat loss, carrying for 15 minutes with bare hands, health and taste, and efficiency had been criteria, keeping the 750 mL coffee hot at 60°C and above up to 15 minutes before the end of study, length of thermos, width/diameter of thermos, and thickness of materials had been restrictions and limitations.

As a result of the classroom observation of the researcher, the students had not been in difficulty in this step. According to the data obtained from the students' and teacher' feedbacks and as a result of the classroom observation of the researcher, it was observed that in case of problems and the information given in the tables provided easy progress for the students. Since they could associate the information previously given in the problem with the minimum requirement table and the evaluation table, in this step, they were able to determine what the problem gives us, what the restrictions and limitations and the criteria of the problem are. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 15 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 10 minutes during the activity. Therefore, the allocated time had been revised.

6. Examine possible solutions

In this step, the students are expected to create at least 3 possible solutions along with the criteria, restrictions, and limitations they have identified in the previous step.

The teacher had stated “Create at least 3 possible solutions.” The first group had produced three possible solutions. The first solution was to design a thermos using a glass bottle, then covering the outside of this glass bottle with Styrofoam, and then using a cork stopper. The second solution was to design a thermos using a glass bottle, and then covering the outside of this glass bottle with aluminum foil. The third solution was to design a thermos using a glass bottle, then covering the outside of this glass bottle with Styrofoam, and then covering it with rubber. The second group had produced three possible solutions. The first solution was to design a thermos using a glass bottle, and then covering the outside of this glass bottle with band. The second solution was to design a thermos using a glass bottle, and then covering wool fabric. The third solution was to design a thermos using plastic bottle with using cork stopper.

The students were able to produce solutions by exchanging ideas within their groups as a result of the classroom observation of the researcher. They had worked on which solutions they could produce by using their knowledge obtained from their research. They had argued amongst themselves why they had determined these solutions. As a result of the interview with the students, as a result of the interview with the teacher, and as a result of the classroom observation of the researcher, no problem was observed here. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 15 minutes. As a result of the classroom observation of the researcher, the duration of this step had 15 minutes during the activity. Therefore, the allocated time had not been revised.

7. Choose the best possible/applicable/probable/feasible solution

The students proceeded to the next step by choosing the most probable solution with their own predictions, their researches and the guidance of the teacher and determining the dependent, independent, control-constant variables in the problem.

The students from the first group had chosen the third solution among their possible solutions. This was to design a thermos using a glass bottle, then covering the outside of this glass bottle with Styrofoam, and then covering it with rubber. The students from the second group had chosen the first solution among their possible solutions. This was to design a thermos using a glass bottle, and then covering the outside of this glass bottle with band. Then, the teacher had asked to students "Why did you choose these solutions?" Both groups had stated that they would provide the best thermal insulation with their solutions.

After these, the teacher had asked "Is there any dependent, independent, and control-constant variable in the problem?" The first group had stated that heat loss was dependent variable, the types and amount of insulation materials, and the sizes of the thermos were independent variables, and the time that the coffee should remain hot and the amount of coffee were control-constant variable. The second group had stated that heat loss was dependent variable, the materials of thermos in terms of health, types of insulation materials, number of cups, the sizes of thermos were independent variable, and initial temperature of water, and amount of water were control-constant variable.

Then, the teacher had stated that they could state water instead of the coffee in their explanations because the inquiry experiments and the test of prototype would be carried out over water. Then, the teacher had stated that water temperature change, outer temperature change of thermos were dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials were independent, and amount of water, temperature of environment, the initial temperature of water were control-constant.

Then, the teacher had asked “When you consider all these restrictions-limitations, and your most likely solution, which materials can you choose to develop a thermos with desired features? Are the materials you mentioned before sufficient to develop a thermos with desired features?” and the teacher had asked "What materials do you need to improve this thermos?" Then, both groups had discussed to choose their materials. The first group had wanted aluminum foil, cork stopper, sponge, rubber, thermometer, Styrofoam, adhesive, glue, silicone gun, band, scissors, cotton, utility knife, ruler, kettle, wool fabric, chronometer, plastic cup with different size, cardboard cup with different size, glass cup with different size. The second group had wanted kettle, thermometer, utility knife, ruler, band, cotton, cork stopper, glue, tongue sticks, rubber, silicon gun, aluminum foil, Styrofoam, chronometer, plastic cup with different size, cardboard cup with different size, glass cup with different size.

Then, the teacher had said “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

According to the feedback of the students, teacher, and researcher's observation, no problem was observed here. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 10 minutes. As a result of the classroom observation of the researcher, the duration of this step had enough 10 minutes during the activity. Therefore, the allocated time had not been revised.

Day 2

8. Develop or redevelop a prototype

This step is the step that begins on the second day. In this step, the students are expected to develop a prototype or redevelop this prototype. They are expected to experience the variables they have identified in doing so with the inquiry experiments. The students experienced the dependent, independent and control-constant variables with inquiry experiments.

The teacher had brought the materials they had wanted to the groups and had said “Let's observe how variables affect to develop a prototype.”

The students from the first group had chosen to experience the variables as types of cups as the first independent variable. In the meantime, the number and size of the cups, the types of insulation materials, the amount of insulation materials had remained the control variable. As a dependent variable, they had experienced at the temperature change of water. To do this, they had first experimented with cardboard and glass cups and had taken the same amount of boiling water at 95 ° C as they all had the problem and had taken a five minute with chronometer. When the teacher had asked why they did not take measurements with plastic cups, they had stated that plastic was more harmful for health than cardboard and glass cups. They had used the same amount of boiled water at 95 ° C in both cups and had taken a 15 minute measurement. The temperature change of the glass cup had changed from 95 ° C to 85.6 ° C. At the same time, the temperature change of the cardboard cup had changed from 95 ° C to 65 ° C. When the teacher had asked what they were observing, they had stated that it was observed that the glass cup kept the boiled water at 95 ° C at a higher temperature than the cardboard cup at the same time. When the teacher had asked which material they had chosen as the cup of thermos, they had replied as a glass cup. The measurements are in Table 4.1.

Table 4.1. *Measurements of the Temperature based on the Types of Cups of the First Group*

The Temperature based on the Types of Cups of the First Group		
	Types of Cups	
	Glass Cup	Cardboard cup
Initial temperature of water	95 ° C	95 ° C
Final temperature of water after 15 minutes	85.6 ° C	65 ° C

The students in the first group had then begun experimenting by changing the types of insulation materials as the second argument. Here, they had chosen to experience the types of insulation materials with this glass cup because they had identified the glass cup as a thermos cup in their first experiments. They had started using cotton and Styrofoam as insulation materials. In the meantime, the type of cup, the amount of insulation material and the number of cup had been determined as the control-constant variable. Here, they had taken a 5-minute measurement. They had covered with a round of cotton around the glass cup and the boiled water at 95 ° C had decreased to 92 ° C after 5 minutes. In this instance, they had covered the glass bottle with Styrofoam and had taken a 5-minute measurement. In this instance, they had observed that the boiled water at 95 ° C had decreased to 91.7 ° C within 5 minutes. The measurements are in Table 4.2.

Table 4.2. *Measurements of the Temperature based on the Types of Insulation Material of the First Group*

Measurements of the Temperature based on the Types of Insulation Material of the First Group		
	Types of Insulation Material	
	Cotton	Styrofoam
Initial temperature of water	95 ° C	95 ° C
Final temperature of water after 5 minutes	92 ° C	91.7 ° C

Then, the students from the first group had wrapped one round of cotton around the glass bottle, then had wrapped one round of aluminum foil on cotton and one round of fabric on aluminum foil and had measured the temperature for 15 minutes. Here, they had begun to look at the external temperature of thermos prototype as well as the internal temperature of thermos prototype. Initially, the internal temperature had been 95 ° C due to the boiling temperature of water, while the external temperature had been 25 ° C. After 5 minutes, the internal temperature had been 92 ° C and the external temperature had been 53.4 ° C. After 10 minutes, the internal temperature had been 88.5 ° C and the external temperature had been 45.7 ° C. After 15 minutes, the internal temperature had been 85.6 ° C and the external temperature had been 42.3 ° C. The measurements are in Table 4.3.

Table 4.3. *First Try of Measurements of the Temperature based on the Types of Insulation Material used Together of the First Group*

Measurements of the Temperature based on the Insulation Material used Together of the First Group		
	Types of Insulation Material	
	Internal Temperature (Temperature of Water)	External Temperature (Temperature of Outside of Thermos Prototype)
Initial temperature	95 ° C	25 ° C
Temperature after 5 minutes	92 ° C	53.4 ° C
Temperature after 10 minutes	88.5 ° C	45.7 ° C
Temperature after 15 minutes	85.6 ° C	42.3 ° C

Then, the students from the first group had wrapped Styrofoam around the glass bottle, then had wrapped cotton to the gap on Styrofoam, then had wrapped sponge and one round of aluminum foil on sponge and had measured temperature for 15 minutes. Here, they had begun to look at the external temperature of thermos prototype as well as the internal temperature of thermos prototype. Initially, the internal temperature had been 95 ° C due to the boiling temperature of water, while the external temperature had been 25 ° C. After 5 minutes, the internal temperature had been 91.7 ° C and the external temperature had been 36.3 ° C. After 10 minutes, the internal temperature had been 89.2 ° C and the external temperature had been 33.9 ° C. After 15 minutes, the internal temperature had been 85.5 ° C and the external temperature had been 30.7 ° C. The measurements are in Table 4.4.

Table 4.4. *Second Try of Measurements of the Temperature based on the Types of Insulation Material used Together of the First Group*

Measurements of the Temperature based on the Insulation Material used Together of the First Group		
	Types of Insulation Material	
	Internal Temperature (Temperature of Water)	External Temperature (Temperature of Outside of Thermos Prototype)
Initial temperature	95 ° C	25 ° C
Temperature after 5 minutes	91.7 ° C	36.3 ° C
Temperature after 10 minutes	89.2 ° C	33.9 ° C
Temperature after 15 minutes	85.5 ° C	30.7 ° C

As a result of the classroom observation of the researcher, the students from the second group had stated that the glass bottle was better in terms of health than other cups. However, before experimenting with glass bottles, they had stated they had wanted to do a few experiments with cardboard cups. First, they had filled cotton into the fabric and had wrapped it out of the large cardboard cup. They had put the boiled water at 95 ° C in the glass bottle. The room temperature was 25 degrees. When they had taken a measurement a minute later, they had observed that the internal temperature had remained at 95 ° C and the external temperature was 26 ° C. At 5 minutes, the internal temperature was 86.25 ° C while the external temperature was 35.17 ° C. They had stated that they would not measure the desired temperature after 60 minutes with this experiment. The measurements are in Table 4.5.

Table 4.5. *First Try of Measurements of the Temperature based on the Types of Insulation Material used Together of the Second Group*

Measurements of the Temperature based on the Insulation Material used Together of the Second Group		
	Types of Insulation Material	
	Internal Temperature (Temperature of Water)	External Temperature (Temperature of Outside of Thermos Prototype)
Initial temperature	95 ° C	25 ° C
Temperature after 1 minutes	95 ° C	26 ° C
Temperature after 5 minutes	86.25 ° C	35.17 ° C

Then, the students from the second group had filled cotton into the fabric and had wrapped it around the glass bottle. They had wrapped the tongue sticks in aluminum foil and had made a cover on it. They had put the boiled water at 95 ° C in the glass. The room temperature was 25 ° C. After one minute the internal temperature was 95 ° C, the external temperature was 26 ° C. At the fifth minute, the internal temperature was 80.28 ° C, while the external temperature measurements were 30.13 ° C. They had stated that they would not achieve the desired temperature after 60 minutes with this experiment. The measurements are in Table 4.6.

Table 4.6. *Second Try of Measurements of the Temperature based on the Types of Insulation Material used Together of the Second Group*

Measurements of the Temperature based on the Insulation Material used Together of the Second Group		
	Types of Insulation Material	
	Internal Temperature (Temperature of Water)	External Temperature (Temperature of Outside of Thermos Prototype)
Initial temperature	95 ° C	25 ° C
Temperature after 1 minutes	95 ° C	26 ° C
Temperature after 5 minutes	80.28 ° C	30.13 ° C

Then, the students from the second group had wrapped the tongue sticks with aluminum foil. They had then wrapped cotton around the glass bottle and had then wrapped the tongue sticks covered with aluminum foil. They had put the boiled water in the glass at 95 ° C. The room temperature was 25 ° C. After one minute the internal temperature was 95 ° C, the external temperature was 25 ° C. At the fifth minute, the internal temperature was 90.06 ° C, the external temperature was 30 ° C. In the tenth minute, the internal temperature was 87.04 ° C, while the external temperature was 35 ° C. At the fifteenth minute, the internal temperature was 84.07 ° C, while the external temperature was 43.05 ° C. They had stated that they could achieve the desired temperature after 60 minutes with this experiment and they had wanted to work on this experiment. The measurements are in Table 4.7.

Table 4.7. *Third Try of Measurements of the Temperature based on the Types of Insulation Material used Together of the Second Group*

Measurements of the Temperature based on the Insulation Material used Together of the Second Group		
	Types of Insulation Material	
	Internal Temperature (Temperature of Water)	External Temperature (Temperature of Outside of Thermos Prototype)
Initial temperature	95 ° C	25 ° C
Temperature after 5 minutes	90.06 ° C	30 ° C
Temperature after 10 minutes	87.04 ° C	35 ° C
Temperature after 15 minutes	84.07 ° C	43.05 ° C

In this section, both groups made the prototypes more probable by experimenting with the dependent, independent and control-constant variables before making the thermos they wanted. As a result of the classroom observation of the researcher, the second group had finished developing its prototype seven minutes before the first group. Figure 4.2., Figure 4.3., Figure 4.4., and Figure 4.5. show that both groups tried the variables with inquiry-based experiments before developing their thermos. Figure 4.2. and Figure 4.3 are two of the visuals reflecting the first try and second try of inquiry experiment studies of the first group. Figure 4.4. and Figure 4.5 are two of the visuals reflecting the first try and second try of the inquiry experiment studies of the second group.

Figure 4.2. First try of inquiry experiments before designing thermos for the first group

Figure 4.3. Second try of inquiry experiments before designing thermos for the first group

Figure 4.4. First try of inquiry experiments before designing thermos for the second group

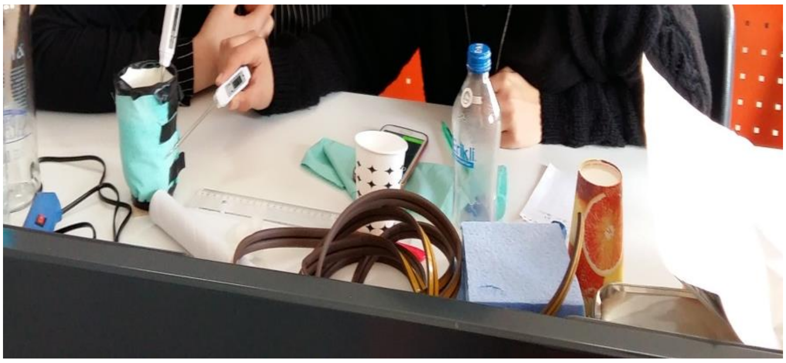

Figure 4.5. Second try of inquiry experiments before designing thermos for the second group

After all of these, as a result of the classroom observation of the researcher, both groups had developed their thermoses. The first group had developed a thermos through the following steps. The students in the first group had preferred and had used 750 mL glass bottle to make a healthy thermos. Then, the students had covered the outside of the thermos with a round of cotton. After doing this, they had covered the cotton with band. The students had then covered the surface of the thermos with a round of wool fabric and then two round aluminum foils. The students had used rubber, an insulating material, to keep the outside temperature low for 15 minutes. The students had also chosen the cork stopper as the cover of the thermos so that the heat loss would not be high. The second group had developed a thermos through the following steps. The second group had chosen to use 750 mL glass bottle for health reasons. Then, the students had wrapped a round of aluminum foil on the outside. Then, the students had used a round of cotton as insulation material. The students had then wrapped the tongue sticks with aluminum foil and had covered the perimeter of the cotton. The students had observed that they had rewound cotton on it in order to keep the outside temperature of their thermos lower, as observed in their previous inquiry experiments. Then, the students had wrapped around the thermos with band. The students had preferred cork stopper as cover. Figure 4.6. is the visual of the thermos of the first group, and Figure 4.7. is the visual of the thermos of the second group.

Figure 4.6. Thermos which had been developed by the first group

Figure 4.7. Thermos which had been developed by the second group

As a result of the classroom observation of the researcher and as a result of the interview with the teacher, the students had experienced the dependent, independent and control-constant variables with inquiry experiments.

During the interview with the students, the researcher asked “What was the most challenging part of your STEM education that you had difficulty in implementing?” As a result of the interview with the students, the students stated that they had difficulty in doing some experiments (inquiry-based part) to reach information used in developing prototype before final prototype. The students had stated that they had difficulty in doing some experiments (inquiry-based part) to reach information used in developing prototype before final prototype. When the researcher asked why, they had explained the reason for this; in fact, they had said that it took a long time. The reason for this was explained to the students. This was a heat and temperature activity; therefore determined time intervals to take measurements were necessary for this activity to reach healthy outcome. Therefore, this feedback could not be considered and revised in this activity. In addition to these, as a result of the interview with the students, in this step, one male and one female student had stated that they had difficulty in applying the criteria that the thermos should have. This was the minimum requirement that the thermos should have. They had expressed that trying to create a prototype without going beyond the dimensions given in this section was a bit difficult. However, since the aim in here was to provide the minimum heat loss of the thermos with the maximum sizes, therefore, the part requiring engineering skills was not revised according to the students' feedback.

As a result of the classroom observation of the researcher, for handicrafts, male students and female students had almost equally participated with an actively engage in the activity. The researcher had observed that students had a good time in the activity process, especially in the second day they had better time because of the design part. As a result of the interview with the students, the researcher had confirmed this. As a result of the classroom observation of the researcher and as a result of the interview with teacher, in this part, the students had not had any difficulties in terms of implementation, and they had completed the process by experimenting with variables and taking measurements regularly. Therefore, no revision had made in this step.

The allocated time for this step before the activity had been administered was 135 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 180 minutes during the activity. Therefore, the allocated time had been revised.

9. Test and evaluate the prototype by individual group

In this step, the students are expected to first check whether their cars have the minimum requirements when evaluating them, and then test their thermoses themselves. In this step, the students are expected to continue with the next step if prototypes are working; or they are expected to go to the previous step if prototypes are not working.

In this step, both groups had looked at whether their prototypes had met the minimum requirements or not. According to the problem, the dimensions of the thermoses should be that the length of the thermos should be 25 cm ± 0.1 cm, the width/diameter of the thermos should be 8 cm ± 0.1 cm. According to these measurements, the thermos of the first group was 25 cm in length and 8 cm in width, while the thermos of the second group was 24.9 cm in length and 8.1 cm in width. The measurements are in Table 4.8.

Table 4.8. *Dimensions of the Thermoses*

	Dimensions of the Thermoses		
	Expected Measurements	First Group	Second Group
Length of Thermos	25 cm ± 0.1 cm	25 cm (cover height included)	24.9 cm (cover height included)
Width/Diameter of Thermos	8 cm ± 0.1 cm	8 cm	8.1 cm

Then, both groups had tested their prototypes. They had taken measurements at five minute intervals. The first group had put the boiled water at 95 ° C into the thermos prototype. The room temperature was 25 ° C. After five minutes, the internal temperature was 92 ° C, the external temperature was 31.8 ° C. In the tenth minute, the internal temperature was 89.6 ° C, while the external temperature was 34.3 ° C. At the fifteenth minute, the internal temperature was 87.3 ° C, while the external temperature was 35.2 ° C. The second group had put the boiled water at 95 ° C into the thermos prototype. The room temperature was 25 ° C. After five minutes, the internal temperature was 91.1 ° C, while the external temperature was 35.3 ° C. In the tenth minute, the internal temperature was 87.8 ° C, while the external temperature was 38.2 ° C. In the fifteenth minute, the internal temperature was 84.6 ° C, while the external temperature was 39 ° C. The measurements are in Table 4.9.

Table 4.9. *Measurements of the Temperature based on Testing*

Measurements of the Temperature based on Testing				
	Internal Temperature (Temperature of Water)		External Temperature (Temperature of Outside of Thermos Prototype)	
	First Group	Second Group	First Group	Second Group
Initial temperature	95 ° C	95 ° C	25 ° C	25 ° C
Temperature after 5 minutes	92 ° C	91.1° C	31.8 ° C	35.3 ° C
Temperature after 10 minutes	89.6 ° C	87.8 ° C	34.3 ° C	38.2 ° C
Temperature after 15 minutes	87.3 ° C	84.6 ° C	35.2 ° C	39 ° C

Then, looking at the measurements they had obtained when they had tested their prototypes, they had stated that their prototypes would give the desired measurement. The foresight of the first group for internal temperature measurement after 60 minutes was 68 ° C, whereas the second group was 71 ° C. The foresight of the first group for external temperature measurement after 15 minutes was 35 °

C, whereas the second group was 40 ° C. The foresights are in Table 4.10 and Table 4.11.

Table 4.10. *Foresights of the Groups for Internal Temperature based on Testing*

Foresight of the Groups for Internal Temperature based on Testing		
	First Group	Second Group
When 95 ° C hot water is added to the thermos (first measurement)	95 °C	95 °C
Foresight of the Groups (60 minutes after the 95 ° C hot water is added to the thermos) (second measurement)	68 °C	71 °C

Table 4.11. *Foresights of the Groups for External Temperature based on Testing*

Foresights of the Groups for External Temperature		
	First Group	Second Group
When 95 ° C hot water is added to the thermos (first measurement)	25 °C (room temperature at the time of study)	25 °C (room temperature at the time of study)
Foresight of the Groups (15 minutes after the 95 ° C hot water is added to the thermos) (second measurement)	35 °C	40 °C

The groups had drawn a temperature-time graph after predicting according to the measurements obtained when they had tested the prototypes. Figure 4.8. is the temperature-time graph of the first group, Figure 4.9. is the temperature-time graph of the second group.

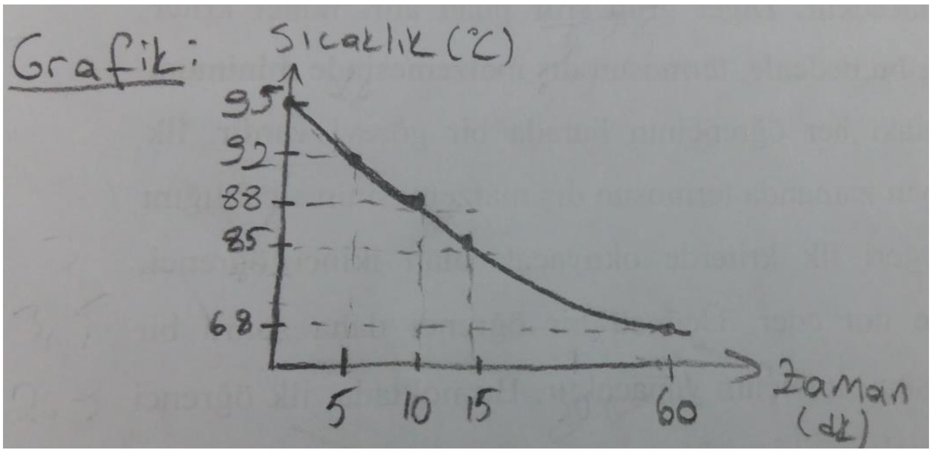

Figure 4.8. The Temperature-Time Graph of the First Group

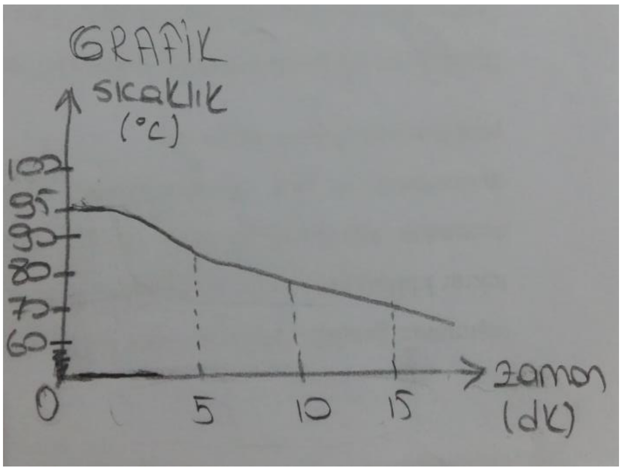

Figure 4.9. The Temperature-Time Graph of the Second Group

In this step, as a result of the classroom observation of the researcher, the prototypes of both groups met the minimum requirements and both groups were able to develop a prototype with the expected characteristics in their measurements. As a result of their measurements at short time intervals, they determined that their thermos can keep their coffee at the desired temperature within one hour.

Therefore, no problems were observed in this step. Therefore, no revision had made for this step.

The allocated time for this step before the activity had been administered was 40 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 70 minutes during the activity. Therefore, the allocated time had been revised.

10. Share

In this step, the teacher is expected to share the prototypes with the whole groups and to evaluate the prototypes.

In this section, the teacher had made measurements about the prototypes of both groups and had identified the first by explaining the reasons. As a result of the classroom observation of the researcher, the students were very excited about the sharing of the prototypes.

The characteristics of the prototypes of the groups are as follows. According to the problem, the dimensions of the thermoses should be that the length of the thermos should be 25 cm ± 0.1 cm, the width/diameter of the thermos should be 8 cm ± 0.1 cm. According to these measurements, the thermos of the first group was 25 cm in length and 8 cm in width, while the thermos of the second group was 24.9 cm in length and 8.1 cm in width. The measurements are in Table 4.8.

The features of these thermoses are as follows. The first group developed a thermos through the following steps. The students in the first group had preferred and had used 750 mL glass bottle to make a healthy thermos. Then, the students had covered the outside of the thermos with a round of cotton. After doing this, they had covered the cotton with band. The students had then covered the surface of the thermos with a round of wool fabric and then two round aluminum foils. The students had used rubber, an insulating material, to keep the outside temperature low for 15 minutes. The students had also chosen the cork stopper as the cover of the thermos so that the heat loss would not be high. The second group had developed a thermos through the following steps. The second group had chosen to use 750 mL glass bottle for health reasons. Then, the students had wrapped a round of aluminum foil on the outside. Then, the students had used a round of cotton as insulation material. The students had then wrapped the tongue sticks with aluminum foil and had covered the perimeter of the cotton. The students had observed that they had rewound cotton on it in order to keep the outside temperature of their thermos lower, as observed in their previous inquiry experiments. Then, the students had wrapped around the thermos with band. The students had preferred cork stopper as cover. Figure 4.6. in eighth step shows the visual of the thermos of the first group, and Figure 4.7. in eighth step shows the visual of the thermos of the second group.

According to these measurements, the temperature inside the thermos of the first group whose foresight had been 68 °C had been 71 °C. The temperature inside the thermos of the second group whose foresight had been 71 °C had been 63.3 °C. These characteristics of their thermoses and predictions according to the data they obtained as a result of the measurements by inquiry experiments they took are indicated in Table 4.12.

Table 4.12. *Temperature Measurements inside the Thermoses*

Temperature Measurements inside the Thermoses		
	First Group	Second Group
When 95 ° C hot water is added to the thermos (first measurement)	95 °C	95 °C
Foresight of the Groups	68 °C	71 °C
60 minutes after the 95 ° C hot water is added to the thermos (second measurement)	71 °C	63.3 °C

According to these measurements, the temperature outside the thermos of the first group whose foresight had been 35 °C had been 40.9 °C. The temperature outside the thermos of the second group whose foresight had been 40 °C had been 47 °C. These characteristics of their thermoses and predictions according to the data they obtained as a result of the measurements by inquiry experiments they took are indicated in Table 4.13.

Table 4.13. *Temperature Measurements outside the Thermoses*

Temperature Measurements outside the Thermos		
	First Group	Second Group
When 95 ° C hot water is added to the thermos (first measurement)	25 °C (room temperature at the time of study)	25 °C (room temperature at the time of study)
Foresight of the Groups	35 °C	40 °C
15 minutes after the 95 ° C hot water is added to the thermos (second measurement)	40.9 °C	47 °C

According to the results, the teacher had identified the first group and explained the reasons to the students. The teacher had chosen the first group by stating that the internal temperature of the thermos of the first group was higher than the other thermos after 1 hour and the external temperature was less than the other thermos after 15 minutes.

As a result of the classroom observation of the researcher, the students had more actively engage starting from the possible solution part of the activity. Also, as a result of the classroom observation of the researcher, the students had a good time in the activity process, especially in second day they had better time because of the design part. As a result of the classroom observation of the researcher, that means the students were more active in both physically and mentally in second day of the activities. The students had expressed the same sharing with the researcher's observation as a result of the interview with the students. Also, the researcher asked

“How was your communication with your physics teacher during STEM education?” As a result of the interview with the students, during the activity processes, they had stated that their communication with the teacher was strong.

The researcher asked “What was the most challenging part of your STEM education that you had difficulty in implementing?” As a result of the interview with the teacher, he stated that he had not pushed me too much; he said that he just had to go a little higher than expected in terms of time allocated to the relevant parts during the activity. In addition, the researcher asked “Did you have difficulty in guiding students during STEM education?” As a result of the interview with the teacher, he stated that he had not difficulty in guiding students during STEM education.

The researcher asked “During STEM education, what questions did you guide students to provide information that they could not foresee?” As a result of the interview of the teacher, the teacher had stated that in the process students did not encounter any unforeseen situations. However, the teacher said that he prepared extra questions for any possible unforeseen situations. They were “Why do birds stop by raising their feathers?” “Why do we use double glazing in our homes?”

The researcher asked “Has the lesson plan and material been achieved to the objectives? Yes or No? If your answer is no, please indicate which objectives have not been achieved.” As a result of the interview with the teacher, he stated that all materials were suitable with the objectives.

The allocated time for this step before the activity had been administered was 60 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 75 minutes during the activity. Therefore, the allocated time had been revised.

In addition to all the activity process, as a result of the interview with the teacher, the teacher had also shared that the time intervals for each activity should be revised. The researcher had also noticed this important point. In most places, the set time was inadequate and extended during the activity period. Therefore, the researcher revised these parts. In this activity, time set for activity increased from 320 minutes to 440 minutes. Table 4.14. shows the Timing of Thermos Activity.

Table 4.14. *The Timing of Thermos Activity*

The Timing of Thermos Activity		
10 Steps of the Proposed Model to Implement STEM PBL Activity	Timing Before Implementation	Timing After Implementation
1. Identify the need	3 min	10 min
2. Generate ideas/Brainstorm	7 min	10 min
3. Searching for the answer	30 min	50 min
4. Associate the disciplines	5 min	10 min
5. Determine the criteria, materials, restrictions, limitations of the problem	15 min	10 min
6. Examine possible solutions	15 min	15 min
7. Choose the best possible/applicable/probable/feasible solution	10 min	10 min
8. Develop or redevelop a prototype	135 min	180 min
9. Test and evaluate the prototype by individual group	40 min	70 min
10. Share	60 min	75 min
Total Timing	320 min	440 min

4.2. Second Activity: Second Iteration (Toy Car Activity)

In the second activity, the parts that the points with problems and without problems encountered in each step have been examined in detail. In other words, if the problem is not observed in one step of the first activity and the problem is observed in the same step of the second activity, it explains why the problem was observed in the same step of this activity and how it was revised. Also, if the problem is observed and revised in one step of the first activity and the problem is not observed in the same step of the second activity, it is explained why the problem is not observed in the same step of this activity.

Day 1

1. Identify the need

This step was revised according to the first step of the first activity. After implementation of the first activity, the revised and integrated part is following: The students should be able to fill the minimum requirement table with the information in the problem and complete the evaluation table with the guidance of the teacher. From the second activity onwards, it has been revised to be completed by the students, and our expectation is that the students will be able to do so.

The context-based problem presented in this section is as follows.

Problem: You're invited to your friend's birthday party. There's a toy car race on his birthday. Everyone has to design their own car and come to the competition. The car that is able to complete the 150 centimeter road as soon as possible will be selected as the fastest car. The mass of the car should be between 50 grams and 250 grams, the total height of the car from the ground should be between 5 cm and 20 cm, the length of the car should be between 10 cm and 20 cm, the width of the car should be between 10 cm and 15 cm and the car should have 4 wheels. Competition rules are as follows. All cars will start racing on a straight whiteboard with a 45 degree incline with the ground. They will start the race with their first wheels at the level of the line on the inclined plane without initial velocity. The length of the inclined plane is 50 cm and the width of the inclined plane is 40 cm. The road will continue as a concrete surface (ground) after the inclined surface is finished. The length of the horizontal plane is 1 meter. The car that managed to complete the 150 centimeter as soon as possible will win the competition. You should design a car that meets all these rules. Come on, start!

The teacher had divided the students into groups and had started discussions for problem analysis. The teacher had asked them what they had thought of the problem and what the problem had given them.

The first group had stated that within the problem they could reach the maximum mass of the car, the dimensions of the car and the volume of the car. The second group had stated that the car should be fast, they should design the car taking into account the friction, the material and size of the wheels should be important.

Then, the teacher had asked "What are the minimum requirements and criteria stated in the problem?" The first group had stated that the mass of the car, the total height of the car from the ground, the length of the car, the width of the car and the number of wheels were the minimum requirements. The second group had stated that the mass of the car, the total height of the car from the ground, the length of the car, the width of the car and the number of wheels were the minimum requirements.

Both groups had stated that the criterion presented in the problem was that the car would be the fastest car to complete the determined distance as soon as possible the criterion for evaluation table. Here, as a result of the classroom observation of the researcher, under the guidance of the teacher, the students had completed the minimum requirement table and the evaluation table.

Then, the teacher had asked "What is the need in the problem?" The first group had stated that the need was a car having up to 200 gram mass, having heavy wheels whose outer material was rubber. The second group had stated that the need was a car having body made by hard material, having a triangular end to reduce friction, and having wheels made by appropriate material to ensure fast on the ground.

After listening to the problem and these answers, as a result of the classroom observation of the researcher, the students had immediately started to think about the designs for the needs. The teacher had guided them with the questions about the characteristics of toy cars; therefore, the students had noticed that they had needed to think about the process before designing. The teacher had asked these questions to the students “How should be the friction between car and the ground?”, “How should be the friction between the shaft in the wheel and the wheel?”, “Why are the front ends designed as spikes or ovals when racing cars are considered?” Thanks to this guidance, as a result of the classroom observation of the researcher, their attention on the procedure was able to stay dynamic.

After that, the teacher had said “To be able answer them, we need to determine our need first.”

On top of that, the teacher had stated by revising and integrating the answers from the students “The need is that a toy car is developed to win the race as quickly as possible that complete the 150 cm road by considering 0 m/s in initial velocity, having between 50 g - 250 g in mass, between 10 cm - 20 cm in total height of the car off the ground in length, between 10 - 15 cm in width, 4 wheels. This part was able to be solved in this way so no revision was required.

As a result of the classroom observation of the researcher and as a result of the interview with the teacher, the students could relate the daily life examples with the problem. The minimum requirement table and the evaluation table were completed by the students. As a result of the classroom observation of the researcher, they had completed this step with teacher-guided question and answer. In this step, as a result of the classroom observation of the researcher and as a result of the interview with the teacher, the students had had no difficulties.

The researcher asked "Did you have difficulty in connecting the problem situation given during STEM education with daily life?" As a result of the interview with the students, the students stated that they had not any difficulty in this issue.

The researcher asked “Did you have difficulty in associating the problem situation given during STEM education with daily life?” As a result of the interview with the teacher, he stated that he did not have difficulty in associating the problem situation given during STEM education with daily life and at this point.

With the revision in the first activity, the visual was integrated to the instructional materials before the implementation. The visual added here is as in Figure 4.10.

Figure 4.10. Toy car as visual for instructional materials

In addition, as a result of the classroom observation of the researcher, the students had misinterpreted the width of the car given in the problem. They had thought that it was just the width of the car body. They had not realized that the wheels would be included in the width of the car. With the guidance of the teacher, they had realized that the wheel was included in the body width. The researcher had then revised both the width of the car as width of the car (distance between the outer ends of the wheels) and the length of the car as length of the car (distance between the front and rear ends of the wheels) and the total height of the car off the ground as total height of the car off the ground (distance from the bottom of the wheel to the highest point of the car). Therefore, this was changed in the revised instructional materials.

Except all above, in this step, it was noted as a result of the classroom observation of the researcher and as a result of the interview with the teacher, the students had no difficulties.

The allocated time for this step before the activity had been administered was 3 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 15minutes during the activity. Therefore, the allocated time had been revised.

2. Generate ideas/Brainstorm

In this step, the students are expected to discuss the situation and produce ideas by seeking answers to questions such as whether they have developed such a toy car before or what would they have done if they had faced such a situation.

In this step, as a result of the classroom observation of the researcher, the students had exchanged their ideas with their group friends and had shared their previous experiences. Some had expressed that they made a toy car before. Some had expressed that they had not encountered such a situation. Those who had made a toy car before told their friends about how they had made this toy car. In addition, as a result of the classroom observation of the researcher, male students had produced more ideas about characteristics and design of the prototype in the toy car activity than female students. These ideas had been about the shape of the toy car, how the toy car could be made, what the materials of toy car could be. Also, the students had stated that STEM activities had been the activities forcing to think. In this step, as a result of the classroom observation of the researcher, as a result of the interview with the students and as a result of the interview with the teacher, there had been no problem. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The allocated time for this step before the activity had been administered was 7 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had been revised.

3. Searching for the answer

In this step, the students are expected to answer to the following questions; “Did you make a toy car before?” and “Is this previously made toy car like toy car you need?” Then, teacher had asked “Did you make a toy car before?” and “Is this previously made toy car like toy car you need?" After that, the teacher had asked the following questions to the students "What kind of toy car has been made so far?", "What solutions have been found?" and "What information is made use of the design of toy car?" Then, the teacher had given to a 9^{th} grade MEB physics book and computer to each group and the students had been expected to seek answer these questions.

As a result of the interview with the teacher, the most comfortable part of the students had been this step because the teacher had observed and had stated that the students could make correct researches about the problem.

As a result of the classroom observation of the researcher, the students had researched the motion and force unit, friction force. The students from the first group had stated that they had reached the concepts of distance, displacement, speed and velocity and the variables to which the friction force depends. The students from the second group had stated that they had reached the concepts of friction force, speed and velocity, displacement, and force and mass relation.

After the search, the teacher had asked "Which resources did you use and what did you find?" and "Which materials are used in making toy cars?"

Both groups had stated that they had used MEB Physics book to get information about subjects, and Internet to get detail information about subjects and design. The first group had stated that during their research, toy cars had been previously made by using metal, plastic, cardboard materials and incorporating electricity unit. The second group had stated that during their research, cars had been previously made by using plastic materials, and propeller made for energy storage.

The researcher asked "What were the most comfortable parts during STEM education?" As a result of the interview with the teacher, he stated that searching for the answer part was most comfortable part for him and students.

The researcher asked “Are there places where you think the activity and its execution need revision? If so, what are these?” As a result of the interview with the teacher, he stated that there were no revision in the activity and added the activities were successful. He stated that only the time reserved for the activities should be revised.

As a result of the classroom observation of the researcher, the students had proceeded in harmony discussing their research with each other. As a result of the classroom observation of the researcher and as a result of the interview with the teacher, no problem had been observed here. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The allocated time for this step before the activity had been administered was 30 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 45 minutes during the activity. Therefore, the allocated time had been revised.

4. Associate the disciplines

In this step, the students are expected to associate disciplines, courses, and subjects needed to solve the problem.

In this step, the students had difficulty in understanding the concept of discipline. The teacher had asked “Which disciplines do you need for the solution of this problem?” to the students. As a result of the classroom observation of the researcher, they had confused the sub-branches of physics and disciplines. Both groups had stated that mechanics and electromagnetism. Therefore, during the activity, the teacher told them about the difference between the sub-branches of physics and disciplines. The teacher had given them these examples; mechanics as sub-branch of physics, and chemistry as discipline. After that, the teacher had asked again the same question to the groups “Which disciplines do you need for the solution of this problem?” First group had stated that mathematics, physics, technology, design and architecture were disciplines. Second group had stated that mathematics, physics, technology, design, architecture, engineering were disciplines. Then, the teacher had stated physics as science in here, mathematics, engineering and technology were disciplines. Then, the teacher had asked “Which chapters will you need to know about in these lessons’ content?” Both groups had stated the lesson contents as disciplines were Motion and Force in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a toy car. Then, the teacher had asked “Which subtitles of chapters are useful for your problem-solving?” Both groups had said Motion, and Friction Force.

In order to solve such a problem, the researcher had changed the concept of “Associate the disciplines” as “Associate the courses” in the revised student activity guide sheet. The concept of “Associate the disciplines” was not changed in the lesson plan and the teacher activity guide sheet because the main aim was to give the disciplines that create STEM.

The allocated time for this step before the activity had been administered was 5 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had been revised.

5. Determine the criteria, materials, restrictions, limitations of the problem

In this step, the students are expected to answer the following questions; What information does the problem give us?, Does the problem put restrictions and limitations on us?, What are the criteria of the problem?

The teacher had asked respectively “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?” and “What are the criteria of the problem?” and had waited the students answer. As the students had completed the minimum requirement table and evaluation table together with the guidance of the teacher, they could proceed in these parts without any problem. Both groups had stated that mass of car, the total height of the car off the ground, length of car, width of car, number of wheels were restrictions and limitations. Also, both groups had stated that designing a car that managed to complete the 150 centimeter as soon as possible was a criterion. Also, the teacher had stated that both group should pay attention to the environment in which the race would take place and had stated that the environment in which the race would take place should have the following characteristics: initial velocity, material of inclined plane, angle between inclined plane and floor, length of inclined plane, width of inclined plane, material of inclined plane, length of horizontal plane and a horizontal line on the inclined plane.

As a result of the classroom observation of the researcher, the students had not been in difficulty in this step. According to the data obtained from the students' and teacher' feedbacks and as a result of the observations of the researcher, it was observed that in case of problems and the information filled in the tables provided easy progress for the students. Since they could associate the information previously given in the problem with the minimum requirement table and the evaluation table, in this step, they were able to determine what the problem gave us, what the restrictions and limitations and the criteria of the problem were. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The allocated time for this step before the activity had been administered was 15 minutes. As a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had not been revised.

6. Examine possible solutions

In this step, the students are expected to create at least 3 possible solutions along with the criteria, restrictions, and limitations they have identified in the previous step.

The teacher had stated "Create at least 3 possible solutions." The first group had produced three possible solutions. The first was to design a car whose body was made of wood and cardboard and whose wheels were wrapped with rubber. The second was to design a toy car with weight on it to prevent it from skidding while moving. The third was to design a toy car with 10 cm wide, 15 cm long and 5 cm high. The second group had produced three possible solutions. The first was to design a toy car having wooden body and wooden sticks supported by pipette, having wheels of plastic cover wrapped with rubber, having a triangular front, having 5 cm in height, having 15 cm in length, and having mass between 150 g and 250 g. The second was to design a car having a rigid plastic body, having wheels made of bottle covers wrapped with rubber, having a connection between the wheels provided with a pipette and a stick, and having a triangular front. The third was to design a toy car having a soft triangle shape on the front, having wheels connected to by passing sticks into the pipette.

As a result of the classroom observation of the researcher, the students were able to produce solutions by exchanging ideas within their groups. They worked on which solutions they could produce by using their knowledge obtained from their research. They had argued amongst themselves why they had determined these possible solutions. According to the feedback of the students, teacher, and researcher's observation, no problem was observed here. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The allocated time for this step before the activity had been administered was 15 minutes. As a result of the classroom observation of the researcher, the duration of this step had enough 15 minutes during the activity. Therefore, the allocated time had not been revised.

7. Choose the best possible/applicable/probable/feasible solution

The students proceeded to the next step by choosing the most probable solution with their own predictions, their researches and the guidance of the teacher and determining the dependent, independent, control-constant variables in the problem.

The first group had chosen the third solution among their possible solutions. This was to design a toy car 10 cm wide, 15 cm long and 5 cm high. The second group had chosen the first solution among their possible solutions. This was to design a toy car having wooden body and wooden sticks supported by pipette, having wheels of plastic cover wrapped with rubber, having a triangular front, having 5 cm in height, having 15 cm in length, and having mass between 150 g and 250 g. Then, the teacher had asked to students "Why did you choose these solutions?" Both groups had stated that they would complete the determined path as soon as possible with their solutions.

After these, the teacher had asked "Is there any dependent, independent, and control-constant variable in the problem?" The first group had stated that time was dependent variable, sizes of car and mass of car were independent variable, and types of inclined path, types of horizontal path and angle of gradient were control-constant variable. The second group had stated that time was dependent variable, materials used, dimensions of materials used, shape of materials used, and mass of the car were independent variables, and initial velocity of car, number of wheels, determined path to complete, 45 degree angled path, types of inclined path and types of horizontal path were control-constant variable.

Then, teacher had stated that time taken of the groups to finish the race was dependent, mass of car, the type of the wheels (material of the wheels), the surface of the wheels, size of the wheels, and the thickness of the wheels, the material of the shaft inside the wheel, the size of the shaft inside the wheel, total height of the car off the ground, length of car, width of car were independent, and initial velocity of cars, number of wheels were control-constant. Also, the teacher had stated that for race and measurement environment; material of inclined plane, angle between inclined plane and floor, length of inclined plane, width of inclined plane, material of horizontal plane, length of horizontal plane, a horizontal line on the inclined plane could be accepted as control-constant because all cars would race under the same conditions.

Then, the teacher had asked “When you consider all these restrictions-limitations, and your most likely solution, which materials can you choose to develop a toy car with desired features? Are the materials you mentioned before sufficient to develop a toy car with desired features?” and the teacher had asked "What materials do you need to improve this toy car?" The first group had wanted tongue sticks, stones, barbeque sticks, pipette, 8 pcs 5 liter water bottle cover, rubber band, silicone gun, scissors, cardboard box, utility knife, screw, adhesive. The second group had wanted tongue stick, sticks, pipette, 8 pcs 0.5 liter water bottle cover, scissors, silicone gun, utility knife, play dough, screw, thick rubber band.

Then, the teacher had said “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

The students had chosen the best possible solution of the 3 possible solutions they identified in the previous step. Then, students had determined the dependent, independent and control-constant variables in the problem. Also, they had chosen their materials for their prototypes. As a result of the classroom observation of the researcher, no problem was observed as in the previous activity.

The allocated time for this step before the activity had been administered was 10 minutes. As a result of the classroom observation of the researcher, the duration of this step had enough 10 minutes during the activity. Therefore, the allocated time had not been revised.

Day 2

8. Develop or redevelop a prototype

This step is the step that begins on the second day. In this step, the students are expected to develop a prototype or redevelop this prototype. They are expected to experience the variables they have identified in doing so with the inquiry experiments.

The teacher had brought the materials they had wanted to the groups and had said “Let's observe how variables affect to develop a prototype.”

Before making inquiry experiments, both groups had drawn the prototype that they wanted to work on. Figure 4.11. and Figure 4.12. show that students had drew the drafts of their toy cars and had then done some inquiry-based experiments with variables before developing toy cars.

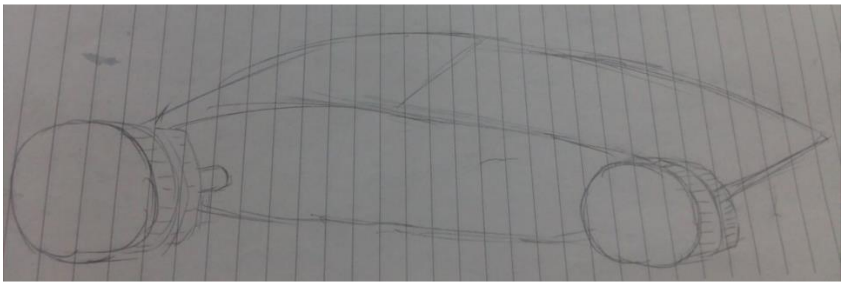

Figure 4.11. Drawing of toy car for the first group

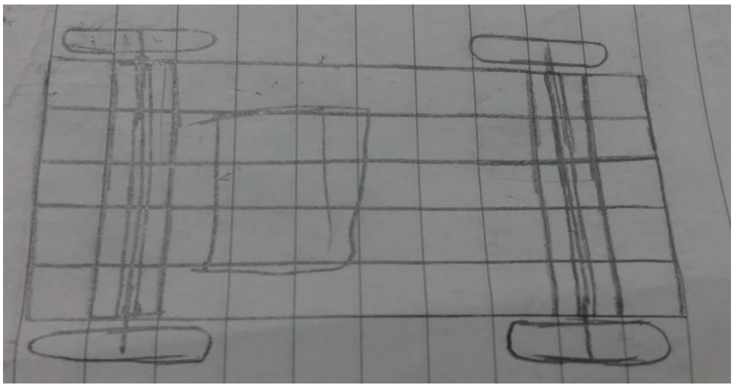

Figure 4.12. Drawing of toy car for the second group

Before the groups had started working, the researcher had prepared the race platform for the toy cars. The first group had chosen to change its possible solution over the wheel and the mass. First, the students from the first group had tested the 5 liter water bottle covers on the prepared platform. In the meantime, they had observed that the wheels were moving very smoothly and turning. Then, they had tried wrapping one round rubber band around the wheel. They had then tried two, three and four rubber bands, respectively. In the meantime, they had observed that they were able to move more easily on the road with the rubber band rotating four ones. They had then drilled holes in the middle to fasten their wheels together. They had got a connection here with barbecue sticks. They had tried to make sure that the friction force was minimum so that the wheel could move freely in the shaft here. They had then passed these sticks in a pipette and had tied them together. In this way, they had said that they had observed the wheels moving more easily. They had then made a flat body with tongue sticks and had finally integrated them on the wheels they had experienced on the platform, and so they had tried on the assembly. In the meantime, they had decided to try by putting stones on the car to avoid being slipping of prototypes and this time they had observed that the car was slipped less when the stones were added. In the meantime, a male student had stated that they should pay attention to the aerodynamic structure of the car by making the front of the car inclined as in the question directed by the teacher at the beginning of the lesson. The second group had chosen to change its possible solution over the wheels. First, the students from the second group had tried the 0.5 liter water bottle covers on the platform. Then, they had tried by sticking the two water bottle covers together. Here, they had observed that the wheels could move on the road easily. This time they had tried to wrap the thick rubber band with one layer and had then wrapped two thick rubber bands on the surface of the wheel to make a balanced system. They had observed the movements of the wheels. A male student had asked how the wheels would go if the mass was more. Therefore, they had put some play dough in the last wheel they had tried, and this time they had tried the wheel on the platform. They had stated that they would prefer to use this wheel in their prototype.

In this section, as a result of the classroom observation of the researcher, the students had made the prototypes more probable by experimenting with the dependent, independent and control-constant variables before making the toy car they wanted. As a result of the classroom observation of the researcher, the second group had finished developing its prototype five minutes before the first group. Figure 4.13. and Figure 4.14. show that both groups had developed their toy car.

Figure 4.13. is the visual reflecting the developing process of the first group. Figure 4.14. is the visual reflecting the developing process of the second group.

Figure 4.13. The visuals reflecting the developing process of the first group

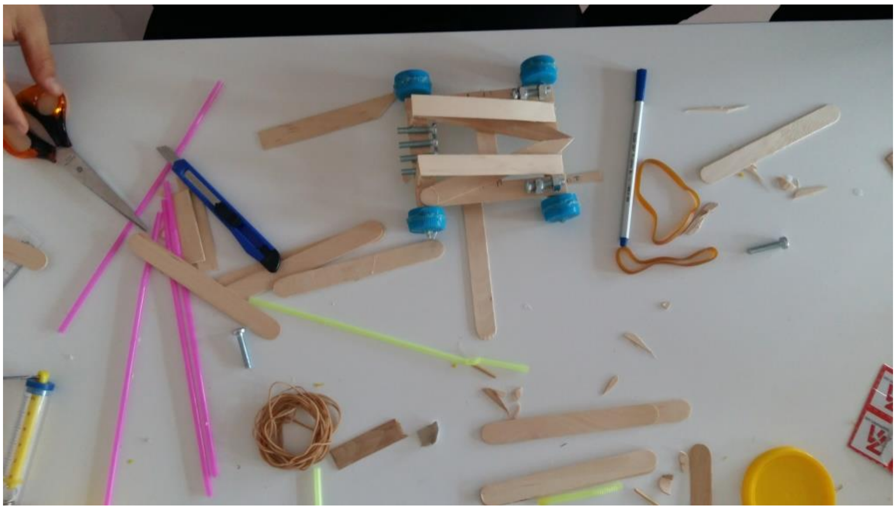

Figure 4.14. The visuals reflecting the developing process of the second group

After all of these, as a result of the classroom observation of the researcher, both groups had developed their toy cars. The first group had developed a toy car through the following steps. The students in the first group formed the car body to stick the tongue sticks with the silicon gun. The students preferred 4 plastic covers of 4.9 cm in diameter as car wheels. The width of these covers was 1.5 cm. In order to balance for the friction between the floor and the cover, they wrapped 4 thin rubber bands on each wheel. The students then pierced a hole on the center of these covers. The students used the barbecue sticks to tie the wheels together. Before doing this, the students passed the barbecue sticks through the pipette. The students passed the sticks between the wheels and connected the wheels to each other. The students then attached the wheels to the lower body of the car with the aid of a silicon gun. In order to balance the mass of the car, the students used stones and screws, and glued them onto the car body. The second group had developed a toy car through the following steps. The students in the second group formed the car body to stick the tongue sticks with the silicon gun. The students preferred 8 plastic covers of 3 cm in diameter as car wheels. The width of each cover was 0.8 cm. They filled the play dough into the covers. They then glued the inner surfaces of the covers together in pairs and obtained 4 wheels. The width of each wheel was 1.6 cm. In order to balance for the friction between the floor and the cover, they wrapped 2 pieces of thick rubber bands on each wheel. Students then pierced a hole on the center of these covers. The students used the barbecue sticks to tie the wheels together. Before doing this, students passed the barbecue sticks through the pipette. The students passed the sticks between the wheels and connected the wheels to each other. The students then attached the wheels to the lower body of the car with the aid of a silicon gun. In order to balance the mass of the car, the students used screws, and glued them onto the car body. Final version of the toy cars of each group is in Figure 4.15.

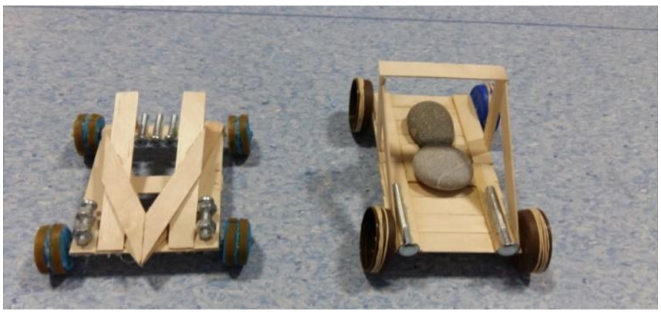

Figure 4.15. Toy cars (Right one is the first group's car, left one is the second group's car)

As a result of the classroom observation of the researcher, for handcraft, male students were more active than the female students by designing car prototype. The researcher asked “What was the most challenging part of your STEM education that you had difficulty in implementing?” As a result of the interview with the students, the students had expressed that they were very difficult to determine the design of the wheel. They had stated that it was difficult to balance the friction force between the wheel and the ground, and to allow the car to move on the road. Finally, they had overcome this difficulty with inquiry experiments. The researcher had not needed a revision of this part because it was a place that required doing inquiry experiments by the students.

As a result of the classroom observation of the researcher and as a result of the interview with the teacher, in this part, except above, the students did not have any difficulties in terms of implementation and they completed the process by experimenting with variables. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The researcher asked “What were the most comfortable parts during STEM education?” As a result of the interview with the students, the students said that the most comfortable part was to design the car.

The allocated time for this step before the activity had been administered was 115 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 100 minutes during the activity. Therefore, the allocated time had been revised.

9. Test and evaluate the prototype by individual group

In this step, the students are expected to first check whether their cars have the minimum requirements when evaluating them, and then test their cars themselves. In this step, the students are expected to continue with the next step if prototypes are working; or they are expected to go to the previous step if prototypes are not working.

In this step, both groups had looked at whether their prototypes had met the minimum requirements or not. According to the problem, the mass of the cars should be between 50 g and 250 g, the total height of the car off the ground (distance from the bottom of the wheel to the highest point of the car) should be between 5 cm and 20 cm, the length of the car (distance between the front and rear ends of the wheels) should between 10 cm and 20 cm, the width of the cars (distance between the outer ends of the wheels) should be 10 cm and 15 cm. Number of wheels should be 4. According to these measurements, the car of the first group was 226.40 g in mass, 10.5 cm in height off the ground, 20 cm in length and 13.2 in width, while the car of the second group was 152.70 g in mass, 6.3 cm in height off the ground, 14.7 cm in length and 13.9 cm in width. Although specific reference range for the diameter of the wheels and the width of the wheels was not given, the wheel diameter and width they had used are as follows: 4.9 cm in diameter for the first group and 3 cm in diameter for the second group, 1.5 cm in width for the first group and 1.7 cm in width for the second group. The measurements are in Table 4.15. Figure 4.16 and Figure 4.17. represent the measurements of the mass of toy cars.

Table 4.15. *Measurements of the Characteristics of Toy Cars*

Measurements of the Characteristics of Toy Cars		
	First group	Second group
Mass of the car	226.40 g	152.70 g
Total height of the car off the ground (distance from the bottom of the wheel to the highest point of the car)	10.5 cm	6.3 cm
Length of the car (distance between the front and rear ends of the wheels)	20 cm	14.7 cm
Width of the car (distance between the outer ends of the wheels)	13.2 cm	13.9
Diameter of the wheel	4.9 cm	3 cm
Width of the wheel	1.5 cm	1.6 cm

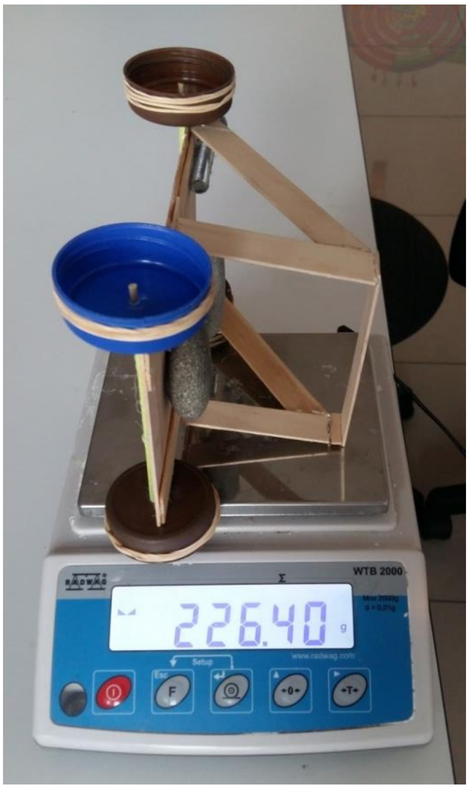

Figure 4.16. Mass of the first group’s car

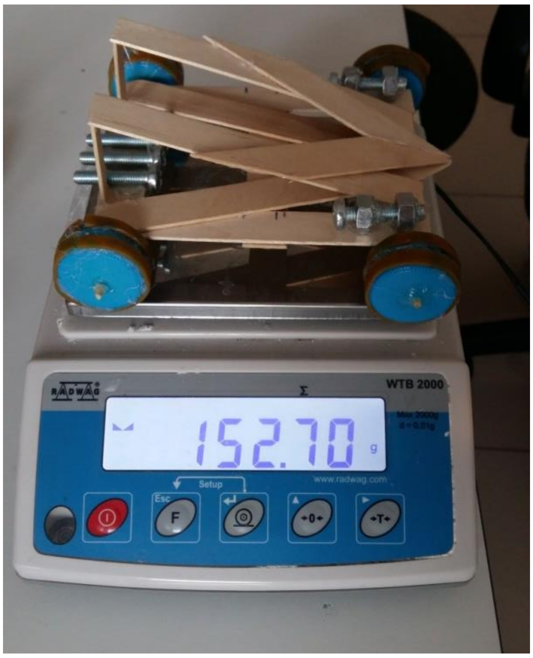

Figure 4.17. Mass of the second group’s car

In this step, the prototypes of the students met the minimum requirements and both groups were able to develop a prototype with the expected characteristics in their measurements.

After that, the groups had tested their cars on the platform. As a result of the classroom observation of the researcher, the toy car prototype of the second group had completed the determined without any problem. The car of the second group was successful at test part. Therefore, no problems were observed in this step for the second group. However, there was a problem for the first group. Their prototype met the minimum requirements. As a result of the classroom observation of the researcher, in test part, when the car of the first group had finished the inclined plane and had reached the horizontal road during its first inquiry experiments measurement, the wheels had been separated from the body of the car with their sticks. Therefore, they had gone back to the previous step to determine the problem in their car and redevelop the car. In this case, as a result of the classroom observation of the researcher, they had investigated the reasons why these cars had not worked and had identified the problem, and had redeveloped it again. It would be advantageous to have big wheels according to their predictions and they would finish the race first. They found that the problem here was due to the dexterity of the design part. Then, the students made sure their cars were working by testing again.

The researcher asked “Was there any situation you did not anticipate during STEM education?” As a result of the interview with the students, students had stated that in a group thought that their cars would win the race while the cars competed in the final part of the competition, while their cars descended from the inclined plane and the wheels left the body with their sticks. They said they didn't expect that. The reason for this was that they could not fasten the wheels to the body of the car with enough support.

As a result of the classroom observation of the researcher and as a result of the interview with the teacher, no problem was observed here. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The allocated time for this step before the activity had been administered was 20 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had been revised.

10. Share

In this step, the teacher is expected to share the prototypes with the whole groups and to evaluate the prototypes.

In this section, the teacher made measurements about the prototypes of the groups and identified the first group by explaining the reasons. It was observed that the students were very excited about the sharing of the prototypes.

The characteristics of the prototypes of the groups are as follows. According to the problem, the mass of the cars should be between 50 g and 250 g. The total height of the car off the ground (distance from the bottom of the wheel to the highest point of the car) should be between 5 cm and 20 cm, the length of the car (distance between the front and rear ends of the wheels) should between 10 cm and 20 cm, the width of the cars (distance between the outer ends of the wheels) should be 10 cm and 15 cm. Number of wheels should be 4. According to these measurements, the car of the first group was 226.40 g in mass, 10.5 cm in height off the ground, 20 cm in length and 13.2 in width, while the car of the second group was 152.70 g in mass, 6.3 cm in height off the ground, 14.7 cm in length and 13.9 cm in width. Although specific reference range for the diameter of the wheels and the width of the wheels was not given, the wheel diameter and width they used are as follows: 4.9 cm in diameter for the first group and 3 cm in diameter for the second group, 1.5 cm in width for the first group and 1.7 cm in width for the second group. The measurements are in Table 4.16 in ninth step. Figure 4.16. and Figure 4.17. in ninth step represent measurements of the mass of toy cars.

The features of these toy cars are as follows. The first group developed a toy car through the following steps. The students in the first group formed the car body to stick the tongue sticks with the silicon gun. The students preferred 4 plastic covers of 4.9 cm in diameter as car wheels. The width of these covers was 1.5 cm. In order to balance for the friction between the floor and the cover, they wrapped 4 thin rubber bands on each wheel. The students then pierced a hole on the center of these covers. The students used the barbecue sticks to tie the wheels together. Before doing this, the students passed the barbecue sticks through the pipette. The students passed the sticks between the wheels and connected the wheels to each other. The students then attached the wheels to the lower body of the car with the aid of a silicon gun. In order to balance the mass of the car, the students used stones and screws and glued them onto the car body. The second group developed a toy car through the following steps. The students in the second group formed the car body to stick the tongue sticks with the silicon gun. The students preferred 8 plastic covers of 3 cm in diameter as car wheels. The width of each cover was 0.8 cm. They filled the play dough into the covers. They then glued the inner surfaces of the covers together in pairs and obtained 4 wheels. The width of each wheel was 1.6 cm. In order to balance for the friction between the floor and the cover, they wrapped 2 pieces of thick rubber bands on each wheel. The students then pierced a hole on the center of these covers. The students used the barbecue sticks to tie the wheels together. Before doing this, the students passed the barbecue sticks through the pipette. The students passed the sticks between the wheels and connected the wheels to each other. The students then attached the wheels to the lower body of the car with the aid of a silicon gun. In order to balance the mass of the car, the students used screws and glued them onto the car body. Final version of the toy cars of each group is in Figure 4.15. in eighth step.

The total of 6 measurements had been taken for each car and a healthier data process had been obtained. Measurements were made to determine how long the prototypes could take the determined path. According to the measurements, the first group’s average second was 0.841 second, while the second group’s average second was 0.963 second. The measurements obtained are as follows in Table 4.16.

Table 4.16. *Time Measurements for Toy Cars*

Time Measurements for Toy Cars		
	First Group	Second Group
First measurement	0.98 second	0.88 second
Second measurement	0.83 second	0.96 second
Third measurement	0.80 second	1.16 second
Fourth measurement	0.80 second	0.95 second
Fifth measurement	0.86 second	0.95 second
Sixth measurement	0.78 second	0.88 second
Average	0.841 second	0.963 second

As a result of the classroom observation of the researcher, the students had more actively engage starting from the possible solution part of the activity. Also, as a resuşt of the classroom observation of the researcher, the students had a good time in the activity process, especially in second day they had better time because of the design part. As a result of the classroom observation, that means the students were more active in both physically and mentally in second day of the activities. As a result of the interview with the students, the students had expressed the same sharing with the researcher's observation. Also, during the activity processes, as a result of the interview with the students, the students had stated that their communication with the teacher was strong.

The researcher asked “Are there any places where you think the study needs revision? If so, what are these?” after the competition. As a result of the interview with the students, the students said that there was not any need to revision because they like designing the car.

The researcher asked "What was the most challenging part of your STEM education that you had difficulty in implementing?" As a result of the interview with the teacher, he stated that he had not pushed me too much; he said that he just had to go a little higher than expected in terms of time allocated to the relevant parts during the activity. In addition, the researcher asked "Did you have difficulty in guiding students during STEM education?" As a result of the interview with the teacher, he stated that he had not difficulty in guiding students during STEM education.

The researcher asked "During STEM education, what questions did you guide students to provide information that they could not foresee?" As a result of the interview of the teacher, the teacher had stated that in the process students did not encounter any unforeseen situations. However, the teacher said that he prepared extra questions for any possible unforeseen situations. They were "How should be the friction between car and the ground? How should be the friction between the shaft in the wheel and the wheel?"

The researcher asked "Has the lesson plan and material been achieved to the objectives? Yes or No? If your answer is no, please indicate which objectives have not been achieved." As a result of the interview with the teacher, he stated that all materials were suitable with the objectives.

The allocated time for this step before the activity had been administered was 20 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had been revised.

In addition to all the activity process, as a result of the interview with the teacher, the teacher also shared that the time intervals for each activity should be revised. The researcher also noticed this important point. In most places, the set time was inadequate and extended during the activity period. So the researcher revised these parts. In this activity, time set for activity increased from 240 minutes to 260 minutes. Table 4.17. shows the Timing of Toy Car Activity.

Table 4.17. *The Timing of Toy Car Activity*

The Timing of Toy Car Activity		
10 Steps of the Proposed Model to Implement STEM PBL Activity	Timing Before Implementation	Timing After Implementation
1. Identify the need	3 min	15 min
2. Generate ideas/Brainstorm	7 min	15 min
3. Searching for the answer	30 min	45 min
4. Associate the disciplines	5 min	15 min
5. Determine the criteria, materials, restrictions, limitations of the problem	15 min	15 min
6. Examine possible solutions	15 min	15 min
7. Choose the best possible/applicable/probable/feasible solution	10 min	10 min
8. Develop or redevelop a prototype	115 min	100 min
9. Test and evaluate the prototype by individual group	20 min	15 min
10. Share	20 min	15 min
Total Timing	240 min	260 min

4.3. Third activity: Third Iteration (Table Activity)

In the third activity, the parts that the points with problems and without problems encountered in each step have been examined in detail. In other words, if the problem is not observed in one step of the second activity and the problem is observed in the same step of the third activity, it explains why the problem was observed in the same step of this activity and how it was revised. Also, if the problem is observed and revised in one step of the second activity and the problem is not observed in the same step of the third activity, it is explained why the problem is not observed in the same step of this activity.

Day 1

1. Identify the need

In this step, the students are expected to analyze the given problem and determine the need. To do this, they need to be able to determine what the problem gives and what the problem does not give. The students should be able to fill the minimum requirement table with the information in the problem and complete the evaluation table with the guidance of the teacher. Also, the students and the teacher are expected to be able to comprehend the integration of the problem with daily life.

The context-based problem presented in this section is as follows.

Problem: You started working at a buffet for a summer vacation. Your boss ordered too much water. Each water pack contains 12 water bottles, and each of which is 0.5 liters. You can't keep your water packets out of the buffet because the weather is too hot, and all the refrigerators are full of ice cream. That's why you need to keep the water bottles in the buffet. However, the area you can allocate for water bottles is only 2500 square centimeters. For the top material of the table, the boss wants to use the 0.3 cm thick decota sheet, which he used in the signboard last month and remain a residual material. You cannot put the water bottles in direct contact with the ground because it can be used in buffet, bakery and so on where are certain conditions for keeping food and beverages in places. According to these conditions, you should keep food and beverages at a height from the ground between minimum 8 centimeters and maximum 20 centimeters from the ground. Your boss wants to make a table with choosing one of the materials of 15 toilet paper rolls, 15 paper towel rolls, 20 cardboard cups and various sized cardboard boxes. How can you design a table to keep water bottles from tipping over under these circumstances?

The teacher had divided the students into groups and had started discussions for problem analysis. The teacher had asked them what they had thought of the problem and what the problem had given them.

The first group had stated that they could reach length of the legs of the table, the type of the upper material of the table. The second group had stated that within the problem they could reach the area reserved for the table, the length of the table's legs, and the upper material of the table.

Then, the teacher had asked "What are the minimum requirements and criteria stated in the problem?" The first group had stated that area reserved for water bottles, height of table legs from the ground, table top material, number of table top material, thickness of table top material, materials that can be used for the legs of the table wheels were the minimum requirements. The second group had stated that area reserved for water bottles, height of table legs from the ground, table top material, number of table top material were the minimum requirements.

Then, the teacher had asked “What is the criterion?” Both groups had stated that the criterion presented in the problem was that the table would be the most strength table to carry max number of water bottles.

After that, the teacher had stated that the area reserved for water bottles is 2500 square centimeter, height of table legs from the ground is between 8 cm and 20 cm, table top material is dekota sheet, number of table top material is 1 piece, thickness of table top material is 0.3 cm, materials that could be used for the legs of the table were 15 paper towel rolls, 15 toilet paper rolls, 20 cardboard cups with different sizes, cardboard boxes of various sizes were the minimum requirements. Also, the teacher had stated that designing a table that managed to carry the maximum number of water bottles without tipping over was a criterion for evaluation table.

Here, as a result of the classroom observation of the researcher, under the guidance of the teacher, the students had completed the minimum requirement table and the evaluation table.

Then, the teacher had asked "What is the need in the problem?" The first group had stated that the need was a table having 2500 centimeter square area, being made using different daily life materials. The second group had stated that the need was to design a table with maximum strength with minimum requirements.

On top of that, the teacher had stated by revising and integrating the answers from the students “The need is that a table which carries max number of water bottles developed as the most strength table by considering max 2500 square centimeter in area reserved for water bottle table, having height of table legs from the ground is between 8 cm and 20 cm, having dekota sheet table top material, having 1 piece of table top material, having thickness of table top material is 0.3 cm, using one type of materials that can be used for the legs of the table are max 15 paper towel rolls, max 15 toilet paper rolls, max 20 cardboard cups, cardboard boxes of various sizes for legs of table.” This part was able to be solved in this way so no revision was required.

As a result of the classroom observation of the researcher, students could relate the daily life examples with the problem. The minimum requirement table and the evaluation table were completed by the students. They had completed this step with teacher-guided question and answer. In this step, it was observed that according to the teacher's feedback and the researcher's observation, the students had had no difficulties.

The researcher asked "Did you have difficulty in connecting the problem situation given during STEM education with daily life?" As a result of the interview with the students, one male and one female student stated that they had a little difficulty in this issue, but then, they understood the problem better with examples in their search part with internet.

The researcher asked “Did you have difficulty in associating the problem situation given during STEM education with daily life?” As a result of the interview with the teacher, he stated that he did not have difficulty in associating the problem situation given during STEM education with daily life and at this point.

With the revision in the first activity, the visual was integrated to the instructional materials. The visual added here is as in Figure 4.18.

Figure 4.18. Table as visual for instructional materials

Except all above, in this step, it was noted thanks to the teacher's feedback and the researcher’s observation that the students had no difficulties.

The allocated time for this step before the activity had been administered was 3 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 10 minutes during the activity. Therefore, the allocated time had been revised.

2. Generate ideas/Brainstorm

In this step, the students are expected to discuss the situation and produce ideas by seeking answers to questions such as whether they have developed such a table before or what would they have done if they had faced such a situation.

In this step, as a result of the classroom observation of the researcher, the students had exchanged their ideas with their group friends and had shared their previous experiences. Some had expressed that they made a table before. Some had expressed that they had not encountered such a situation. Those who had made table before told their friends about how they had made this table. They had stated that they had used cardboard box to design a table with 4 legs. According to the feedback of the students, teacher and researcher's observation, no problem had been observed here. In addition, as a result of the classroom observation of the researcher, male students had produced more ideas about characteristics and design of the prototype in the table activity than female students. These ideas had been about the design of the legs of the table, how the table could be made, what the materials of table could be. Also, as a result of the interview with the students, the students had stated that STEM activities had been the activities forcing to think. In this step, according to the feedbacks of the students, teacher, and researcher's observations, there had been no problem. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 7 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 10 minutes during the activity. Therefore, the allocated time had been revised.

3. Searching for the answer

In this step, the students are expected to answer to the following questions; “Did you make a table before?” and “Is this previously made table like table you need?”

Then, teacher had asked “Did you make a table before?” and “Is this previously made table like table you need?” After that, the teacher had asked the following questions to the students “What kind of table has been made so far?”, “What solutions have been found?” and “What information is made use of the design of tables?” Then, the teacher had given to a 9th grade MEB physics book and computer to each group and the students had been expected to seek answer these questions.

According to the teacher, the most comfortable part of the students had been this step because the teacher had observed and had stated that the students could make correct researches about the problem.

The teacher and the researcher had observed that the students had researched the properties of matter unit, and strength. The students from the first group had stated that they had reached the relationship between strength of materials and shapes of materials, and properties of matter unit. The students from the second group had stated that they had reached the strength in properties of matter unit, strength of uniform geometric shapes.

After the search, the teacher had asked “Which resources did you use and what did you find?” and “Which materials are used in making tables?”

Both groups had stated that they had used MEB Physics book to get information about subjects, and Internet to get detail information about subjects and design. The first group had stated that during their research, the tables had been previously made by using wooden materials with different sizes. The second group had stated that during their research, the tables had been previously made by using plastic and cardboard materials.

The researcher asked “What were the most comfortable parts during STEM education?” As a result of the interview with the teacher, he stated that searching for the answer part was most comfortable part for him and students.

The researcher asked “Are there places where you think the activity and its execution need revision? If so, what are these?” As a result of the interview with the teacher, he stated that there were no revision in the activity and added the activities were successful. He stated that only the time reserved for the activities should be revised.

As a result of the classroom observation of the researcher, the students had proceeded in harmony discussing their research with each other. According to the feedback of the students, teacher, and researcher's observation, no problem had been observed here. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 30 minutes. As a result of the classroom observation of the researcher, the duration of this step had lasted 30 minutes during the activity. Therefore, the allocated time had not been revised.

4. Associate the disciplines

In this step of the previous activity, the concept of "Associate the disciplines" was revised as "Associate the courses" in the student activity guide sheet after the confusion between the concept of discipline and the concept of sub-branch of physics. After this revision, in this step in this activity, the teacher had directed the students with the concept of "Associate the courses".

The teacher had asked “Which courses do you need for the solution of this?” Both groups had stated that mathematics, physics, engineering, technology and design were the courses. Then, the teacher had stated physics as science in here, mathematics, engineering and technology were the courses mentioned as disciplines. Then, the teacher had asked “Which chapters will you need to know about in these lessons’ content?” Both groups had stated the lesson contents as courses were Properties of Matter in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a table. Then, the teacher had asked “Which subtitles of chapters are useful for your problem-solving?” Both groups had stated that strength had been necessary to design a table.

When guided by this concept, there was no problem as in the previous activity, and as a result of the classroom observation of the researcher, students were able to access the expected answers as science, mathematics, engineering and technology. Therefore, the researcher and the teacher stated that this step was able to be proceeded without any difficulties. No revision had required at this step.

The allocated time for this step before the activity had been administered was 5 minutes. As a result of the classroom observation of the researcher, the duration of this step had lasted 5 minutes during the activity. Therefore, the allocated time had not been revised.

5. Determine the criteria, materials, restrictions, limitations of the problem

In this step, the students are expected to answer the following questions; What information does the problem give us?, Does the problem put restrictions and limitations on us?, What are the criteria of the problem?

The teacher had asked respectively “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?” and “What are the criteria of the problem?” and had waited the students answer. As the students had completed the minimum requirement table and assessment table together with the guidance of the teacher, they could proceed in these parts without any problem. First group had stated that area reserved for water bottles, height of table legs from the ground, materials that can be used for the legs of the table were restrictions and limitations. Second group had stated that area reserved for water bottles, height of table legs from the ground, table top material, thickness of table top material, materials that can be used for the legs of the table were restrictions and limitations. Then, the teacher had integrated and had summarized the answers of groups that area reserved for water bottles, height of table legs from the ground, table top material, number of table top material, thickness of table top material, materials that can be used for the legs of the table were restrictions and limitations. Also, both groups had stated that designing a table that managed to carry the maximum number of water bottles without tipping over was a criterion.

As a result of the classroom observation of the researcher, the students had not been in difficulty in this step. As a result of the classroom observation of the researcher and as a result of the interview with the teacher, in case of problems and the information filled in the tables provided easy progress for the students. Since they could associate the information previously given in the problem with the minimum requirement table and the evaluation table, in this step, they were able to determine what the problem gave us, what the restrictions and limitations and the criteria of the problem were. Therefore, no revision had required at this step. In this step, there was no problem as in the same step of the previous activity.

The allocated time for this step before the activity had been administered was 15 minutes. As a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had not been revised.

6. Examine possible solutions

In this step, the students are expected to create at least 3 possible solutions along with the criteria, restrictions, and limitations they have identified in the previous step.

The teacher had stated "Create at least 3 possible solutions." The first group had produced three possible solutions. The first was to design a table having toilet paper rolls put on top of each other as the legs of the table. The second was to design a table having toilet paper rolls placed as scattered under the dekota sheet as the legs of the table. The third was to design a table having the cardboard cups placed in the middle of the dekota sheet as the legs of the table. The second group had produced three possible solutions. The first was to design a five-legged table, each of which is formed by the combination of 3 rolls of toilet paper rolls. The second was to design a table having the cardboard box-legs. The third was to design a table having rectangular legs.

As a result of the classroom observation of the researcher, the students were able to produce solutions by exchanging ideas within their groups. They had worked on which solutions they could produce by using their knowledge obtained from their research. They had argued amongst themselves why they had determined that solution. According to the feedback of the students, teacher, and researcher's observation, no problem was observed here. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 15 minutes. As a result of the classroom observation of the researcher, the duration of this step had enough 15 minutes during the activity. Therefore, the allocated time had not been revised.

7. Choose the best possible/applicable/probable/feasible solution

The students proceeded to the next step by choosing the most probable solution with their own predictions, their researches and the guidance of the teacher and determining the dependent, independent, control-constant variables in the problem.

The first group had chosen the second solution among their possible solutions. This was to design a table having toilet paper rolls placed as scattered under the dekota sheet as the legs of the table. The second group had chosen the first solution among their possible solutions. This was to design a five-legged table, each of which is formed by the combination of 3 rolls of toilet paper rolls. Then, the teacher had asked to students “Why did you choose these solutions?” The first group had stated that the legs of the table should be placed as scattered so that the mass of the water bottles could be balanced. The second group had stated that in order for the water bottles to remain in balance, it was necessary to cluster the legs of the table instead of scattered. Both groups had stated that the most strength uniform geometric-shaped object was the sphere in nature, but they had stated that they could not use the spherical legs for tables. Therefore, they had stated that they would use the toilet paper rolls whose form was cylindrical form similar close to the spherical form.

After these, the teacher had asked “Is there any dependent, independent, and control-constant variable in the problem?” The first group had stated that max number of water bottles for tables was dependent, height of table legs from the ground, materials that could be used for the legs of the table, and number of legs were independent, area reserved for water bottles, table top material, number of table top material, thickness of table top material were control-constant variables. The second group had stated that max number of water bottles for tables was dependent, height of table legs from the ground, materials that could be used for the legs of the table, size of the legs, shape of the legs, and number of legs were independent, area reserved for water bottles, table top material, number of table top material, thickness of table top material were control-constant variables.

Then, teacher had stated that max number of water bottles for tables was dependent, height of table legs from the ground, materials that could be used for the legs of the table, size of the legs, shape of the legs, and number of legs were independent, area reserved for water bottles, table top material, number of table top material, thickness of table top material were control-constant variables.

Then, the teacher had asked “When you consider all these restrictions-limitations, and your most likely solution, which materials can you choose to develop a table with desired features? Are the materials you mentioned before sufficient to develop a table with desired features?” and the teacher had asked "What materials do you need to improve this table?" The first group had wanted utility knife, scissors, white thin cardboard paper, silicon gun, ruler, 15 pcs toilet paper rolls, dekote sheet, rope, and adhesive. The second group had wanted 15 pcs toilet paper rolls, ruler, silicon gun, scissors, utility knife, dekota sheet, and adhesive.

Then, the teacher had said “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

The students had chosen the best possible solution of the 3 possible solutions they identified in the previous step. Then, the students had determined the dependent, independent and control-constant variables in the problem. Also, they had chosen their materials for their prototypes. According to the feedback of the students, teacher and researcher's observation, no problem was observed as in the previous activity. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 10 minutes. As a result of the classroom observation of the researcher, the duration of this step had enough 10 minutes during the activity. Therefore, the allocated time had not been revised.

Day 2

8. Develop or redevelop a prototype

This step is the step that begins on the second day. In this step, the students are expected to develop a prototype or redevelop this prototype. They are expected to experience the variables they have identified in doing so with the inquiry experiments. The students experienced the dependent, independent and control-constant variables with inquiry experiments.

The teacher had brought the materials they had wanted to the groups and had said “Let's observe how variables affect to develop a prototype.”

In this section, the students made the prototypes more probable by experimenting with the dependent, independent and control-constant variables before making the table they wanted.

Before the groups had started working, the researcher had brought the buckets for the tables.

Before the students had started to work, the teacher had given a bucket and 12 pieces of 0.5 liter water to each group. While doing the experiments, the teacher had wanted the groups to use the bucket and see how each group's table would react to these 12 water bottles. Thus, during the experiments, they would be able to identify places that did not work while developing their prototypes. The first group had chosen to change its possible solution over the length of legs of the table. First, the students from the first group had placed two rolls of toilet paper vertically on top of each other, with 4 legs under the decota sheet on each corner. Then, they had observed what happened when they had put one by one water bottle to the bucket. In this way, they had stated that there was a prototype that would not be very strength. Then, they had tried to place the rolls vertically under the tables, one by one. This time, they had stated that the legs were more strength than their first attempts because the legs were shorter. Also, one male student had stated that as the length of the legs had increased, the strength had decreased. They had stated that they would design a table leg with the rolls of toilet paper to be placed perpendicular to decota sheet. The second group had chosen to conduct their experiments with the location and number of legs. First, the students from the second group had chosen to put the toilet paper rolls in the bottom four corners of the table vertically. When they had put a water bottle on the bucket on the table one by one, they observed that the middle of the table was bent. As a result, they had realized that they had also had to put the legs in the middle of the table. Later, they had stated that when they had put a roll in the middle, they had observed that the middle of the table was less bent. Thus, they had decided to make five legs by turning the leg into groups of three, as in their possible solutions. They had placed one of them in the bottom center of the table. They had placed other legs around the center, close to the center. In this way, they had stated that they would obtain a more strength table and had stated that they would work on this prototype.

After all of these, both groups had developed their tables. The first group developed a table through the following steps. The first group used a decota sheet with an area of 2500 square centimeters for the surface of the table. The students from the first group then chose the rolls of toilet paper to make a foot on the sheet. They used 15 rolls of toilet paper. They attached 4 of the toilet paper rolls with a silicone gun to the center of the plane of the table and tied the perimeter with a rope. The rest of the rolls were placed in random. They put white cardboard paper under the table legs. They said that the reason they did this is to keep the table in balance everywhere and increase its strength. The second group used a decota sheet with an area of 2500 square centimeters for the surface of the table. The students from the second group then chose the rolls of toilet paper to make a foot on the sheet. They used 15 rolls of toilet paper. With these rolls, they formed groups of three. They placed a group of three rolls in the very middle of the sheet. They placed other groups around it. They said that the reason for doing this is to provide balance because the water bottles will be placed in the middle of the table. They stressed that their tables would be more strength.

As a result of the classroom observation of the researcher, the first group had finished developing its prototype five minutes before the second group. Figure 4.19. is the visual of the table of the first group, Figure 4.20. is the visual of the legs of the table of the first group, Figure 4.21. is the visual of the table of the second group, and Figure 4.22. is the visual of the legs of the table of the second group.

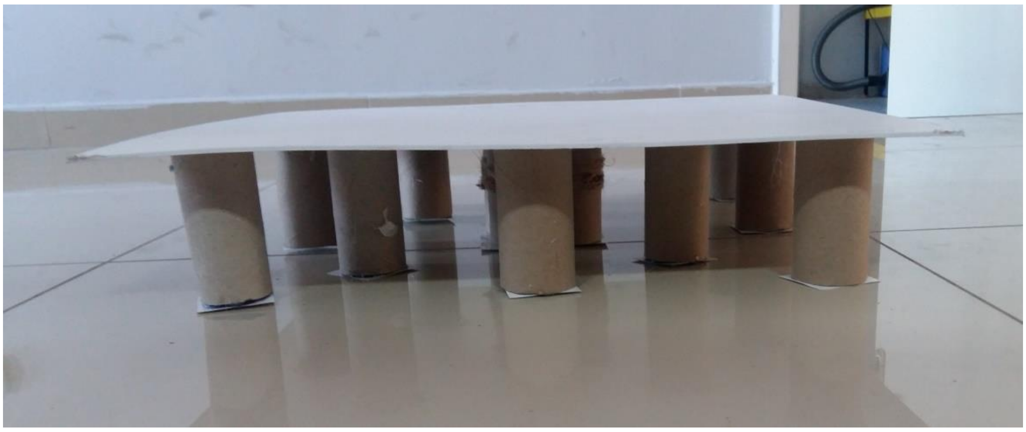

Figure 4.19. The table which had been developed by the first group

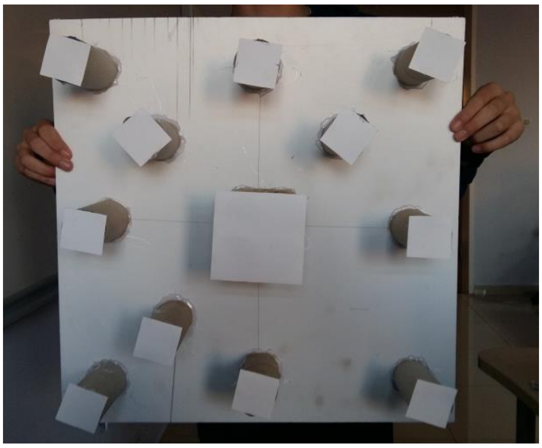

Figure 4.20. The legs of the table which had been developed by the first group

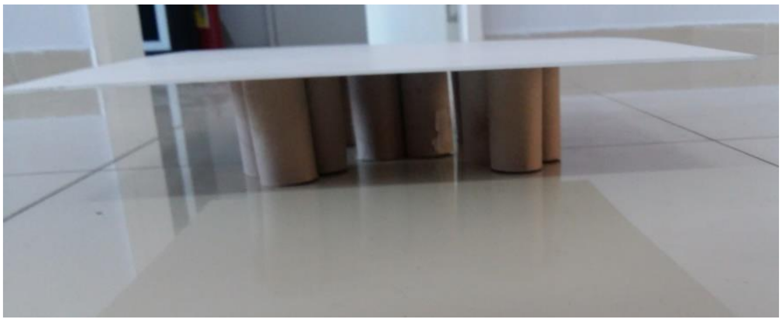

Figure 4.21. The table which had been developed by the second group

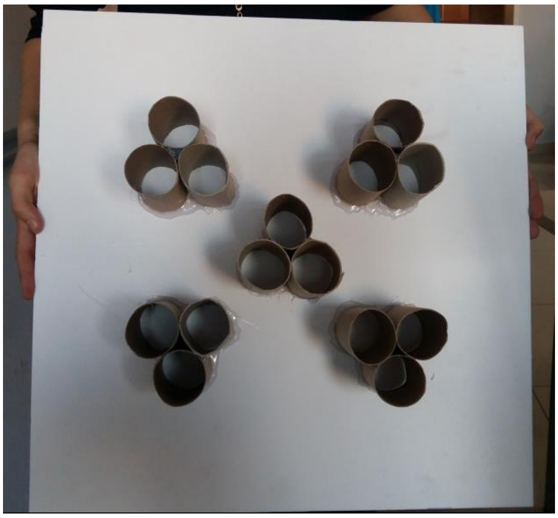

Figure 4.22. The legs of the table which had been developed by the second group

As a result of the classroom observation of the researcher, the students were very excited in this step and for handcrafts; male students were more active than the female students.

The researcher asked “Are there any places where you think the study needs revision? If so, what are these?” As a result of the interview with the students, one male student stated that it would be better if they made a table directly and that he said that previous steps up to develop a prototype part (developing a table for water bottles) were unnecessary. However, since this was a material development study, this feedback from the student was not taken into consideration because certain steps for engineering design process had to be followed. Therefore, no revision had required at this step. Also, the researcher asked “What were the most comfortable parts during STEM education?” As a result of the interview with the students, students said that the most comfortable part was to develop the table for water bottles.

According to the teacher’s feedbacks and researcher's observations, in this part, except above, the students did not have any difficulties in terms of implementation and they completed the process by experimenting with variables.

The allocated time for this step before the activity had been administered was 115 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 110 minutes during the activity. Therefore, the allocated time had been revised.

9. Test and evaluate the prototype by individual group

In this step, the students first checked whether their tables had the minimum requirements when evaluating them, and then tested their tables themselves. In this step, the students are expected to continue with the next step if prototypes are working; or they are expected to go to the previous step if prototypes are not working.

In this step, both groups had looked at whether their prototypes had met the minimum requirements or not. According to the problem, the area reserved for water bottles should be 2500 square centimeters, the top material of the table should be decota sheet, the thickness of the decota sheet should be 0.3 cm, the height of the legs should be between minimum 8 cm and maximum 20 cm, the materials of the legs should be a variety of toilet paper rolls, paper towel rolls, cardboard cups with different sizes. According to these measurements, the table of the first group was 2500 centimeter square in area, 8 cm in height of the table legs, 0.3 cm in thickness of decota sheet, 15 pcs toilet paper rolls in the legs of the table, while the table of the second group was 2500 centimeter square in area, 8 cm in height of the table legs, 0.3 cm in thickness of decota sheet, 15 pcs toilet paper rolls in the legs of the table. The measurements are in Table 4.18.

Table 4.18. *Characteristics of the Tables*

Characteristics of the Tables		
	First Group	Second Group
Area	2500 centimeter square	2500 centimeter square
Height of the legs	8 cm	8 cm
Thickness of the decota sheet	0.3 cm	0.3 cm
Materials used for the table legs	15 toilet paper rolls	15 toilet paper rolls
The total number of toilet paper rolls used for the design of the legs	15 pcs (a total of 12 legs, 11 rolls were placed in random, other 4 rolls were combined as 1 leg in the middle of the table)	15 pcs (a total of 5 legs, each of which is a combination of 3 rolls; 1 leg in the middle of the table, other 4 legs were placed around the middle leg)

In this step, the prototypes of the students met the minimum requirements and were able to develop a prototype with the expected characteristics in their measurements.

After that, the groups had tested their tables with the buckets. The students from the second group had placed a bucket on the table. Then, they had placed 12 bottles of 0.5 liter water, one by one, into this bucket. 12 bottles of 0.5 liter water was 6 kg. They had observed that the water bottles did not overturn and that the legs of the table could carry the water bottles without skewing. The table of the second group was successful at test part. Therefore, no problems were observed in this step for the second group. However, there was a problem for the first group. Their prototype met the minimum requirements. The first group had placed a bucket on the table. Then, they had placed 12 bottles of 0.5 liter water, one by one, into this bucket. 12 bottles of 0.5 liter water was 6 kg. They had observed that the water bottles did not overturn, but two of the legs of the table were bended. Then, when more water bottles were added, they had foreseen that the table's legs could not carry the water bottles. Therefore, they had immediately gone to the steps of redeveloping their table and they had worked again on their legs of the table. This time, they had changed the location of bended legs. When they had tested this time, they had stated that they did not observe any bend on their legs of the table when they had added 12 water bottles. The visuals related to the test part are as in Figure 4.23. and Figure 4.24.

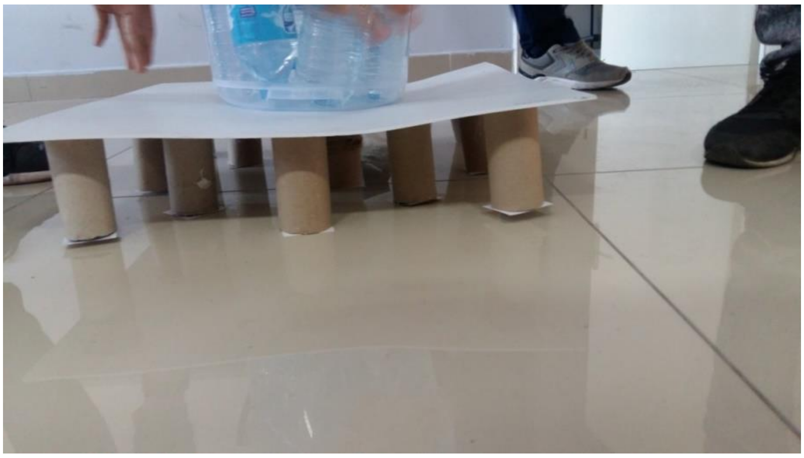

Figure 4.23. The table of the first group in testing part

Figure 4.24. The table of the second group in testing part

In this step, the students first checked whether tables had the minimum requirements when evaluating them, and then tested their tables themselves. In this step, the prototypes of the students met the minimum requirements and were able to develop a prototype with the expected characteristics in their measurements. Therefore, no problems were observed in this step. Therefore, no revision had required at this step.

The allocated time for this step before the activity had been administered was 20 minutes. As a result of the classroom observation of the researcher, the duration of this step had lasted 20 minutes during the activity. Therefore, the allocated time had not been revised.

10. Share

In this step, the teacher is expected to share the prototypes with the whole groups and to evaluate the prototypes.

In this section, the teacher made measurements about the prototypes of the groups and identified the first group by explaining the reasons. It was observed that the students were very excited about the sharing of the prototypes.

The characteristics of the prototypes of the groups are as follows. According to the problem, the area reserved for water bottles should be 2500 centimeter square. Height of table legs from the ground should be between 8 cm and 20 cm. According to these measurements, the table of the first group was 2500 centimeter square in area, 8 cm in height of the table legs, 0.3 cm in thickness of decota sheet, 15 pcs toilet paper rolls in the legs of the table, while the table of the second group was 2500 centimeter square in area, 8 cm in height of the table legs, 0.3 cm in thickness of decota sheet, 15 pcs toilet paper rolls in the legs of the table. The measurements are in Table 4.19 in ninth step.

The features of these tables are as follows. The first group developed a table through the following steps. The first group used a decota sheet with an area of 2500 square centimeters for the surface of the table. They then chose the rolls of toilet paper to make a foot on the sheet. They used 15 rolls of toilet paper. They attached 4 of the toilet paper rolls with a silicone gun to the center of the plane of the table and tied the perimeter with a rope. The rest of the rolls were placed in random. They put white cardboard paper under the table legs. They said that the reason they did this is to keep the table in balance everywhere and increase its strength. The second group used a decota sheet with an area of 2500 square centimeters for the surface of the table. They then chose the rolls of toilet paper to make a foot on the sheet. They used 15 rolls of toilet paper. With these rolls, they formed groups of three. They placed a group of three rolls in the very middle of the sheet. They placed other groups around it. They said that the reason for doing this is to provide balance because the water bottles will be placed in the middle of the table. They stressed that their tables would be more strength. Figure 4.19. in eighth step is the visual of the table of the first group, Figure 4.20. in eighth step is the visual of the legs of the table of the first group, Figure 4.21. in eighth step is the visual of the table of the second group, and Figure 4.22. in eighth step is the visual of the legs of the table of the second group.

Then, when the final measurements were made, the table of the first group was able to carry 14 packs of water bottles whose total mass was 84 kg while the table of the second group was able to carry 13 packs of water bottles whose total mass was 78 kg. The measured values are in Table 4.19. as follows.

Table 4.19. *Measurements of How Much Water Bottles the Tables Can Carry*

Measurements of How Much Water Bottles the Tables Can Carry		
	First Group	Second Group
Number of Water Bottles Packs (One pack has 12 water bottles and each one is 0.5 L)	14 packs (Total mass was 84 kg)	13 packs (Total mass was 78 kg)

Figure 4.25. is visual of the first group's table after final measurements, and Figure 4.26. is visual of the second group's table after the measurements are as follows.

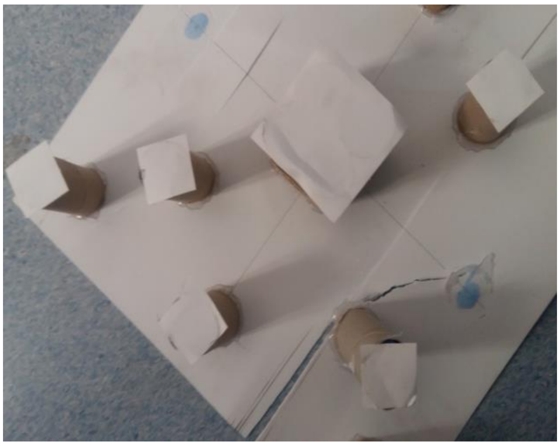

Figure 4.25. The legs of the tables of the first group after measurement

Figure 4.26. The legs of the tables of the second group after measurement

As a result of the classroom observation of the researcher, the students had more actively engage starting from the possible solution part of the activity. Also, as a result of the classroom observation of the researcher, students had a good time in the activity process, especially in second day they had better time because of the design part. As a result of the classroom observation of the researcher, that means that the students were more active in both physically and mentally in second day of the activities. As a result of the interviews with the students, the students had expressed the same sharing with the researcher's observation. Also, during the activity processes, as a result of the classroom observation of the researcher, the students had stated that their communication with the teacher was strong.

The researcher asked “What were the most comfortable parts during STEM education?” As a result of the interview with the students, students said that the most comfortable part was competition part.

The researcher asked “What was the most challenging part of your STEM education that you had difficulty in implementing?” As a result of the interview with the teacher, he stated that he had not pushed me too much; he said that he just had to go a little higher than expected in terms of time allocated to the relevant parts during the activity. In addition, the researcher asked “Did you have difficulty in guiding students during STEM education?” As a result of the interview with the teacher, he stated that he had not difficulty in guiding students during STEM education.

The researcher asked “Are there any places where you think the study needs revision? If so, what are these?” As a result of the interview with the students, two male and two female students stated that it would be better if there were no student guide papers. Since these are necessary for students to follow the process, no revisions had been made in this regard.

The researcher asked “During STEM education, what questions did you guide students to provide information that they could not foresee?” As a result of the interview of the teacher, the teacher had stated that in the process students did not encounter any unforeseen situations. However, the teacher said that he prepared extra questions for any possible unforeseen situations. They were “How can we increase the strength of table?”, “What are the characteristics of the table that we can see in all around?”

The researcher asked “Has the lesson plan and material been achieved to the objectives? Yes or No? If your answer is no, please indicate which objectives have not been achieved.” As a result of the interview with the teacher, he stated that all materials were suitable with the objectives.

The allocated time for this step before the activity had been administered was 20 minutes. However, as a result of the classroom observation of the researcher, the duration of this step had lasted 15 minutes during the activity. Therefore, the allocated time had been revised.

The total duration determined for this activity did not change, but changes were made to the periods determined within the activity steps. The total time allocated to the activity remained 240 minutes and was not changed. Table 4.20. shows the Timing of Table Activity.

Table 4.20. The Timing of Table Activity.

Timing of Table Activity		
10 Steps of the Proposed Model to Implement STEM PBL Activity	Timing Before Implementation	Timing After Implementati on
1. Identify the need	3 min	10 min
2. Generate ideas/Brainstorm	7 min	10 min
3. Searching for the answer	30 min	30 min
4. Associate the disciplines	5 min	5 min
5. Determine the criteria, materials, restrictions, limitations of the problem	15 min	15 min
6. Examine possible solutions	15 min	15 min
7. Choose the best possible/applicable/probable/feasible solution	10 min	10 min
8. Develop or redevelop a prototype	115 min	110 min
9. Test and evaluate the prototype by individual group	20 min	20 min
10. Share	20 min	15 min
Total Timing	240 min	240 min

4.4. Summaries of the Results

1. Identify the need

In this step, the students are expected to analyze the given problem and determine the need. To do this, they need to be able to determine what the problem gives and what the problem does not give. The students should be able to fill the minimum requirement table with the information in the problem and complete the evaluation table with the guidance of the teacher. Also, the students and the teacher are expected to be able to comprehend the integration of the problem with daily life.

In the thermos activity, as a result of the classroom observation of the researcher, the students could easily proceed in the question-answer section regarding the problem in this step because the minimum requirement table and evaluation table were given in a ready way. In the first activity, as the first step provided all the information in the problem and tables and because as a result of the classroom observation of the researcher, it did not provide sufficient question and answer inquiry to the students; the minimum requirements and evaluation table were left blank for the students to proceed further analysis and question-answer. These sections were revised to be completed by the students. It has been observed that the minimum requirement table and evaluation table could be filled by the students with question-answer in the guidance of teacher in the toy car and the table activities without any problem. At this point in this step, the minimum requirement and evaluation table should be left blank to proceed with inquiry-based process with the students.

In this part, a male student had stated that he had difficulty in associating the problem with daily life in the thermos activity. When the teacher had asked why the student had difficulty, the student had expressed that the student had difficulty in visualization because he had never experienced anything like this before. The student had stated that he had not seen a broken thermos in real life, so he could not relate the problem situation to daily life. At this point, the teacher and the researcher had showed a broken thermos photograph to the student. Thus, the student was able to visualize it and relate with the problem. To prevent this situation, visuals were added to the instructional materials. Therefore, no problems were observed in the toy car and the table activity. At this point in this step, visuals related to the problem should be added to the instructional materials to help the students visualize.

According to the classroom observation of the researcher, there were no problems in this step of the thermos and the table activities, the students in the toy car activity started to think the design of the needs immediately after the problem. This part was solved without revision with the guidance of teacher-guided questions because the aim was to develop a prototype with the desired features by following the determined steps. In order to prevent the students from directing towards design, various questions were asked to them in toy car activity. These questions were “How should be the friction between car and the ground?”, “How should be the friction between the shaft in the wheel and the wheel?”, “Why are the front ends designed as spikes or ovals when racing cars are considered?” At this point in this step, some extra questions to be perceived that the students need to follow the process should be ready next to the activity process.

In this step of the toy car activity, the students misunderstood the size of the car; therefore, the "width of the car" item was revised and changed to "width of the car (distance between the outer ends of the wheels)". Also, "length of the car" was changed to "length of the car (distance between the front and rear ends of the wheels)" to avoid possible problems, and "total height of the car" was changed to "total height of the car (distance from the bottom of the wheel to the highest point of the car)". At this point in this step, the items related to minimum requirements should be written more detail to prevent the students misunderstanding.

This step had lasted 10 minutes in the thermos activity, 15 minutes in the toy car activity and 10 minutes in the table activity. As a result, the allocated time should be an average of 12 minutes for this step.

2. Generate ideas/Brainstorm

In this step, the students are expected to discuss the situation and produce ideas by seeking answers to questions such as whether they have developed such a prototype before or what they would have done if they had faced such a situation. In this step, the students are expected to exchange their ideas with their group friends and share their previous experiences.

In all three activities, as a result of the classroom observation of the researcher and and a result of the interview with the teacher, the students had shared their ideas and experiences with the other students. In the thermos activity, some students had expressed that they made a thermos before. Some had expressed that they had not encountered such a situation. Those who had made thermos before told their friends about how they had made this thermos. In the toy car activity, some students had expressed that they made a toy car before. Some had expressed that they had not encountered such a situation. Those who had made toy car before told their friends about how they had made this toy car. In the table activity, some students had expressed that they made a table before. Some had expressed that they had not encountered such a situation. Those who had made table before told their friends about how they had made this table. In this step of all 3 activities, there had not been observed any problem.

As a result of the classroom observation of the researcher, in the thermos activity, the idea generation about the characteristics and design of the thermos prototype of the male and female students was almost equal to each other; while in the toy car and the table activities, male students had more idea production about the characteristics and design of the toy car prototype and the table prototype than female students. In addition, for all 3 activities, the students had stated that STEM activities were the activities forcing to think.

This step had lasted 10 minutes in the thermos activity, 15 minutes in the toy car activity and 10 minutes in the table activity. As a result, the allocated time should be an average of 12 minutes for this step.

3. Searching for the Answer

In this step, the students are expected to answer to the following questions; “Did you make a prototype before?” and “Is this previously made prototype like prototype you need?” questions to the students “What kind of prototypes has been made so far?”, “What solutions have been found?” and “What information is made use of the design of prototype?” Then, the teacher gives to a 9th grade MEB physics book and computer to each group and the students are expected to seek answer these questions.

For the thermos activity, these questions are “Did you make a thermos before?” and “Is this previously made thermos like thermos you need?”, “What kind of thermoses has been made so far?”, “What solutions have been found?” and “What information is made use of the design of thermos?” For the toy car activity, these questions are “Did you make a toy car before?” and “Is this previously made toy car like toy car you need?”, “What kind of toy cars has been made so far?”, “What solutions have been found?” and “What information is made use of the design of toy car?” For the table activity, these questions are “Did you make a table before?” and “Is this previously made table like table you need?”, “What kind of tables has been made so far?”, “What solutions have been found?” and “What information is made use of the design of tables?”

As a result of the classroom observation of the researcher, both groups had stated that they had used MEB Physics book to get information about subjects, and Internet to get detail information about subjects and design. For the thermos activity, the students had explored heat and temperature unit, the variables that affect the energy transmission rate. For the toy car activity, they had explored Motion and Force unit, friction force. For the table activity, they had explored Matter and Properties unit, strength. While using the 9^{th} grade MEB book and the Internet for this information, they had used the Internet to investigate what has been done on these issues and what materials are used in the prototypes.

For all 3 activities, as a result of the interview with the teacher, the most comfortable part of the students was this step because the teacher had observed and had stated that students could make correct researches about the problem. As a result of the classroom observation of the researcher, the students proceeded in harmony discussing their research with each other. No problem was observed in this step.

This step had lasted 50 minutes in the thermos activity, 45 minutes in the toy car activity and 30 minutes in the table activity. As a result, the allocated time should be an average of 42 minutes for this step.

4. Associate the disciplines

In this step, the students are expected to associate disciplines, courses, and subjects needed to solve the problem.

The teacher had asked “Which disciplines do you need for the solution of the problem?”, “Which chapters will you need to know about in these lessons’ content?”, and “Which subtitles of chapters are useful for your problem-solving?” respectively.

As a result of the classroom observation of the researcher, the students had no problems in this step of the thermos activity. They had reached the correct answers with the guidance of the teacher and had answered respectively the asked questions. They had stated disciplines as physics (science), technology, engineering, mathematics. They had stated lesson's content as Heat and Temperature in science discipline, graphics and algebra in mathematics discipline, design a thermos in engineering and technology disciplines. They had stated subtitles of chapters as Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate.

However, in the toy car activity, as a result of the classroom observation of the researcher and as a result of the interview with the teacher, the students had confused the concepts of discipline and sub-branches of physics. The teacher had given them these examples; mechanics as sub-branch of physics, and chemistry as discipline. After these, the students could answer the questions. They had stated disciplines as physics (science), technology, engineering, mathematics. They had stated lesson's content as Motion and Force in science discipline, graphics and algebra in mathematics discipline, design a toy car in engineering and technology disciplines. They had stated subtitles of chapters as Motion, and Friction Force.

After this confusion, “Associate the disciplines” was revised as “Associate the courses” in student activity guide sheet. This revision was made only on the student activity guide sheet. This revision was not made in the lesson plan and teacher activity guide sheet because the aim was to provide material development through the concept of discipline. Therefore, the concept of "Associate the disciplines" remained same in the lesson plan and the teacher activity guide sheet.

After the revision, as a result of the classroom observation of the researcher, there was not any problem in this step of the table activity. They had reached the correct answers with the guidance of the teacher and had answered respectively the asked questions. They had stated disciplines as physics (science), technology, engineering, mathematics. They had stated lesson's content as Properties of Matter in science discipline, graphics and algebra in mathematics discipline, design a table in engineering and technology disciplines. They had stated subtitles of chapters as Strength.

This step had lasted 10 minutes in the thermos activity, 15 minutes in the toy car activity and 5 minutes in the table activity. As a result, the allocated time should be an average of 10 minutes for this step.

5. Determine the criteria, materials, restrictions, limitations of the problem

In this step, the students are expected to answer the following questions; What information does the problem give us?, Does the problem put restrictions and limitations on us?, What are the criteria of the problem?

As a result of the classroom observation of the researcher, the students had not been in difficulty in this step of all 3 activities. According to the data obtained from the students’ and teacher’ feedbacks and as a result of the observations of the researcher, it was observed that in case of problems and the information filled in the tables provided easy progress for the students. Since they could associate the information previously given in the problem with the minimum requirement table and the evaluation table, in this step, they were able to determine what the problem gave us, what the restrictions and limitations and the criteria of the problem were. Therefore, no revision had required at this step.

The students had reached and had answered with the guidance of the teacher that for the thermos activity, designing a thermos that managed to keep coffee hot, minimum heat loss, carrying for 15 minutes with bare hands, health and taste, and efficiency had been criteria, keeping the 750 mL coffee hot at 60°C and above up to 15 minutes before the end of study, length of thermos, width/diameter of thermos, thickness of material; for the toy car activity, the mass of car, the total height of the car off the ground, length of car, width of car, number of wheels were restrictions and limitations, designing a car that managed to complete the 150 centimeter as soon as possible was a criterion; for the table activity, the area reserved for water bottles, height of table legs from the ground, table top material, number of table top material, thickness of table top material, materials that can be used for the legs of the table were restrictions and limitations, designing a table that managed to carry the maximum number of water bottles without tipping over was a criterion.

This step had lasted 10 minutes in the thermos activity, 15 minutes in the toy car activity and 15 minutes in the table activity. As a result, the allocated time should be an average of 14 minutes for this step.

6. Examine possible solutions

In this step, the students are expected to create at least 3 possible solutions along with the criteria, restrictions, and limitations they have identified in the previous step.

Each group had worked with their teammates on 3 possible solutions for the prototype they would develop. As a result of the classroom observation of the researcher, each group had produced solution suggestions. Both groups in all 3 activities could create 3 possible solutions.

In the thermos activity, the first group had produced three possible solutions. The first solution was to design a thermos using a glass bottle, then covering the outside of this glass bottle with Styrofoam, and then using a cork stopper. The second solution was to design a thermos using a glass bottle, and then covering the outside of this glass bottle with aluminum foil. The third solution was to design a thermos using a glass bottle, then covering the outside of this glass bottle with Styrofoam, and then covering it with rubber. The second group had produced three possible solutions. The first solution was to design a thermos using a glass bottle, and then covering the outside of this glass bottle with band. The second solution was to design a thermos using a glass bottle, and then covering wool fabric. The third solution was to design a thermos using plastic bottle with using cork stopper.

In the toy car activity, the first group had produced three possible solutions. The first group had produced three possible solutions. The first was to design a car whose body was made of wood and cardboard and whose wheels were wrapped with rubber. The second was to design a toy car with weight on it to prevent it from skidding while moving. The third was to design a toy car with 10 cm wide, 15 cm long and 5 cm high. The second group had produced three possible solutions. The first was to design a toy car having wooden body and wooden sticks supported by pipette, having wheels of plastic cover wrapped with rubber, having a triangular front, having 5 cm in height, having 15 cm in length, and having mass between 150 g and 250 g. The second was to design a car having a rigid plastic body, having wheels made of bottle covers wrapped with rubber, having a connection between the wheels provided with a pipette and a stick, and having a triangular front. The third was to design a toy car having a soft triangle shape on the front, having wheels connected to by passing sticks into the pipette.

In the table activity, the first group had produced three possible solutions. The first group had produced three possible solutions. The first was to design a table having toilet paper rolls put on top of each other as the legs of the table. The second was to design a table having toilet paper rolls placed as scattered under the dekota sheet as the legs of the table. The third was to design a table having the cardboard cups placed in the middle of the dekota sheet as the legs of the table. The second group had produced three possible solutions. The first was to design a five-legged table, each of which is formed by the combination of 3 rolls of toilet paper rolls. The second was to design a table having the cardboard box-legs. The third was to design a table having rectangular legs.

The students were able to produce solutions by exchanging ideas within their groups. They had worked on which solutions they could produce by using their knowledge obtained from their research. They had argued amongst themselves why they had determined these solutions. As a result of the classroom observation of the researcher, as a result of the interview with the teacher, there was no problem here. Therefore, no revision had required at this step.

This step had lasted 15 minutes in the thermos activity, 15 minutes in the toy car activity and 15 minutes in the table activity. As a result, the allocated time should be an average of 15 minutes for this step.

7. Choose the best possible/applicable/probable/feasible solution

First, each group in each activity is expected to choose the most probable solution among the three possible solutions identified in the previous step. Then, they are expected to determine dependent, independent and control variables from the problems given in each activity. Then, they are expected to determine their own materials for their prototype. After the students determine their materials, the teacher ends the activity there for that day and shares it with the students that the teacher will bring the materials and continue where they left off the next day.

The students, together with their group friends, examined the possible solutions they identified in the previous step and stated the solution they chose with their reasons. In the thermos activity, the students from the first group had chosen the third solution among their possible solutions. This was to design a thermos using a glass bottle, then covering the outside of this glass bottle with Styrofoam, and then covering it with rubber. The students from the second group had chosen the first solution among their possible solutions. This was to design a thermos using a glass bottle, and then covering the outside of this glass bottle with band. Both groups had stated that they would provide the best thermal insulation with their solutions.

In the toy car activity, the first group had chosen the third solution among their possible solutions. This was to design a toy car 10 cm wide, 15 cm long and 5 cm high. The second group had chosen the first solution among their possible solutions. This was to design a toy car having wooden body and wooden sticks supported by pipette, having wheels of plastic cover wrapped with rubber, having a triangular front, having 5 cm in height, having 15 cm in length, and having mass between 150 g and 250 g. Both groups had stated that they would complete the determined path as soon as possible with their solutions.

In the table activity, the first group had chosen the second solution among their possible solutions. This was to design a table having toilet paper rolls placed as scattered under the dekota sheet as the legs of the table. The second group had chosen the first solution among their possible solutions. This was to design a five-legged table, each of which is formed by the combination of 3 rolls of toilet paper rolls. Then, the teacher had asked to students "Why did you choose these solutions?" The first group had stated that the legs of the table should be placed as scattered so that the mass of the water bottles could be balanced. The second group had stated that in order for the water bottles to remain in balance, it was necessary to cluster the legs of the table instead of scattered. Both groups had stated that the most strength uniform geometric-shaped object was the sphere in nature, but they had stated that they could not use the spherical legs for tables. Therefore, they had stated that they would use the toilet paper rolls whose form was cylindrical form similar close to the spherical form.

Then, dependent, independent and control variables were determined under the guidance of the teacher. For the thermos activity, water temperature change, outer temperature change of thermos were dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials were independent, and amount of water, temperature of environment, the initial temperature of water were control-constant. For the toy car activity, time taken of the groups to finish the race was dependent, mass of car, the type of the wheels (material of the wheels), the surface of the wheels, size of the wheels, and the thickness of the wheels, the material of the shaft inside the wheel, the size of the shaft inside the wheel, total height of the car off the ground, length of car, width of car were independent, and initial velocity of cars, number of wheels were control-constant. For the table activity, max number of water bottles for tables was dependent, height of table legs from the ground, materials that could be used for the legs of the table, size of the legs, shape of the legs, and number of legs were independent, area reserved for water bottles, table top material, number of table top material, thickness of table top material were control-constant variables.

Then, all groups had determined their materials through their most probable solution for their prototypes. Then, the teacher had said "I will bring the materials tomorrow. Therefore, we will continue tomorrow."

As a result of the interview with the students, as a result of the interview with the teacher, as a result of the classroom observation of the researcher, there was no problem here. Therefore, no revision had required at this step.

This step had lasted 10 minutes in the thermos activity, 10 minutes in the toy car activity and 10 minutes in the table activity. As a result, the allocated time should be an average of 10 minutes for this step.

Day 2

8. Develop or redevelop a prototype

This step is the step that begins on the second day. In this step, the students are expected to develop a prototype or redevelop this prototype. They are expected to experience the variables they have identified in doing so with the inquiry experiments. The students experienced the dependent, independent and control-constant variables with inquiry experiments.

The teacher had brought the materials they had wanted to the groups and had said “Let's observe how variables affect to develop a prototype.”

In the thermos activity, both groups had observed the time-dependent variation of the temperature inside and outside their thermos while changing the variables they determined when making the thermos prototype. In the toy car activity, both groups had observed the time changes that toy cars could complete the specified platform as soon as possible while changing the variables they set while making the toy car prototype. In the table activity, both groups had observed how the strength of their tables changed while changing the variables they set when making the table prototype. As a result, they had developed their prototypes. In the thermos activity, the second group had finished developing its prototype seven minutes before the first group. In the toy car activity, the second group had finished developing its prototype five minutes before the first group. In the table activity, the first group had finished developing its prototype five minutes before the second group.

In this step of the thermos activity, the students had had difficulty in the experimental part because they had found the experiment part long. However, the teacher had stated that these steps were necessary to get a healthy prototype at the end of the process. The students had continued to conduct experiments without revising this section. A similar problem was observed in the same step of the toy car activity. While students had had difficulty in wheel design, no revision was necessary because the goal was to move with the friction force in mind. In another case, in this step in the table activity, a male student had wanted to design a table directly and had considered the inquiry experiments unnecessary. However, the teacher had stated that this was a material development study and therefore they had had to develop a material by following certain steps. Therefore, no revisions were made at this step.

Also, in this step of the thermos activity, as a result of the interview with the students, a male student and a female student had expressed difficulty in applying the dimensions of the thermos. They had said it would be better if the thermos dimensions were released. However, this feedback was not considered for revision because the aim was to achieve a minimum heat loss with a thermos of maximum size.

This step had lasted 180 minutes in the thermos activity, 100 minutes in the toy car activity and 110 minutes in the table activity. As a result, the allocated time should be an average of 130 minutes for this step.

9. Test and evaluate the prototype by individual group

In this step, the students are expected to first check whether their cars have the minimum requirements when evaluating them, and then test their thermoses themselves. In this step, the students are expected to continue with the next step if prototypes are working; or they are expected to go to the previous step if prototypes are not working.

In this step of all 3 activities, all groups had controlled the prototypes through the minimum requirement table. Both prototypes developed in thermos activity had met minimum requirements. When they had tested their prototypes, they had observed that both prototypes would provide the desired temperature in the specified time. Both prototypes developed in toy car activity had met the minimum requirements. When they had tested the prototypes, when the prototype of the first group had completed the inclined surface, the car's body and the wheels were separated from each other. The car of the second group was able to complete the platform without any problems. The first group had returned to the previous step and had identified where their cars were not working. The problem happened because the wheels and the body were not stuck together well enough. Later, they had come back to this step again and had tested their prototypes, and had not encountered a problem. Both prototypes developed in table activity had met minimum requirements. When they had tested their prototypes, they had observed in the prototype of the first group that two of the legs of the table were bent. No problems were observed in the prototype of the second group. The first group had returned to the previous step and had found the place where their tables were not working. The problem was about the locations of the legs of the table. They had changed the location of the legs of the table. When they had come back to this step and had tested their tables, and they had not encountered any problems.

As a result of the classroom observation of the researcher and as a result of the interview with the teacher, no revision was required at this step.

This step had lasted 70 minutes in the thermos activity, 15 minutes in the toy car activity and 20 minutes in the table activity. As a result, the allocated time should be an average of 35 minutes for this step.

10. Share

In this step, the teacher is expected to share the prototypes with the whole groups and to evaluate the prototypes.

This step is the step by teacher assessment of prototypes that meet the minimum requirements in the previous step and do not encounter any problems when tested. As a result of the measurements made when the prototypes were tested in thermos activity, it was observed that the prototype of both groups met the minimum requirements, but according to the evaluation criteria of the problem, the thermos of the first group was better than the thermos of the second group. As a result of the measurements made when the prototypes were tested in toy car activity, it was observed that the prototype of both groups met the minimum requirements, but according to the evaluation criteria of the problem, the toy car of the first group was better than the toy car of the second group. As a result of the measurements made when the prototypes were tested in table activity, it was observed that the prototype of both groups met the minimum requirements, but according to the evaluation criteria of the problem, the table of the first group was better than the table of the second group.

As a result of the classroom observation of the researcher and as a result of the interview with the teacher, no revision was required at this step.

This step had lasted 75 minutes in the thermos activity, 15 minutes in the toy car activity and 15 minutes in the table activity. As a result, the allocated time should be an average of 35 minutes for this step.

In general:

As a result of the classroom observation of the researcher, the students had worked in harmony at all the steps of the all activities and were able to generate ideas interactively with each other in all steps. Also, as a result of the interview with the students, the students had stated that STEM activities had been the activities forcing to think. As a result of the classroom observation of the researcher, the students had proceeded in harmony discussing their research with each other.

As a result of the interview with the teacher, the most comfortable step for the students was the third step of all activities. They had tried to collect information by doing research here, and then they were able to associate this information with other information they would get to develop a prototype.

As a result of the classroom observation of the researcher, for handicrafts, male students and female students had almost equally engaged in the eight step of the thermos activity. However, in the same step of the toy car and table activity, for handcrafts, male students had more actively engaged than female students.

Apart from these, in generally, as a result of the classroom observation of the researcher, the students had more actively engaged starting from the possible solution part of the activity. Also, as a result of the classroom observation of the researcher, students had a good time in the activity process, especially in second day they had better time because of the design part. That means the researcher had observed that the students were more active in both physically and mentally in second day of the activities. As a result of the interview with the students, the students had expressed the same sharing with the researcher's observation. As a result of the classroom observation of the researcher and as a result of the interview with the teacher, the students were very excited about the share step of the activity. Also, during the activity processes, as a result of the interview with the students, the students stated that their communication with the teacher was strong.

Also, while time allocated was insufficient for the first and second activity, it was sufficient for the third activity. In first activity, time set for activity increased from 320 minutes to 440 minutes. In second activity, time set for activity increased from 240 minutes to 260 minutes. In third activity, the total time allocated to the activity remained 240 minutes and was not changed. The reason for this was that in the thermos activity, the activity process had taken longer than expected, as temperature - time measurements were taken periodically. For the toy car activity, more time was spent than expected because in the first step the students had wanted to design the prototypes. Therefore, some questions had been asked to prevent them proceed the design of the prototypes. Also, in the fourth step the students had confused sub-branches of physics and the disciplines. Therefore, the teacher had explained the differences between them. More time than expected was spent due to these two steps.

CHAPTER 5

DISCUSSION, CONCLUSION AND IMPLICATIONS

This study is about the process of development of effective STEM education materials. The purpose of the study is to develop STEM Project-Based Learning activities by using an ASSURE Model for 9^{th} grade students in Turkey. For this, 3 STEM PBL activities had been developed. The first of these activities is the thermos activity from the heat temperature unit. Six students and one teacher had participated in the activity. The second activity is toy car activity from motion and force unit. Six students and one teacher had participated in the activity. The third activity is the table activity from properties of matter unit. Six students and one teacher had participated in the activity. Each student had participated in only one activity. The researcher had taken part in all three activities and had supported the teacher. During this time, the researcher had been an observer in all activities and the teacher guided the students in each activity. Lesson plans, teacher activity guide sheets, and student activity guide sheets had been developed for each activity. The researcher and teacher studied on the activity, especially on lesson plans because of having detail information than teacher activity guide sheet and student activity guide sheets, together for approximately 1 hour for each activity. In other words, the teacher had participated in each activity process with the knowledge studied during one hour of study. The toy car and table activity had been divided into two consecutive days and completed; the thermos activity had been divided into two days with one day apart and completed. During the activity, the students had determined the materials they had wanted to use. All materials requested by the students during the activity had been provided by the researcher. The researcher conducted interviews with teacher and students at the end of each activity. The interviews had been conducted after the activities had been completed, that is at the end of the second day. Student interviews had been conducted in groups. The interview with the teacher had lasted approximately 30 minutes for each activity. The interview with the students had lasted approximately 20 minutes for each activity. The aim is to revise and make the activities feasible thanks to the feedback from the teacher and the student. For these activities, in total 18 students and 1 physics teacher had participated the study. The results of this study were performed under the conditions stated above and are valid under these conditions.

In this chapter, discussion of the results, conclusions, implications and suggestions for further researches are explained.

5.1. Discussion of the Results

Research and Development (R&D) methodology was used in this study. According to Creswell (2009), there are 4 types of qualitative data collection. They are observations, interviews, documents and audio-visual materials. According to Yin (2011), there are 4 types of data collection methods. They are interviewing, observing, collecting, and feeling. In this study, interviews and observations were used as data collection instruments. Certain methods had been used to ensure these instruments' validity and reliability. According to Lincoln and Guba (1985), there are 4 criteria of trustworthiness. They are credibility for internal validity, transferability for external validity, dependability for reliability, and confirmability for objectivity. Triangulation, prolonged engagement and permanent engagement were used to provide credibility for internal validity in this study. Firstly, the triangulation method was used to prevent the data from forming a bias. Triangulation means using different data collection methods (Merriam, 1995). That is, this method argues that the studies should be supported by more than one data source and not by one data source. In this study, both semi-structured interviews with students, semi-structured interviews with teachers and observations made by the researcher were used. In other words, there is a trilogy based on the students, the teacher and the researcher. Although these are time-consuming processes, they were meticulously devoted to time. Face-to-face interviews were conducted in order to gain in-depth information and semi-structured interview questions were preferred. Meanwhile, new ideas were enabled in the process. Also, as a substantial process, a detailed literature review was done, data were collected from different studies at different times, and the findings were discussed with the supervisor of the study. In other words, the data collected during the study, the feedback of the experts related to STEM area involved in the study, and the information obtained in the observations by triangulation of the situations documented in the study were used. Thus, the use of different sources contributed to the strengthening of the study. In addition, in terms of the reliability of the data, the researcher had dealt with the study objectively. This is also important for the objectivity of the study. While all of this is carried out in a systematic way, some points appear to be more curable. During these activity processes, the researcher and the teacher had worked together for approximately 1 hour for each activity before starting the activities with students. This study period had prepared the teacher for the activity. However, in this study, since the readiness of the teacher and the students had not been taken into consideration, the study time allocated before the activities could be kept longer. In addition, after each activity was completed, interviews had been held with teachers and students. The teacher had been interviewed 30 minutes and the students had been interviewed 20 minutes. The interviews of the teacher and the students had been conducted after the activities were completed. At this point, since the activities had been divided into two days, these interviews could have been done to be conducted in two stages. Interviews could have been done to be held both at the end of the first day and at the end of the second day. These will be extra time-consuming for all activities but these will contribute to the activities by enriching the content of the activities.

According to García-Valderrama and Mulero-Mendigorri (2005), content validity is important validation method. In this study, expert opinions were received for each material. Since there was more than one expert opinion on each material, it was enriched by the integration of different views. These experts are physics educators and science educators working in the field of STEM.

The transferable and/or reproducible property of an activity, which is one of the most important features of an R & D study, creates a cycle in the activity process. When innovation is required or when the prototype is not working, the process enters a redevelopment cycle, which leads us to the iterative process part of the R & D studies (OECD, 2015). In this study, iteration method was utilized. In the study, the researcher had also applied the first activity with a group of students and had the chance to identify the problems that might occur during the application. The researcher had then revised first activity with the findings here and had started pilot study of the first activity. It had created a content that enriches this work. For this purpose, with the findings following the implementation of the first activity, both the first activity was revised and these findings were integrated into the second activity. After the implementation of the second activity, the second activity was revised and the findings were integrated into the third activity. After the implementation of the third activity, the third activity was revised. Subsequently, all changes had been integrated into the final version of all activities and revisions had been made. Thus, iteration processes had been completed. Similar to this study, the iteration process had been used for Earthquake board game developed as STEM education material (Perkins, 2016). There, the iteration had proceeded only through one activity. In this activity, 8 focus groups had been used in the Develop Phase section based on R & D. The teacher workshop had lasted one week. When the study had been completed, the Earthquake board game had appeared with revisions.

In addition to all above, while conducting this study, the researcher had divided each activity into two days and the time intervals required in each of the steps applied had been detailed in the lesson plans. In doing so, the researcher had presented how the researcher had developed and had implemented the activities in a systematic way. Characteristics of STEM activity and objective integrations had also been systematically completed. The materials had been determined by the students and had been taken by the teacher at the end of the first day of each activity. In the second day, the materials had been delivered to the students at the beginning of the activity. This had given students a more flexible, free and creative work environment in terms of freedom of choice of materials. It had been a detail that had enriched this study. Also, Egg Drop Parachute can be a good example for comparing the characteristics of STEM activity. The Egg Drop Parachute activity (Bicer & Nite, 2016), which is accepted as a common example of STEM activity, has not presented how to develop the activity, but has presented how it is implemented in separated days. Science objectives and mathematics objectives are presented in the activity. However, technology and engineering objectives has not been mentioned. Also, on the first day of the study, students had been given limited materials to use. In addition, an oral presentation rubric had been prepared and evaluated for the students. However, in this study, there had been no oral presentation rubric or peer evaluation rubric to evaluate the students in each activity. There had been only observations made by the researcher. In addition, the teacher and the students had shared their opinions via interviews. In this respect, these rubrics can be added to the other studies.

The researcher had observed that the students could better understand the problem with the visual and added a photograph that could match and describe the context-based problem in the instructional materials for each activity after the implementation of the first activity. After this revision, there had not been seen any problem in other activities. This leads the study to the conclusion that an appropriate visual integrated into the text makes it easier for students to grasp the process. These views are among the overlapping parts of the following study. According to Gustiani, Widodo and Suwarna (2017), 100% conformity of the image used in the text content presented as a finding. In addition, the researcher had left the tables blank in the instructional materials, so that the relationship between context-based problem, minimum requirements table and evaluation table is more inquiry-based, so that the students should fill in during problem analysis. In order to help the students better understand the instructional materials, the "Associate the Disciplines" had been corrected as "Associate the Courses" in the student activity guide sheets and thus this change has a better understanding of the instructional materials. On the other hand, Sari, Sumatri and Bachtiar (2018) had used R & D using Dick and Cary model having ten steps and had stated that in their study. They had stated that these ten steps were respectively; identifying learning objectives, conducting instructional analysis, analyzing student characteristics and learning contexts, formulating special learning objectives, developing assessment instruments, develop learning strategies, developing and selecting teaching materials, carry out formative evaluations, making a revision of learning, design and carry out summative evaluation. However, there had not been given any detail about these steps. Therefore, no systematic progress had been seen.

In this study, the teacher had expressed that totally understanding the problem was very important therefore, the teacher had stated that instructional material could be understood better in the process. That means the continuity of the instructional materials in terms of implementation can be ensured with the revision of the determined problems.

In the activity processes, the teacher and the researcher had observed that the students had worked with great pleasure and had attended an active participation. The researcher and the teacher had stated that the students had been more active in both physically and mentally in second day of the activity. The students had stated that STEM activities had been the activities forcing to think. These views are among the overlapping parts of the following study. According to Taştan-Akdağ and Güneş (2017), STEM provides having good time and active participation in the lessons, and STEM activities are thought-based activities, which mean forcing to think.

Systematic development and implementation of activities is very important. In this regard, the researcher had developed each activity by using ASSURE Model with a systematic way. Later, these activities were applied with a 10-step proposed model developed by the researcher. On the other hand, when looking at the following study, according to Le, Le, Vu, Nguyen, Nguyen and Vu (2015), their study is related to 8^{th} grade students. Their study has 5 recommended steps for technical toy's design for teachers (Le, Le, Vu, Nguyen, Nguyen, & Vu, 2015). In the first of these five steps, teachers should study STEM issues. In the second, teachers examine STEM content issues and learning outcomes and examine integrability. In the meantime, they study the learning materials of each subject. In the third, teachers decide on the types of technical toys they will design. Fourth, teachers design technical toys and evaluate the possible applications of these toys for STEM training. Then, they test and evaluate. Therefore, they can redesign. In the fifth step, teachers organize a class for the students to make a technical toy. Also, there is a procedure for technical toy's design for students (Le, Le, Vu, Nguyen, Nguyen & Vu, 2015). These steps of procedure are to understand the requirements of technical toys, to discuss to find out solution and make a design with graphics, to create, test and modify, to determine materials to make technical toys, and to disclose products. In these steps, what is to be done and what is expected is briefly mentioned, but with a detailed document, how much time will be allocated to the part and what the students encounter during these steps and solution suggestions are not specified. In addition, the results of the above study showed that an individual and group working environment was presented. But in STEM education, group work, which has become one of the benefits of 21st century skills and one of the characteristics of STEM, is at the forefront. In addition, in the third of the steps presented for the students, it was mentioned that the materials were determined but in the results section of the study, it was seen that the same materials were given to each group. In all of these above, whether the dimensions of their study were included in the STEM content was not presented in detail, the study mentioned an implementation process, but no systematic material development method was mentioned.

Also, timing is very important in STEM activities. In this study, while time allocated had been insufficient for the first and second activity, it had been sufficient for the third activity. Time changes had been revised and detailed according to the steps in the instructional materials. However, an activity with a detailed time revision like these had not been observed in the literature.

5.2. Conclusions

The conclusion of the study is that effective STEM Project-Based Learning activities, which were developed by using ASSURE Model, were applied according to the proposed 10-step implementation model without any problem as a result of three iterations within the scope of the Research and Development (R & D) design.

5.3. Implications

The following implications may be drawn from the findings of this study. In each bullet, the findings and then the implication drawn from that finding are presented.

- As a result of a detailed literature review, the researcher had determined the characteristics of STEM activities and according to these characteristics, STEM activities had been developed. These characteristics are integration of STEM dimensions, problem-based centered, project-based centered, inquiry-based instruction, teamwork, student-centered, assessment, research-oriented, and 21st century skills (see Table 2.1. in Chapter 2 for detail explanation). When I added these characteristics to the activity, I observed that I could integrate them systematically. At the end of the process, students were able to produce prototypes with these characteristics. As a result, it has been observed that STEM activities were developed without problems. As a result of this, other researchers would develop STEM activities by using these characteristics.
- Integration of disciplines is the main feature of STEM activities. The researcher had determined science, technology, engineering and technology curriculum objectives and integrated them in detail in these activities. Thus, STEM instructional materials had been developed. While there was no problem in the first activity in the process, I observed that in the second activity, the students confused the concept of "disciplines" with the concept of "sub-branches of physics". Therefore, I revised it to "course" on student

activity guide sheets. Then, in the implementation of the third activity, I observed that the students had no difficulty in the process. Therefore, I think I integrated the objectives without any problem into the activity. As a result of this, other researchers would integrate disciplines according to the curriculums into the STEM instructional materials.

- Correct development and implementation of STEM activities is very important. In this study, the researcher had developed STEM activities with the ASSURE Model. As a result, I observed that there was no problem with the implementation of STEM activities developed systematically with this model, and that students could progress step by step in activities and reach a product-oriented result that meets the minimum requirements. As a result of this, other researchers would develop STEM activities by using this model.
- It is also very important that a developed STEM activity is implemented correctly in the classroom. After detailed literature review, the researcher had developed the proposed model to implement STEM PBL Activity in this study. This model has 10 steps. The activities were implemented by this model. As a result, I observed that the students and the teacher had no problems in terms of process follow-up. Thanks to this implementation model, STEM activities were developed without any problem at the end of the implementation process. As a result of this, teachers and researchers would implement their STEM activities by using this proposed model.
- It is very important to STEM PBL activities within the framework of a correct research methodology. The researcher developed STEM PBL activities comprehensibly and without any problem by using Research and Development (R & D). As a result of this, other researchers should develop STEM instructional materials by using R & D.
- It is very important for students to work in a creative way to produce authentic products because STEM activities are student-centered activities. In this study, students had determined their own materials and had told the teacher their materials. The teacher had taken the materials and had brought

them to the students. In other words, the students were not given pre-determined materials for the activity. Students developed prototypes which met the minimum requirements and criteria of the problem, expectations and optimized. In the process, according to the findings obtained from the interviews with the students and the observation of the researcher, the students stated that the most actively engaged part which they had attended was the design step because they worked by determining their own materials. As a result of this, the other researchers and the teachers should let students determine their own materials in the activity process.

- It is very important to plan a lesson integrated with STEM activity in terms of time since STEM activities are lesson and objective-based. The researcher made a timeline in order to realize the objectives and meet the expectations in the implementation steps in the lesson with the integration of STEM activity. In doing so, the researcher considered the lesson hour distribution in the curriculum according to yearly plan for the physics and mathematics objectives. The researcher made predictions of technology-engineering objectives and visual arts objectives about lesson hour. The objective timing for the first activity is expected to be as follows: 4 lesson hour for physics objectives, 24 lesson hour for mathematics objectives, 6 lesson hour for technology-engineering objectives, 3 lesson hour for visual arts objectives. The total number of lesson hours to be reserved is 37. However, the researcher realized that the researcher could complete the STEM activity the researcher created by integrating all these objectives within 11 lesson hours within the timetable the researcher determined. The objective timing for the second activity is expected to be as follows: 10 lesson hour for physics objectives, 24 lesson hour for mathematics objectives, 6 lesson hour for technology-engineering objectives, 3 lesson hour for visual arts objectives. The total number of lesson hours to be reserved is 43. However, the researcher realized that the researcher could complete the STEM activity the researcher created by integrating all these objectives within 6.5 lesson hours within the timetable the researcher determined. The objective timing for the third activity is expected to be as follows: 3 lesson hour for physics objectives, 24 lesson hour for mathematics objectives, 6 lesson hour for technology-engineering objectives, 3 lesson hour for visual arts objectives. The total number of lesson hours to be reserved is 36. However, the researcher realized that the researcher could complete the STEM activity the researcher created by integrating all these objectives within 6 lesson hours within the timetable the researcher determined. Thus, the researcher realized the necessary objectives with given sufficient time to each step while implementing the activity. As a result of this, the other researchers and the teachers should make a timeline for their STEM activities.

5.4. Suggestions for Further Researches

The following suggestions may be drawn from the observations of this study. In each bullet, the observations and then the suggestion drawn from that observation are presented.

- According to McDermott, Shaffer, and Constantinou (2000), if teachers do not examine the relevant context together with the teaching method, they may miss important points in the process. Even an instructional material with all the details and beautifully prepared is misused if it is not understood by the teacher. Also, teachers should be trained by experts because the curriculum does not have information about teachers' training (McDermott, Shaffer, & Constantinou, 2000). In this study, the researcher studied with the teacher for approximately 1 hour before implementation of each activity. This teacher had no knowledge of STEM education other than the introduction of materials given before the activities. The researcher conducted this study with a teacher of this nature and concluded that the materials were suitable for further studies after their revisions. The same applies to our country. There is no framework within the existing physics education curriculum to develop teachers for this field. Therefore, in other studies, teachers may be given long-term training in advance and may be included in the process after such training. Therefore, trainings should be given to teachers by STEM experts. In addition, undergraduate and graduate departments related to this field can be opened in faculties of education.

- Students were faced with a way of learning as STEM PBL that they were not used to. I thought that the students would not have difficulty in the activity steps; however, I observed that the students had difficulties at this stage. Therefore, the students wanted to go directly to the prototype development stage. STEM education was not given to the students before this study. In order to prevent such a situation, information about STEM education and engineering design process can be given to the students in advance. Thus, it can be taught that these steps are necessary to develop a prototype.
- In this study, students had determined their own materials and had told the teacher their materials. According to the observation of the researcher, students thought that they would get the materials with money given to them. The teacher had taken the materials and had brought them to the students. Due to the limited time of the study, the budget allocated for the activities had not been given to the students and receipt of material could not be done by them. According to Capraro, Capraro, and Morgan (2013), students should have determined restrictions-limitations like budget, time and materials to conclude their duties. In this respect, in subsequent studies, students can be given a set budget and be told to buy the materials themselves.
- Although heterogeneous groups were formed during the study, it was observed that in the second and the third activity, male students produced more ideas about design, content and characteristics of the activity in the process than female students. However, in the first activity, male and

female students produced ideas about design, content and characteristics of the activity almost equally in the process. In order to increase the active participation of female students according to design, content and characteristics of the activity, studies can be developed for the interests of female students.

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APPENDICES

A.1. Pilot Study of Heat and Temperature STEM PBL Activity Lesson Plan

STEM PBL ACTIVITY LESSON PLAN

1. Grade Level: 9

2. Lesson: Physics

3. Unit: HEAT AND TEMPERATURE

4. Objectives:

The following objectives are the maximum number of objectives that students can integrate to the solution of the problem.

At the end of the lesson, students are able;

Physics (MEB (2018), High School Physics Course Curriculum.)

9.5.1.5. To analyze the variables that depend on the change in the temperature of pure substances which receive heat or give heat. **(S.O.1)**

9.5.4.2. To analyze the variables that affect the energy transmission rate in matters. **(S.O.2)**

9.5.4.3. To design for insulation of life space to save energy. **(S.O.3)**

b. To determine a problem related to thermal insulation from daily life and produced solutions for this problem. **(S.O.4)**

c. To pay attention to the necessity of budgeting in order to financial awareness in the designs to be made. **(S.O.5)**

Mathematics (MEB (2018), High School Mathematics Course Curriculum)

9.5.2.2. To interpret the data groups reflecting the real life situation by representing them with appropriate graph types. **(M.O.1)**

Mathematics (MEB (2018), Primary and Middle School Mathematics Curriculum.)

M.7.1.1.5. To solve problems that require operations with integers **(M.O.2)**

M.8.2.2.3. To express how one of the two variables, which have linear relations, changes depending on the other with tables and equations. **(M.O.3)**

a. To use expression in the form of ordered pairs in the representations made with the table. **(M.O.4)**

b. To examine how the value of one of the two variables changes according to the value of the other variable and in which case, which is dependent and which is independent. **(M.O.5)**

M.8.2.2.5. To create and interpret equations, tables and graphs of real life situations involving linear relationships. **(M.O.6)**

M.8.2.2.6. To explain the slope of line with models, associate linear equations and graphs with slope. **(M.O.7)**

c. To utilize appropriate information and communication technologies when necessary. **(M.O.8)**

M.8.4.1.1. To interpret line and column graphs of up to three data groups. **(M.O.9)**

Technology-Engineering (NGSS Lead States (2013), Engineering Design Cycle. NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.)

1. To detail in the problem. **(T.E.O.1)**
2. To create different solution ways. **(T.E.O.2)**
3. To determine criteria and constraints. **(T.E.O.3)**
4. To reach the best solution with necessary technological tools. **(T.E.O.4)**
5. To test the solution ways under different conditions. **(T.E.O.5)**
6. To use mathematics and computers for solution ways. **(T.E.O.6)**
7. To create a prototype. **(T.E.O.7)**
8. To optimize the solution. **(T.E.O.8)**

Visual Arts (MEB (2018), High School Visual Arts Course Curriculum.)

1. To create original products using traditional and contemporary materials. **(V.A.O.1)**
2. To reflect their imagination on their works/studies. **(V.A.O.2)**

21st Century Skills (Partnership for 21st Century Skills (2010). Framework for 21st century learning.)

1. Learning and Innovation Skills

    Critical Thinking and Problem Solving **(L.I.S.1)**

    Creativity and Innovation **(L.I.S.2)**

    Collaboration **(L.I.S.3)**

    Communication **(L.I.S.4)**

2. Life and Career Skills

    Flexibility and Adaptability **(L.C.S.1)**

    Initiative and Self-Direction **(L.C.S.2)**

    Social and Cross-Cultural Skills **(L.C.S.3)**

    Productivity and Accountability **(L.C.S.4)**

    Leadership and Responsibility **(L.C.S.5)**

3. Information, Media and Technology Skills

    Information Literacy **(I.M.T.S.1)**

    Media Literacy **(I.M.T.S.2)**

    ICT (Information, Communications and Technology) Literacy **(I.M.T.S.3)**

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

Problem: In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95°C to 60°C (ideal coffee drinking temperature) within 1 hour. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60°C and above up to 15 minutes before the end of your study?

The project is evaluated by following tables.

Minimum requirements to be observed
Time (it will be determined from the problem)
Desired temperature (it will be determined from the problem)
Quantity of water (it will be determined from the problem)
Length of thermos: 25 cm ± 0.1 cm
Width/diameter of thermos: 8 cm ± 0.1 cm
Thickness of materials: 0.2 cm ± 0.1 cm

Note: All prototypes must meet the minimum requirements in this table. In order to select the winner, the winner will receive the highest score according to the points listed in the table below.

Note: Prototypes will not be considered if their minimum requirements are not met.

Evaluation Criteria			
		Temperature measured for first group	**Temperature measured for second group**
Heat loss (Although the thermos is max sizes, there will	Minimum heat lost: 4 points Maximum heat lost: 0 point	Initial measurement (at the beginning): Second measurement (at the sixty minute):	Initial measurement (at the beginning): Second measurement (at the sixty minute):

be minimal heat loss) (It will be determined by temperature change of coffee)			
Carry for 15 minutes with bare hands (It will be determined by tempe	After 15 minutes, if the temperature change of the outer material of thermos is minimum: 4 points After 15	Initial measurement (at the beginning): Second measurement (at the fifteenth minute):	Initial measurement (at the beginning): Second measurement (at

rature change of outer material of thermos)	minutes, if the temperature change of the outer material of thermos is maximum: 0 point		the fifteenth minute):
Health and Taste (It will be assessed in terms of materials that come into contact with coffee) Glass	Use of materials suitable for human health (Using the least harmful material): 4 points Use of materials suitable for human health (Using the most harmful material): 0		

>Paper Cup> Plastic Cup	point		
Efficiency (It will be evaluated in terms of how many times thermos can be reused)	Several times availability: 2 points Disposable: 0 point		

To explain the evaluation criteria, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured when the water is filled in the thermos and teacher writes the measurement. After 60 minutes, teacher will measure the temperature of water and take notes. All measurements will be written in the evaluation table. As a result, the highest score will go to the group that provides the minimum heat loss. Other group will get zero point.

Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and take note it. All measurements will be written in the evaluation table. During this period, the group with the least temperature changes of outer material of thermos gets the highest points. The other group gets zero points.

Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. To measure this, the group using the least harmful material for human health gets highest points. Other group will get zero points.

Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused. A group making a thermos which can be used several times gets two more points besides the health criterion. The group making a thermos with several times availability in using gets highest points. The group making a thermos with disposable in using gets zero points.

Note: After all prototypes meet the minimum requirements in the table, the criteria of evaluation table are checked. All groups will start to measure at the same time and all measurements are taken at the same time. Teacher will observe and control the measurements and results of the groups. The teacher selects the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group.

Note: Teachers and students can predict the time to stay at the desired temperature with these measurements. Considering the heat loss of the coffee within 15 minutes, the heat loss within 1 hour will be measured. There's an important point here. Even in the evaluation part, even the highest score cannot be selected as first group if it fails to keep the coffee at the desired temperature for the desired time.

5. Topical Outline, Planning and Timing (2 days-8 lesson hours: 320 min)

- 1. Identify the need (3 min)
- 2. Generate ideas/Brainstorm (7 min)
- 3. Searching for the answer (30 min)
- 4. Associate the disciplines (5 min)
- 5. Determine the criteria, materials, restrictions, limitations of the problem (15 min)
- 6. Examine possible solutions (15 min)
- 7. Choose the best possible/applicable/probable/feasible solution (10 min)
- 8. Develop or redevelop a prototype (135 min)
- 9. Test and evaluate the prototype by individual group (40 min)
- 10. Share (60 min)

8. Presentation of STEM PBL Lesson

Day 1: 85 min

1. Identify the need

At the beginning of the lesson, teacher gives the problem to the students. Teacher says "Here is a problem. The problem is that in the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95°C to 60°C (ideal coffee drinking temperature) within 1 hour. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60°C and above up to 15 minutes before the end of your study?" and "Now, I will separate you into two groups. Every group has 3 students. In your group, you will determine the need" Teacher says **"**Every student in each group has the same responsibility to the activity. You share duties within your own groups." **(L.I.S.3) (L.C.S.3) (L.C.S.5)** Also, teacher says "Considerations in the evaluation are as follows. You will determine the desired time and desired temperature for the coffee to remain hot and quantity of water from the problem. Length of thermos is 25 cm ± 0.1 cm. Width/Diameter of thermos is 8 cm ± 0.1 cm. For heat loss, although the thermos is max sizes, there will be minimum heat loss. You need to carry for 15 minutes with bare hands. Thickness of materials is 0.2 cm ± 0.1 cm. Efficacy is related to how many times thermos can be reused. Health is important. It will be assessed in terms of materials that come into contact with coffee." and adds "Accordingly, in the evaluation, the first to keep the coffee hot for the longest time will be selected. Scoring will be used for this. The group with the most points will be selected as the first group."

Then, teacher asks some questions "Does the problem have a need?" and adds "What is the need?" After that, teacher says "I am a guide to you. If there are any question, I will guide you." and adds "You have 3 minutes to think."

While during 3 minutes, teacher distributes the student activity sheet to the students and says "During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet." Teacher observes the students while reading and discussing the problem.

After that, teacher asks students "What is the need?" Teacher expects the following answer from the students "*The need* is that a thermos is developed to keep 750 mL coffee hot to drink in the library by considering in 1 hour and at 60 °C for the coffee to remain hot, 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter, being max sizes with minimal heat loss, able to carry for 15 min with bare hands, 0.2 cm ± 0.1 cm in thickness of materials, being efficacy according to reused, being healthy according to come into contact with coffee." If the students do not give this answer, the teacher will guide the students until the answer comes.

Then, teacher says "Write the need on the second space in the activity sheet." Then, teacher writes the need on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.1)**

2. Generate ideas/Brainstorm

After writing the need on the board, teacher asks to students "Have you ever designed a thermos before in your life?" Teacher says "If you have encountered, you can benefit from your experience." and "If you have not encountered, you will learn what you can do if you encounter such a situation." Then teacher asks "What would you do if such a situation happened to you? Now, you have 7 minutes to discuss it. I want you to generate ideas by talking." Teacher asks "What should you consider when designing this thermos?" and adds "What can you do to keep your coffee warm?" The response from the students is expected to say that a cover or some insulation materials can be used and teacher continues brainstorming until students receive this answer. **(L.C.S.2) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.4) (I.M.T.S.2) (L.I.S.4)**

3. Searching for the answer

Teacher says "Now, I will give you 2 minutes to think what you need to search. After, you will share what you thought" After 2 minutes, teacher asks "What did you think?" Students are expected to receive the following answer that heat-temperature issues, the material that keeps coffee hot for the longest time, the factors that affect the heat conduction rate, how to make a thermos are needed to investigate to keep coffee warm. Students are guided until these answers come from the students.

Teacher says "Now, it's time to do search. During this search, you can find the answers of these questions "Did you make a thermos before?", "Are these thermoses like thermoses you need?", "How are these thermoses made?", "What solutions have been found?" For your search, you need some books and computers with Internet. I prepare you 2 9^{th} grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 28 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search on the third space in the activity sheet." Teacher shares what students write in the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.3)**

After the search, teacher asks "Which resources did you use and what did you find?" and "Which materials are used in making thermoses?" Teacher expects the answer of students which explaining the working principle of a thermos and which materials this thermos is composed. Teacher gets the answers from the students that some people make thermos from paper cups, plastic cups, Styrofoam. Then, teacher asks "Is the use of these materials one or more? Are these materials same size or not?" Teacher expects the answers from students that generally, two nested materials are used and they are not same size because there is double glazing to provide thermal insulation in our homes. If same sizes of cups to make a thermos are used, there will be no space between the cups as in double glazing. Teacher writes these on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.4) (T.E.O.6) (I.M.T.S.2) (I.M.T.S.3)**

4. Associate the disciplines

Then, teacher asks "Which disciplines do you need for the solution of this?" Teacher expects the answers physics, mathematics, engineering and technology. Teacher asks "Which chapters will you need to know about in these lessons' content?" Teacher expects the answers the lesson content as disciplines which are

Heat and Temperature in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a thermos. Also, teacher directs students until these answers get. Teacher tells them “Write these in the fourth space in the activity sheet.” Teacher writes the answers on the board. Also, teacher asks students “Which subtitles of chapters are useful for your problem-solving?” Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate are expected answers, so teacher guide the students until these answers get. Teacher tells them “Write it on the fourth space in the activity sheet.” Then, teacher writes the answers on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1)**

Then, teacher and students associate the problem and the need on the board by brainstorming. If students do not find the heat and temperature, teacher asks them why we wear a few clothes on us in winter. Thus, students discover the relationship between heat and temperature.

5. Determine the criteria, materials, restrictions, limitations of the problem

Teacher says “I will give you 5 minutes to think how the product will be evaluated. After, we will discuss.”

Then, teacher asks “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?”, “What are the criteria of the problem?” The purpose in doing so is the problem can be analyzed easily.

Then, teacher and students start to discuss for 5 minutes. Teacher writes the most common answers of the questions ones are written on the board.

Discussion continues until the following answers from the students that designing a thermos that managed to keep coffee hot, minimum heat loss, carrying for 15 minutes with bare hands, health and taste, and efficiency criteria, measuring coffee temperature at regular intervals, keeping the 750 mL coffee hot at 60°C and above up to 15 minutes before the end of study, length of thermos, width/diameter of thermos, thickness of materials, measuring coffee temperature at regular intervals are restrictions and limitations. Then, teacher writes the all shared information by the students on the board. Then, teacher says “Write these to your findings on the fifth space in the activity sheet.” **(T.E.O.1) (T.E.O.3) (L.I.S.1)**

Then, teacher asks “What materials do you think you need in line with your research, the criteria you have chosen, the constraints, the limitations, the variables you have determined? To decide the materials, you have 5 minutes.” After 5 minutes, plastic cup, paper cup, some fabric, band, aluminum foil are some expected answers from students. Teacher writes them on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (L.C.S.1) (L.C.S.4)**

6. Examine possible solutions

Teacher says them “Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them in the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it.” **(T.E.O.2) (L.I.S.4) (I.M.T.S.2) (L.I.S.3)**

After brainstorming, brainstorming continues until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a thermos is and helps them work with them.

Teacher asks them “How did you decide on these possible solutions?” Teacher asks the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the variables affecting the energy transmission rate in matters; they are surface area, thickness, temperature, types of matter; representation of mathematical inferences on graphs such as the relationship temperature-time, and the use of technology and engineering skills in the design part. The discussion continues until these answers come. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (M.O.1) (M.O.2) (M.O.3) (M.O.4)**

(M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.1) (T.E.O.6) (I.M.T.S.1) (I.M.T.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1)

7. Choose the best possible/applicable/probable/feasible solution

Teacher says “Which of the criteria (number of cups, types of cups, thickness of cups, etc.) mentioned in the assessment change your choice? When these are considered, how to make a thermos? Let's look at this and decide the best solution.”

Then, teacher asks “Which solution you have chosen as the best possible solution?” Developing a thermos by using the variables affecting the energy transmission rate in matters is expected answer from the students. Another answer from the students that the surface area, thickness, temperature, types of materials will be examined. To determine the surface area, the materials which students will use in the activity mathematically will be compared and computed which is the expected answer from the students. For thickness, more thickness, less heat loss; to determine the thickness, expected answer from the students that materials which students will use in the activity mathematically will be compared and computed. For temperature, expected answer from the students is that temperature variable will not affect their study because they will study in the same environment at constant temperature. The answer that different materials provide different thermal insulation is expected one. In addition, another expected example from students that considering the example of double glazing, the use of two glazing instead of one glazing increases the thermal insulation. So, putting two cups instead of one is expected answer because of number of cups. Therefore, teacher makes students aware of trying different types of cups because all of them will have different heat conduction. In addition, the amount of water that can be taken inside the thermos is 750 mL. Therefore, teacher makes students aware of developing a thermos whose internal volume will be at these dimensions; and next is the cup on the outside of the thermos. Also, the expected answer is that if students put two cups of the same size together, this time they cannot provide thermal insulation as in the case of double glazing; so they are going to have to leave some space. In addition to this, another expected answer is that if they do not leave a space, they can use a hollow material. Then, teacher writes the students answers on the board. Then, teacher says “Write the board to in the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons.” **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1) (L.I.S.1) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1) (L.C.S.2)**

After these, teacher asks students “Is there any variable in the problem? If yes, what are they?” Expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant.” Then, teacher writes the variables on the board and tells them “Write it in the eighth space in the activity sheet.”

Then, teacher asks “When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a thermos with desired features? Are the materials you mentioned before sufficient to develop a thermos with desired features?”

In order to design a thermos with the desired characteristics, students choose their own materials and share it with the teacher.

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher. The teacher asks the students questions like “What materials are required for this activity?”, "What other materials can we use in this activity?", "So, if cutting is necessary, how and with what material will you provide it?", "How do you plan to attach the materials?" to determine the materials in this process.

Foreseen Materials that are expected to request by students after material discussion:

Paper cup, plastic cup with various sizes

Glass cup with various sizes

Styrofoam

Cotton

Paper

Cardboard

Pen

Aluminum foil

Fiber

Adhesive

Sponge

Scissors

Band

Thermometer

Water

Kettle/Water heater

Nylon bag

Compasses

Ruler

Stretch Film

Cork Stopper

Chronometer

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, teacher says "I will bring the materials tomorrow. Therefore, we will continue tomorrow."

Day 2: 235 min

8. Develop or redevelop a prototype

At the beginning of the lesson, teacher brings and separated materials to the groups. Teacher says "Here are your determined materials."

Then, teacher adds "Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There should be the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, kettle, hot water, socket. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, scissors is dangerous product. When you need to use it, you will come and take it from me and bring it back to me."

Teacher asks “What were the dependent, independent, and control variables that you previously defined?” The expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant. Then, teacher says “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, teacher gives them as an example with the blanks in the table. For example, if they first look at the changes of types of cups, they write to the table as follows. (The sample table is shown on the board.)

Teacher says “Write the other variables in the table on the ninth space in the activity sheet.”

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	water temperature change	types of cups	-sizes of cups, -types of insulation materials, -amount of insulation materials, -number of cups **Always be kept under control:** -amount of water -temperature of	

			environment -the initial temperature of water	

(T.E.O.5)

Then, teacher tells “Time has come to produce/develop a prototype. Here you can make a 750-milliliter thermos.” **(M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.6) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.1) (L.I.S.2) (L.I.S.3) (L.C.S.4)**

In redevelop part in here, teacher says “You modify and redo the criteria that do not meet the evaluation criteria table. Then, you check again until you meet all the criteria. Then, if your prototype works with all criteria, you skip this step to go to step 10.” **(T.E.O.5) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.2) (L.I.S.3) (L.C.S.1) (L.C.S.4)**

9. Test and evaluate the prototype by individual group

After that, students test and control the prototype whether it works effectively or not.

Teacher says them “You apply your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is working, skip go to step 10. Second, if the prototype does not work, go to step 8 and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to step 10 when prototypes work”

10. Share

At this stage, when the groups finish their work, they will show us whether their prototypes are working and check the criteria. Teacher says "You develop your prototypes, therefore we can control whether they work or not." Then, teacher says "Both groups start their measurements at the same time. At first, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured at the beginning and after 60 minutes by making 2 measurements with 750 milliliters water at 95 degree. First, teacher will put 750 milliliters water at 95 degree in the thermos and measure the temperature of the water with a thermometer. Teacher notes the value read on the thermometer. Teacher will then take a measurement after 60 minutes using a chronometer and takes note. All measurements will be written in the evaluation table. As a result, the highest score will go to the group that provides the minimum heat loss. Other group will get zero point. Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Then, teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and takes note it. All measurements will be written in the evaluation table. During this period, the group with the least temperature changes of outer material of thermos gets the highest points. The other group gets zero points. Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. To measure this, the group using the least harmful material for human health gets highest points. Other group will get zero points. Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused. A group making a thermos which can be used several times gets two more points besides the health criterion. The group making a thermos with several times availability in using gets highest points. The group making a thermos with disposable in using gets zero points." And teacher reminds "All groups will start to measure at the same time and all measurements are taken at the same time. I will observe and control the measurements and results of the groups. After, I select the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group."

After the measurements, teacher interprets the prototypes and says "The thermos of both groups passed the criteria, but the thermos of this group were better than the thermos of the other group. This group has developed a thermos that provides minimum requirements in the table, minimal heat loss, can be carried with bare hands for 15 minutes, uses the least harmful material in contact with coffee and has several times usability in use. Therefore, this group gets more points than other group. Therefore, the first group is this group; the second group is the other group."

Then, teacher says "Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search."

Then, teacher says "Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineering, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future."

9. Budget

This budget is planned according to 2 groups. It can be changed as number of group.

- Paper cup and plastic cup with various sizes (between 100 ml and 1500 ml): Total cost is 10 TL. (It is shared between groups.)
- Glass cup with various sizes (glass water bottles, glass cups) Total cost is 20 TL. (It is shared between groups.)
- Styrofoam (2 cm x 10 cm x 10 cm – 1 piece): 5 TL Total cost is 10 TL.
- Cotton (100 gr – 1 packet): 5 TL Total cost is 10 TL.
- Paper (1 pack): (It is shared between groups.) Total cost is 18 TL
- Cardboard (1 piece): 1 TL Total cost is 2 TL.
- Pen (1 piece): 1 TL Total cost is 2 TL
- Aluminum foil (15 m – 1 packet): (It is shared between groups.) Total cost is 10 TL
- Fiber (200 gr - 1 packet) (It is shared between groups.) Total cost is 8 TL.
- Adhesive (1 piece): 1 TL Total cost is 2 TL.
- Sponge (1 piece): 2 TL Total cost is 4 TL.
- Scissors (1 piece): 1 TL Total cost is 2 TL.
- Band (1 piece): 1 TL

Total cost is 2 TL.

- Thermometers: It will be supplied by school laboratory.
- Water (5 L): 3 TL

  Total cost is 6 TL.
- Kettle/Water heater: It will be supplied by school laboratory.
- Nylon bag (1 packet) (It is shared between groups.)

  Total cost is 10 TL
- Compasses (1 piece):1 TL

  Total cost is 2 TL.
- Ruler (1 piece):1 TL

  Total cost is 2 TL.
- Stretch Film (15 m) (It is shared between groups.)

  Total cost is 10 TL
- Cork Stopper with various sizes

  Total cost is 10 TL.
- Chronometers: It will be supplied by mobile phones.

All total cost of all materials is 140 TL (for 2 groups).

10. Resources and References

MEB (2018), High School Mathematics Course Curriculum

MEB (2018), High School Physics Course Curriculum.

MEB (2018), High School Visual Arts Course Curriculum.

NGSS Lead States., (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Partnership for 21st Century Skills (2010). Framework for 21st Century Learning.

MEB (2018), Primary and Middle School Mathematics Curriculum.

A.2. Pilot Study of Heat and Temperature STEM PBL Activity Teacher Activity Guide Sheet

TEACHER ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 8 lesson hours**

Heat and Temperature STEM PBL Activity

COFFEE TIME

In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95°C to 60°C (ideal coffee drinking temperature) within 1 hour. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60°C and above up to 15 minutes before the end of your study?

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

The project is evaluated by following tables.

Minimum requirements to be observed
Time (it will be determined from the problem)
Desired temperature (it will be determined from the problem)

Quantity of water (it will be determined from the problem)
Length of thermos: 25 cm ± 0.1 cm
Width/diameter of thermos: 8 cm ± 0.1 cm
Thickness of materials: 0.2 cm ± 0.1 cm
Using at least 2 real life materials
Using at least 2 easily accessible materials
Using inexpensive materials (total cost)
Using at least 2 recyclable or recycled materials

Note: All prototypes must meet the minimum requirements in this table. In order to select the winner, the winner will receive the highest score according to the points listed in the table below.

Note: Prototypes will not be considered if their minimum requirements are not met.

Evaluation Criteria			
		Temperature measured for first group	**Temperature measured for second group**
Heat loss (Although the thermos is max sizes, there will	Minimum heat lost: 4 points Maximum heat lost: 0 point	Initial measurement (at the beginning): Second measurement (at the sixty minute):	Initial measurement (at the beginning): Second measurement (at the sixty minute):

be minimal heat loss) (It will be determined by temperature change of coffee)			
Carry for 15 minutes with bare hands (It will be determined by tempe	After 15 minutes, if the temperature change of the outer material of thermos is minimum: 4 points After 15	Initial measurement (at the beginning): Second measurement (at the fifteenth minute):	Initial measurement (at the beginning): Second measurement (at

rature change of outer material of thermos)	minutes, if the temperature change of the outer material of thermos is maximum: 0 point		the fifteenth minute):
Health and Taste (It will be assessed in terms of materials that come into contact with coffee) Glass	Use of materials suitable for human health (Using the least harmful material): 4 points Use of materials suitable for human health (Using the most harmful material): 0		

>Paper Cup> Plastic Cup	point		
Efficiency (It will be evaluated in terms of how many times thermos can be reused)	Several times availability: 2 points Disposable: 0 point		

To explain the evaluation criteria, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured when the water is filled in the thermos and teacher writes the measurement. After 60 minutes, teacher will measure the temperature of water and take notes. All measurements will be written in the evaluation table. As a result, the highest score will go to the group that provides the minimum heat loss. Other group will get zero point.

Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and take note it. All measurements will be written in the evaluation table. During this period, the group with the least temperature changes of outer material of thermos gets the highest points. The other group gets zero points.

Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. To measure this, the group using the least harmful material for human health gets highest points. Other group will get zero points.

Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused. A group making a thermos which can be used several times gets two more points besides the health criterion. The group making a thermos with several times availability in using gets highest points. The group making a thermos with disposable in using gets zero points.

Note: After all prototypes meet the minimum requirements in the table, the criteria of evaluation table are checked. All groups will start to measure at the same time and all measurements are taken at the same time. Teacher will observe and control the measurements and results of the groups. The teacher selects the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group.

Note: Teachers and students can predict the time to stay at the desired temperature with these measurements. Considering the heat loss of the coffee within 15 minutes, the heat loss within 1 hour will be measured. There's an important point here. Even in the evaluation part, even the highest score cannot be selected as first group if it fails to keep the coffee at the desired temperature for the desired time.

Day 1

Read the problem to the students “In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95°C to 60°C (ideal coffee drinking temperature) within 1 hour. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60°C and above up to 15 minutes before the end of your study?”

Separate students into two groups (Every group has 3 students.) and say “In your group, you will determine the need. Every student in each group has the same responsibility to the activity. You share duties within your own groups.”

Say “Considerations in the evaluation are as follows. You will determine the desired time and desired temperature for the coffee to remain hot and quantity of water from the problem. Length of thermos is 25 cm ± 0.1 cm. Width/Diameter of thermos is 8 cm ± 0.1 cm. For heat loss, although the thermos is max sizes, there will be minimum heat loss. You need to carry for 15 minutes with bare hands. Thickness of materials is 0.2 cm ± 0.1 cm. Efficacy is related to how many times thermos can be reused. Health is important. It will be assessed in terms of materials that come into contact with coffee.” add “Accordingly, in the evaluation, the first to keep the coffee hot for the longest time will be selected. Scoring will be used for this. The group with the most points will be selected as the first group.”

Then, ask “Does the problem have a need?” and adds “What is the need?” After that, teacher says “I am a guide to you. If there are any question, I will guide you.” and adds “You have 3 minutes to think.”

While during 3 minutes, distribute the student activity sheet to the students and says “During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet.” Teacher observes the students while reading and discussing the problem.

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Say “Considerations in the evaluation are as follows. You will determine the desired time and desired temperature for the coffee to remain hot and quantity of water from the problem. Length of thermos is 20 cm ± 0.1 cm. Width/Diameter of thermos is 8 cm ± 0.1 cm. For heat loss, although the thermos is max sizes, there will be minimum heat loss. You need to carry for 15 minutes with bare hands. Thickness of materials is 0.2 cm ± 0.1 cm. Efficacy is related to how many times thermos can be reused. Health is important. It will be assessed in terms of materials that come into contact with coffee.” and adds “Accordingly, in the evaluation, the first to keep the coffee hot for the longest time will be selected. Scoring will be used for this. The group with the most points will be selected as the first group.”

Ask “What is the need? Write the need on the second space in the activity sheet.” Write the need on the board. If the students do not give this answer, guide the students until the answer comes.

2.

The need is that a thermos is developed to keep 750 mL coffee hot to drink in the library by considering in 1 hour and at 60 °C for the coffee to remain hot, 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter, being max sizes with minimal heat loss, able to carry for 15 min with bare hands, 0.2 cm ± 0.1 cm in thickness of materials, being efficacy according to reused, being healthy according to come into contact with coffee.

Ask “Have you ever designed a thermos before in your life?” Say “If you have encountered, you can benefit from your experience.” and “If you have not encountered, you will learn what you can do if you encounter such a situation.” Ask “What would you do if such a situation happened to you? Now, you have 7 minutes to discuss it. I want you to generate ideas by talking.” Ask “What should you consider when designing this thermos?” and add “What can you do to keep your coffee warm?” Continue until the response from the students is expected to say that a cover or some insulation materials can be used and continue brainstorming until students receive this answer.

Say “Now, I will give you 2 minutes to think what you need to search. After, you will share what you thought” After 2 minutes, ask “What did you think?” Students are expected to receive the following answer that heat-temperature issues, the material that keeps coffee hot for the longest time, the factors that affect the heat conduction rate, how to make a thermos are needed to investigate to keep coffee warm. Students are guided until these answers come from the students.

Say “Now, it’s time to do search. During this search, you can find the answers of these questions “Did you make a thermos before?”, “Are these thermoses like thermoses you need?”, “How are these thermoses made?”, “What solutions have been found?” For your search, you need some books and computers with Internet. I prepare you 2 9th grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 28 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search in the third space in the activity sheet." Share what students write on the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate.

3.

Heat and Temperature

Energy Transmission Ways

Energy Transmission Rate

Ask "Which resources did you use and what did you find?" and "Which materials are used in making thermoses?" Expect the answer of students which explaining the working principle of a thermos and which materials this thermos is composed. Get the answers from the students that some people make thermos from paper cups, plastic cups, Styrofoam. Then, ask "Is the use of these materials one or more? Are these materials same size or not?" Teacher expect the answers from students that generally, two nested materials are used and they are not same size because there is double glazing to provide thermal insulation in our homes. If same sizes of cups to make a thermos are used, there will be no space between the cups as in double glazing. Write these on the board.

Ask "Which disciplines do you need for the solution of this?" Expect the answers physics, mathematics, engineering and technology. Ask "Which chapters will you need to know about in these lessons' content?" Expect the answers the lesson content as disciplines which are Heat and Temperature in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a thermos. Also, direct students until these answers get. Tell them "Write these on the fourth space in the activity sheet." Write the answers on the board. Also, ask students "Which subtitles of chapters are useful for your problem-solving?" Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate are expected answers, so guide the students until these answers get. Tell them "Write it on the fourth space in the activity sheet." Then, write the answers on the board.

4.

Lessons: Physics, Mathematics, Engineering and Technology

Unit: Heat and Temperature in physics

Chapters: Heat and Temperature, Energy Transmission Ways and Energy Transmission Speed in physics

Chapters: Graphics, Algebra in mathematics

Write the answers on the board and associate the problem and the need on the board by brainstorming with students.

If students cannot find heat and temperature, give them the following example from everyday life "Why do we wear a few clothes on us in winter?"

Says "I will give you 5 minutes to think how the product will be evaluated. After, we will discuss."

Ask "What information does the problem give us?", "Does the problem put restrictions and limitations on us?", "What are the criteria of the problem?" "Write these to your findings in the fifth space in the activity sheet."

Then, teacher asks “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?”, “What are the criteria of the problem?” The purpose in doing so is the problem can be analyzed easily.

Then, discuss for 5 minutes. Write the most common answers of the questions ones are written on the board.

Continue the discussion until the following answers from the students that designing a thermos that managed to keep coffee hot, minimum heat loss, carrying for 15 minutes with bare hands, health and taste, and efficiency criteria, measuring coffee temperature at regular intervals, keeping the 750 mL coffee hot at 60°C and above up to 15 minutes before the end of study, length of thermos, width/diameter of thermos, thickness of materials, measuring coffee temperature at regular intervals, materials are from real life (at least two), easily accessible (at least two), inexpensive, may be recyclable or recycled materials (at least two) are restrictions and limitations. Then, write the all shared information by the students on the board. Then, say “Write these to your findings on the fifth space in the activity sheet.”

5.

Criteria:

-Keeping coffee hot

-Minimum heat loss

-Carry for 15 minutes with bare hands

-Health

-Efficiency

Restrictions-Limitations:

- Length of thermos

- Width/diameter of thermos

- Thickness of materials

-Measuring coffee temperature at regular intervals

-Keeping the 750 mL coffee up to 60°C and above up to 15 minutes before the end of study

Then, ask "What materials do you think you need in line with your research, the criteria you have chosen, the constraints, the limitations, the variables you have determined? Do not forget that these materials are from real life, easily accessible, inexpensive, may be recyclable or recycled materials. To decide the materials, you have 5 minutes." After 5 minutes, plastic cup, paper cup, some fabric, band, aluminum foil are some expected answers from students. Write them on the board.

Say them "Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them on the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it."

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Continue brainstorming until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a thermos is and helps them work with them.

Ask them "How did you decide on these possible solutions?" Ask the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the variables affecting the energy transmission rate in matters; they are surface area, thickness, temperature, types of matter; representation of mathematical inferences on graphs such as the relationship temperature-time, and the use of technology and engineering skills in the design part. The discussion continues until these answers come.

Say "Which of the criteria (number of cups, types of cups, thickness of cups, etc.) mentioned in the assessment change your choice? When these are considered, how to make a thermos? Let's look at this and decide the best solution."

Then, ask "Which solution you have chosen as the best possible solution?" Developing a thermos by using the variables affecting the energy transmission rate in matters is expected answer from the students. Another answer from the students that the surface area, thickness, temperature, types of materials will be examined. To determine the surface area, the materials which students will use in the activity mathematically will be compared and computed which is the expected answer from the students. For thickness, more thickness, less heat loss; to determine the thickness, expected answer from the students that materials which students will use in the activity mathematically will be compared and computed. For temperature, expected answer from the students is that temperature variable will not affect their study because they will study in the same environment at constant temperature. The answer that different materials provide different thermal insulation is expected one. In addition, another expected example from students that considering the example of double glazing, the use of two glazing instead of one glazing increases the thermal insulation. So, putting two cups instead of one is expected answer because of number of cups. Therefore, make students aware of trying different types of cups because all of them will have different heat conduction. In addition, the amount of water that can be taken inside the thermos is 750 mL. Therefore, make students aware of developing a thermos whose internal volume will be at these dimensions; and next is the cup on the outside of the thermos. Also, the expected answer is that if students put two cups of the same size together, this time they cannot provide thermal insulation as in the case of double glazing; so they are going to have to leave some space. In addition to this, another expected answer is that if they do not leave a space, they can use a hollow material. Then, write the students answers on the board. Then, say "Write the board to in the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons."

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After these, ask students "Is there any variable in the problem? If yes, what are they?" Expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant." Then, write the variables on the board and tells them "Write it on the eighth space in the activity sheet."

8.

- *Dependent variables:* water temperature change
- *Independent variables:* types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials
- *Control-constant variables:* amount of water, temperature of environment, the initial temperature of water

Then, ask "When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a thermos with desired features? Are the materials you mentioned before sufficient to develop a thermos with desired features?”

In order to design a thermos with the desired characteristics, students choose their own materials and share it with the teacher.

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher. The teacher asks the students questions like “What materials are required for this activity?”, "What other materials can we use in this activity?", "So, if cutting is necessary, how and with what material will you provide it?", "How do you plan to attach the materials?" to determine the materials in this process.

Foreseen Materials that are expected to request by students after material discussion:

Paper cup, plastic cup with various sizes

Glass cup with various sizes

Styrofoam

Cotton

Paper

Cardboard

Pen

Aluminum foil

Fiber

Adhesive

Sponge

Scissors

Band

Thermometer

Water

Kettle/Water heater

Nylon bag

Compasses

Ruler

Stretch Film

Cork Stopper

Chronometer

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, say “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

Day 2

Bring and separate materials to the groups. Say “Here are your determined materials.”

Then, add “Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There should be the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, kettle, hot water, socket. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, scissors is dangerous product. When you need to use it, you will come and take it from me and bring it back to me.”

Ask “What were the dependent, independent, and control variables that you previously defined?” The expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant. Then, say “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, give them as an example with the blanks in the table. For example, if they first look at the changes of types of cups, they write to the table as follows. (The sample table is shown on the board.)

Say “Write the other variables in the table in the ninth space in the activity sheet.”

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/o**

				bserved
First try	water temperature change	types of cups	-sizes of cups, -types of insulation materials, -amount of insulation materials, -number of cups **Always be kept under control:** -amount of water -temperature of environment -the initial temperature of water	

Then, tell “Time has come to produce/develop a prototype. Here you can make a 750-milliliter thermos.”

For redevelop part, tell **“**You modify and redo the criteria that do not meet the evaluation criteria table. Then, you check again until you meet all the criteria. Then, if your prototype works with all criteria, you skip this step to go to step 10."

Say “Test and control the prototype whether it works effectively or not. You apply your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is working, skip redevelop and go to share your prototype. Second, if the prototype does not work, try again by changing which criterion does not meet in the evaluation criteria table. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.”

Explain why the prototype does not work when the second and third options are encountered. Ask them the problems they observe in the prototype.

Say “You develop your prototypes, therefore we can control whether they work or not.” and add “Both groups start their measurements at the same time. At first, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured at the beginning and after 60 minutes by making 2 measurements with 750 milliliters water at 95 degree. First, teacher will put 750 milliliters water at 95 degree in the thermos and measure the temperature of the water with a thermometer. Teacher notes the value read on the thermometer. Teacher will then take a measurement after 60 minutes using a chronometer and takes note. All measurements will be written in the evaluation table. As a result, the highest score will go to the group that provides the minimum heat loss. Other group will get zero point. Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Then, teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and takes note it. All measurements will be written in the evaluation table. During this period, the group with the least temperature changes of outer material of thermos gets the highest points. The other group gets zero points. Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. To measure this, the group using the least harmful material for human health gets highest points. Other group will get zero points. Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused. A group making a thermos which can be used several times gets two more points besides the health criterion. The group making a thermos with several times availability in using gets highest points. The group making a thermos with disposable in using gets zero points." and remind "All groups will start to measure at the same time and all measurements are taken at the same time. I will observe and control the measurements and results of the groups. After, I select the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group."

After the measurements, interpret the prototypes and say "The thermos of both groups passed the criteria, but the thermos of this group were better than the thermos of the other group. This group has developed a thermos that provides minimum requirements in the table, minimal heat loss, can be carried with bare hands for 15 minutes, uses the least harmful material in contact with coffee and has several times usability in use. Therefore, this group gets more points than other group. Therefore, the first group is this group; the second group is the other group."

Then, say "Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search."

Then, say “Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineering, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future.”

A.3. Pilot Study of Heat and Temperature STEM PBL Activity Student Activity Guide Sheet

STUDENT ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 8 lesson hours**

Heat and Temperature STEM PBL Activity

COFFEE TIME

In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95°C to 60°C (ideal coffee drinking temperature) within 1 hour. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60°C and above up to 15 minutes before the end of your study?

The project is evaluated by following tables.

Minimum requirements to be observed
Time (it will be determined from the problem)
Desired temperature (it will be determined from the problem)
Quantity of water (it will be determined from the problem)
Length of thermos: 25 cm ± 0.1 cm
Width/diameter of thermos: 8 cm ± 0.1 cm
Thickness of materials: 0.2 cm ± 0.1 cm
Using at least 2 real life materials

Using at least 2 easily accessible materials
Using inexpensive materials (total cost)
Using at least 2 recyclable or recycled materials

Note: All prototypes must meet the minimum requirements in this table. In order to select the winner, the winner will receive the highest score according to the points listed in the table below.

Note: Prototypes will not be considered if their minimum requirements are not met.

Evaluation Criteria			
		Temperature measured for first group	**Temperature measured for second group**
Heat loss (Although the thermos is max sizes, there will be minimal heat loss) (It will	Minimum heat lost: 4 points Maximum heat lost: 0 point	Initial measurement (at the beginning): Second measurement (at the sixty minute):	Initial measurement (at the beginning): Second measurement (at the sixty minute):

be determined by temperature change of coffee)			
Carry for 15 minutes with bare hands (It will be determined by temperature change of outer material of	After 15 minutes, if the temperature change of the outer material of thermos is minimum: 4 points After 15 minutes, if the temperature change of the outer material of	Initial measurement (at the beginning): Second measurement (at the fifteenth minute):	Initial measurement (at the beginning): Second measurement (at the fifteenth minute):

thermos)	thermos is maximum: 0 point		
Health and Taste (It will be assessed in terms of materials that come into contact with coffee) Glass >Paper Cup> Plastic Cup	Use of materials suitable for human health (Using the least harmful material): 4 points Use of materials suitable for human health (Using the most harmful material): 0 point		
Effici	Several		

ency (It will be evaluated in terms of how many times thermos can be reused)	times availability: 2 points Disposable: 0 point		

To explain the evaluation criteria, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured when the water is filled in the thermos and teacher writes the measurement. After 60 minutes, teacher will measure the temperature of water and take notes. All measurements will be written in the evaluation table. As a result, the highest score will go to the group that provides the minimum heat loss. Other group will get zero point.

Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and take note it. All measurements will be written in the evaluation table. During this period, the group with the least temperature changes of outer material of thermos gets the highest points. The other group gets zero points.

Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. To measure this, the group using the least harmful material for human health gets highest points. Other group will get zero points.

Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused. A group making a thermos which can be used several times gets two more points besides the health criterion. The group making a thermos with several times availability in using gets highest points. The group making a thermos with disposable in using gets zero points.

Note: After all prototypes meet the minimum requirements in the table, the criteria of evaluation table are checked. All groups will start to measure at the same time and all measurements are taken at the same time. Teacher will observe and control the measurements and results of the groups. The teacher selects the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group.

Note: Teachers and students can predict the time to stay at the desired temperature with these measurements. Considering the heat loss of the coffee within 15 minutes, the heat loss within 1 hour will be measured. There's an important point here. Even in the evaluation part, even the highest score cannot be selected as first group if it fails to keep the coffee at the desired temperature for the desired time.

Write on the first space whether the problem has a need, and what the need is.

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Write what the need on the second space in the activity sheet.

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Write on the third space what you have found during your search about whether thermos is made of before, whether these thermoses are like the thermos you need, how these thermos are made, and what solutions have been found.

3.

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Write which disciplines are necessary for the solution of the problem in the fourth space below.

4.

<u>Lessons:</u>

<u>Unit:</u>

<u>Chapters:</u>

<u>Chapters:</u>

Write your findings on the fifth space about what information the problem gives us, whether the problem puts restrictions and limitations on us, what criteria of the problem are.

5.

Criteria:

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Restrictions and Limitations:

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Create at least 3 possible solutions and write them in the sixth space.

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Write which solution you have chosen as the best possible solution in the seventh space.

7.

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Write what they are on the eighth space if there is a variable (dependent, independent, control-constant) in the problem.

8.

- *Dependent variables:*

- *Independent variables:*

- *Control-constant variables:*

Note: The application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Be careful while using scissors, snap blade knife, wire. When you need to use them, you will come and take them from the teacher and bring it back to the teacher.

Try the information you use and obtain it quickly. Observe how variables affect to develop a prototype.

Write the other variables in the table on the ninth space.

9.

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	water temperature change	types of cups	-sizes of cups, -types of insulation materials, -amount of insulation materials, -number of cups **Always be kept under control:**	

			-amount of water -temperature of environment -the initial temperature of water	

After developing prototype, test it according to the criteria in the evaluation. You have 3 options. First, if the prototype is finished, you can share it with all class. Second, if the prototype does not work, go back and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.

After developing your prototypes, control whether they work or not.

Both groups start their measurements at the same time. At first, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured at the beginning and after 60 minutes by making 2 measurements with 750 milliliters water at 95 degree. First, teacher will put 750 milliliters water at 95 degree in the thermos and measure the temperature of the water with a thermometer. Teacher notes the value read on the thermometer. Teacher will then take a measurement after 60 minutes using a chronometer and takes note. All measurements will be written in the evaluation table. As a result, the highest score will go to the group that provides the minimum heat loss. Other group will get zero point. Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Then, teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and takes note it. All measurements will be written in the evaluation table. During this period, the group with the least temperature changes of outer material of thermos gets the highest points. The other group gets zero points. Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. To measure this, the group using the least harmful material for human health gets highest points. Other group will get zero points. Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused. A group making a thermos which can be used several times gets two more points besides the health criterion. The group making a thermos with several times availability in using gets highest points. The group making a thermos with disposable in using gets zero points." and remind "All groups will start to measure at the same time and all measurements are taken at the same time. I will observe and control the measurements and results of the groups. After, I select the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group.

B.1. Revised Heat and Temperature STEM PBL Activity Lesson Plan

STEM PBL ACTIVITY LESSON PLAN

1. Grade Level: 9

2. Lesson: Physics

3. Unit: HEAT AND TEMPERATURE

4. Objectives:

The following objectives are the maximum number of objectives that students can integrate to the solution of the problem.

At the end of the lesson, students are able;

Physics (MEB (2018), High School Physics Course Curriculum.)

9.5.1.5. To analyze the variables that depend on the change in the temperature of pure substances which receive heat or give heat. **(S.O.1)**

9.5.4.2. To analyze the variables that affect the energy transmission rate in matters. **(S.O.2)**

9.5.4.3. To design for insulation of life space to save energy. **(S.O.3)**

b. To determine a problem related to thermal insulation from daily life and produced solutions for this problem. **(S.O.4)**

c. To pay attention to the necessity of budgeting in order to financial awareness in the designs to be made. **(S.O.5)**

Mathematics (MEB (2018), High School Mathematics Course Curriculum)

9.5.2.2. To interpret the data groups reflecting the real life situation by representing them with appropriate graph types. **(M.O.1)**

Mathematics (MEB (2018), Primary and Middle School Mathematics Curriculum.)

M.7.1.1.5. To solve problems that require operations with integers **(M.O.2)**

M.8.2.2.3. To express how one of the two variables, which have linear relations, changes depending on the other with tables and equations. **(M.O.3)**

a. To use expression in the form of ordered pairs in the representations made with the table. **(M.O.4)**

b. To examine how the value of one of the two variables changes according to the value of the other variable and in which case, which is dependent and which is independent. **(M.O.5)**

M.8.2.2.5. To create and interpret equations, tables and graphs of real life situations involving linear relationships. **(M.O.6)**

M.8.2.2.6. To explain the slope of line with models, associate linear equations and graphs with slope. **(M.O.7)**

c. To utilize appropriate information and communication technologies when necessary. **(M.O.8)**

M.8.4.1.1. To interpret line and column graphs of up to three data groups. **(M.O.9)**

Technology-Engineering (NGSS Lead States (2013), Engineering Design Cycle. NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.)

1. To detail in the problem. **(T.E.O.1)**
2. To create different solution ways. **(T.E.O.2)**
3. To determine criteria and constraints. **(T.E.O.3)**
4. To reach the best solution with necessary technological tools. **(T.E.O.4)**
5. To test the solution ways under different conditions. **(T.E.O.5)**
6. To use mathematics and computers for solution ways. **(T.E.O.6)**
7. To create a prototype. **(T.E.O.7)**
8. To optimize the solution. **(T.E.O.8)**

Visual Arts (MEB (2018), High School Visual Arts Course Curriculum.)

1. To create original products using traditional and contemporary materials. **(V.A.O.1)**
2. To reflect their imagination on their works/studies. **(V.A.O.2)**

21st Century Skills (Partnership for 21st Century Skills (2010). Framework for 21st century learning.)

1. Learning and Innovation Skills

Critical Thinking and Problem Solving **(L.I.S.1)**

Creativity and Innovation **(L.I.S.2)**

Collaboration **(L.I.S.3)**

Communication **(L.I.S.4)**

2. Life and Career Skills

Flexibility and Adaptability **(L.C.S.1)**

Initiative and Self-Direction **(L.C.S.2)**

Social and Cross-Cultural Skills **(L.C.S.3)**

Productivity and Accountability **(L.C.S.4)**

Leadership and Responsibility **(L.C.S.5)**

3. Information, Media and Technology Skills

Information Literacy **(I.M.T.S.1)**

Media Literacy **(I.M.T.S.2)**

ICT (Information, Communications and Technology) Literacy **(I.M.T.S.3)**

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

Problem: In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95 ° C to 60 ° C (ideal coffee drinking temperature) within 1 hour. The size of broken thermos was 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter of thermos, and 0.2 cm ± 0.1 cm in thickness of materials. Also, the broken thermos was very good in terms of health and taste and you could bring with it wherever you went. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60 ° C and above up to 15 minutes before the end of your study like as your old thermos?

Note: All prototypes must meet the minimum requirements in this table.

To explain the evaluation criteria, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured when the water is filled in the thermos and teacher writes the measurement. After 60 minutes, teacher will measure the temperature of water and take notes. All measurements will be written in the evaluation table.

Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and take note it. All measurements will be written in the evaluation table.

Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table.

Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused.

Note: After all prototypes meet the minimum requirements in the table, the criteria of evaluation table are checked. All groups will start to measure at the same time and all measurements are taken at the same time. Teacher will observe and control the measurements and results of the groups. The teacher selects the group that meets the minimum requirements in the table.

Note: Teachers and students can predict the time to stay at the desired temperature with these measurements. Considering the heat loss of the coffee within 15 minutes, the heat loss within 1 hour will be measured. There's an important point here.

5. Topical Outline, Planning and Timing (2 days-11 lesson hours: 440 min)

- 1. Identify the need (10 min)
- 2. Generate ideas/Brainstorm (10 min)
- 3. Searching for the answer (50 min)
- 4. Associate the disciplines (10 min)
- 5. Determine the criteria, materials, restrictions, limitations of the problem (10 min)
- 6. Examine possible solutions (15 min)
- 7. Choose the best possible/applicable/probable/feasible solution (10 min)
- 8. Develop or redevelop a prototype (180 min)
- 9. Test and evaluate the prototype by individual group (70 min)
- 10. Share (75 min)
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8. Presentation of STEM PBL Lesson

Day 1: 115 min

1. Identify the need

At the beginning of the lesson, teacher gives the problem to the students. Teacher says “Here is a problem. The problem is that in the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95 ° C to 60 ° C (ideal coffee drinking temperature) within 1 hour. The size of broken thermos was 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter of thermos, and 0.2 cm ± 0.1 cm in thickness of materials. Also, the broken thermos was very good in terms of health and taste and you could bring with it wherever you went. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60 ° C and above up to 15 minutes before the end of your study like as your old thermos?” and “Now, I will separate you into two groups. Every group has 3 students. In your group, you will determine the need” Teacher says **“**Every student in each group has the same responsibility to the activity. You share duties within your own groups.” **(L.I.S.3) (L.C.S.3) (L.C.S.5)**

Then, teacher asks “What are the minimum requirements and evaluation criteria that this thermos should have?” Also, teacher discusses this question with students and the expected answer come from the students. Teacher says “Fill the table” and says “Considerations in the evaluation are as follows. You will determine the desired time and desired temperature for the coffee to remain hot and quantity of water from the problem. Length of thermos is 25 cm ± 0.1 cm. Width/Diameter of thermos is 8 cm ± 0.1 cm. For heat loss, although the thermos is max sizes, there will be minimum heat loss. You need to carry for 15 minutes with bare hands. Thickness of materials is 0.2 cm ± 0.1 cm. Efficacy is related to how many times thermos can be reused. Health and taste are important. It will be assessed in terms of materials that come into contact with coffee.” and adds “Accordingly, in the evaluation, the first to keep the coffee hot for the longest time will be selected.”

Minimum requirements to be observed
Evaluation Criteria

Then, teacher asks some questions “Does the problem have a need?” and adds “What is the need?” After that, teacher says “I am a guide to you. If there are any question, I will guide you.” and adds “You have 10 minutes to think.”

While during 10 minutes, teacher distributes the student activity sheet to the students and says “During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet.” Teacher observes the students while reading and discussing the problem.

After that, teacher asks students “What is the need?” Teacher expects the following answer from the students “*The need* is that a thermos is developed to keep 750 mL coffee hot to drink in the library by considering in 1 hour and at 60 °C for the coffee to remain hot, 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter, being max sizes with minimal heat loss, able to carry for 15 min with bare hands, 0.2 cm ± 0.1 cm in thickness of materials, being efficacy according to reused, being healthy according to come into contact with coffee." If the students do not give this answer, the teacher will guide the students until the answer comes.

Then, teacher says "Write the need on the second space in the activity sheet." Then, teacher writes the need on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.1)**

2. Generate ideas/Brainstorm

After writing the need on the board, teacher asks to students "Have you ever designed a thermos before in your life?" Teacher says "If you have encountered, you can benefit from your experience." and "If you have not encountered, you will learn what you can do if you encounter such a situation." Then teacher asks "What would you do if such a situation happened to you? Now, you have 10 minutes to discuss it. I want you to generate ideas by talking." Teacher asks "What should you consider when designing this thermos?" and adds "What can you do to keep your coffee warm?" The response from the students is expected to say that a cover or some insulation materials can be used and teacher continues brainstorming until students receive this answer. **(L.C.S.2) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.4) (I.M.T.S.2) (L.I.S.4)**

3. Searching for the answer

Teacher says "Now, I will give you 5 minutes to think what you need to search. After, you will share what you thought" After 5 minutes, teacher asks "What did you think?" Students are expected to receive the following answer that heat-temperature issues, the material that keeps coffee hot for the longest time, the factors that affect the heat conduction rate, how to make a thermos are needed to investigate to keep coffee warm. Students are guided until these answers come from the students.

Teacher says "Now, it's time to do search. During this search, you can find the answers of these questions "Did you make a thermos before?", "Are these thermoses like thermoses you need?", "How are these thermoses made?", "What solutions have been found?" For your search, you need some books and computers with Internet. I prepare you 2 9th grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 45 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search on the third space in the activity sheet." Teacher shares what students write in the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.3)**

After the search, teacher asks "Which resources did you use and what did you find?" and "Which materials are used in making thermoses?" Teacher expects the answer of students which explaining the working principle of a thermos and which materials this thermos is composed. Teacher gets the answers from the students that some people make thermos from paper cups, plastic cups, Styrofoam. Then, teacher asks "Is the use of these materials one or more? Are these materials same size or not?" Teacher expects the answers from students that generally, two nested materials are used and they are not same size because there is double glazing to provide thermal insulation in our homes. If same sizes of cups to make a thermos are used, there will be no space between the cups as in double glazing. Teacher writes these on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.4) (T.E.O.6) (I.M.T.S.2) (I.M.T.S.3)**

4. Associate the disciplines

Then, teacher asks "Which disciplines do you need for the solution of this?" Teacher expects the answers physics, mathematics, engineering and technology. Teacher asks "Which chapters will you need to know about in these lessons' content?" Teacher expects the answers the lesson content as disciplines which are

Heat and Temperature in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a thermos. Also, teacher directs students until these answers get. Teacher tells them “Write these in the fourth space in the activity sheet.” Teacher writes the answers on the board. Also, teacher asks students “Which subtitles of chapters are useful for your problem-solving?” Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate are expected answers, so teacher guide the students until these answers get. Teacher tells them “Write it on the fourth space in the activity sheet.” Then, teacher writes the answers on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1)**

Then, teacher and students associate the problem and the need on the board by brainstorming. If students do not find the heat and temperature, teacher asks them why we wear a few clothes on us in winter. Thus, students discover the relationship between heat and temperature.

5. Determine the criteria, materials, restrictions, limitations of the problem

Teacher says “I will give you 10 minutes to think how the product will be evaluated. After, we will discuss.”

Then, teacher asks “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?”, “What are the criteria of the problem?” The purpose in doing so is the problem can be analyzed easily.

Then, teacher and students start to discuss for 10 minutes. Teacher writes the most common answers of the questions ones are written on the board.

Discussion continues until the following answers from the students that designing a thermos that managed to keep coffee hot, minimum heat loss, carrying for 15 minutes with bare hands, health and taste, and efficiency criteria, keeping the 750 mL coffee hot at 60°C and above up to 15 minutes before the end of study, length of thermos, width/diameter of thermos, thickness of materials, measuring coffee temperature at regular intervals are restrictions and limitations. Then, teacher writes the all shared information by the students on the board. Then, teacher says "Write these to your findings on the fifth space in the activity sheet." **(T.E.O.1) (T.E.O.3) (L.I.S.1)**

6. Examine possible solutions

Teacher says them "Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them in the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it." **(T.E.O.2) (L.I.S.4) (I.M.T.S.2) (L.I.S.3)**

After brainstorming, brainstorming continues until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a thermos is and helps them work with them.

Teacher asks them "How did you decide on these possible solutions?" Teacher asks the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the variables affecting the energy transmission rate in matters; they are surface area, thickness, temperature, types of matter; representation of mathematical inferences on graphs such as the relationship temperature-time, and the use of technology and engineering skills in the design part. The discussion continues until these answers come. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.1) (T.E.O.6) (I.M.T.S.1) (I.M.T.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1)**

7. Choose the best possible/applicable/probable/feasible solution

Teacher says "Which of the criteria (number of cups, types of cups, thickness of cups, etc.) mentioned in the assessment change your choice? When these are considered, how to make a thermos? Let's look at this and decide the best solution."

Then, teacher asks “Which solution you have chosen as the best possible solution?” Developing a thermos by using the variables affecting the energy transmission rate in matters is expected answer from the students. Another answer from the students that the surface area, thickness, temperature, types of materials will be examined. To determine the surface area, the materials which students will use in the activity mathematically will be compared and computed which is the expected answer from the students. For thickness, more thickness, less heat loss; to determine the thickness, expected answer from the students that materials which students will use in the activity mathematically will be compared and computed. For temperature, expected answer from the students is that temperature variable will not affect their study because they will study in the same environment at constant temperature. The answer that different materials provide different thermal insulation is expected one. In addition, another expected example from students that considering the example of double glazing, the use of two glazing instead of one glazing increases the thermal insulation. So, putting two cups instead of one is expected answer because of number of cups. Therefore, teacher makes students aware of trying different types of cups because all of them will have different heat conduction. In addition, the amount of water that can be taken inside the thermos is 750 mL. Therefore, teacher makes students aware of developing a thermos whose internal volume will be at these dimensions; and next is the cup on the outside of the thermos. Also, the expected answer is that if students put two cups of the same size together, this time they cannot provide thermal insulation as in the case of double glazing; so they are going to have to leave some space. In addition to this, another expected answer is that if they do not leave a space, they can use a hollow material. Then, teacher writes the students answers on the board. Then, teacher says “Write the board to in the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons.” **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (T.E.O.1) (L.I.S.1) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1) (L.C.S.2)**

After these, teacher asks students “Is there any variable in the problem? If yes, what are they?” Expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant." Then, teacher writes the variables on the board and tells them "Write it in the eighth space in the activity sheet."

Then, teacher asks "When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a thermos with desired features? Are the materials you mentioned before sufficient to develop a thermos with desired features?"

In order to design a thermos with the desired characteristics, students choose their own materials and share it with the teacher.

Foreseen Materials that are expected to request by students after material discussion:

Paper cup, plastic cup with various sizes

Glass cup with various sizes

Styrofoam

Cotton

Paper

Cardboard

Pen

Aluminum foil

Fiber

Adhesive

Sponge

Scissors

Band

Thermometer

Water

Kettle/Water heater

Nylon bag

Compasses

Ruler

Stretch Film

Cork Stopper

Chronometer

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, teacher says "I will bring the materials tomorrow. Therefore, we will continue tomorrow."

Day 2: 325 min

8. Develop or redevelop a prototype

At the beginning of the lesson, teacher brings and separated materials to the groups. Teacher says “Here are your determined materials.”

Then, teacher adds “Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There should be the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, kettle, hot water, socket. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, scissors is dangerous product. When you need to use it, you will come and take it from me and bring it back to me.”

Teacher asks “What were the dependent, independent, and control variables that you previously defined?” The expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant. Then, teacher says “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, teacher gives them as an example with the blanks in the table. For example, if they first look at the changes of types of cups, they write to the table as follows. (The sample table is shown on the board.)

Teacher says “Write the other variables in the table on the ninth space in the activity sheet.”

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	water temperature change	types of cups	-sizes of cups, -types of insulation materials, -amount of insulation materials, -number of cups **Always be kept under control:** -amount of water -temperature of environment -the initial temperature of water	

(T.E.O.5)

Then, teacher tells "Time has come to produce/develop a prototype. Here you can make a 750-milliliter thermos." **(M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.6) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.1) (L.I.S.2) (L.I.S.3) (L.C.S.4)**

In redevelop part, teacher says "You modify the criteria that do not meet the evaluation criteria table and redesign your prototype. Then, you check again until you meet all the criteria. Then, if your prototype works with all criteria, you skip this step to go to step 10.” **(T.E.O.5) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.2) (L.I.S.3) (L.C.S.1) (L.C.S.4)**

9. Test and evaluate the prototype by individual group

After that, students test and control the prototype whether it works effectively or not.

Teacher says them “You apply your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is working, go to step 10. Second, if the prototype does not work, go to step 8 and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to step 10 when prototypes work”

10. Share

At this stage, when the groups finish their work, they will show us whether their prototypes are working and check the criteria. Teacher says “You develop your prototypes, therefore we can control whether they work or not.” Then, teacher says “Both groups start their measurements at the same time. At first, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured at the beginning and after 60 minutes by making 2 measurements with 750 milliliters water at 95 degree. First, teacher will put 750 milliliters water at 95 degree in the thermos and measure the temperature of the water with a thermometer. Teacher notes the value read on the thermometer. Teacher will then take a measurement after 60 minutes using a chronometer and takes note. All measurements will be written in the evaluation table. Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Then, teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and takes note it. All measurements will be written in the evaluation table. Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused." and teacher reminds "All groups will start to measure at the same time and all measurements are taken at the same time. I will observe and control the measurements and results of the groups. After, I select the group that meets the minimum requirements in the table and receives the highest score from the evaluation criteria table as the first group."

After the measurements, teacher interprets the prototypes and says "The thermos of both groups passed the criteria, but the thermos of this group were better than the thermos of the other group. This group has developed a thermos that provides minimum requirements in the table, minimal heat loss, can be carried with bare hands for 15 minutes, uses the least harmful material in contact with coffee and has several times usability in use. Therefore, the first group is this group; the second group is the other group."

Then, teacher says "Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search."

Then, teacher says “Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineering, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future.”

9. Budget

This budget is planned according to 2 groups. It can be changed as number of group.

- Paper cup and plastic cup with various sizes (between 100 ml and 1500 ml): Total cost is 10 TL. (It is shared between groups.)
- Glass cup with various sizes (glass water bottles, glass cups) Total cost is 20 TL. (It is shared between groups.)
- Styrofoam (2 cm x 10 cm x 10 cm – 1 piece): 5 TL Total cost is 10 TL.
- Cotton (100 gr – 1 packet): 5 TL Total cost is 10 TL.
- Paper (1 pack): (It is shared between groups.) Total cost is 18 TL
- Cardboard (1 piece): 1 TL Total cost is 2 TL.
- Pen (1 piece): 1 TL Total cost is 2 TL
- Aluminum foil (15 m – 1 packet): (It is shared between groups.) Total cost is 10 TL
- Fiber (200 gr - 1 packet) (It is shared between groups.) Total cost is 8 TL.
- Adhesive (1 piece): 1 TL Total cost is 2 TL.
- Sponge (1 piece): 2 TL Total cost is 4 TL.

- Scissors (1 piece): 1 TL
  Total cost is 2 TL.
- Band (1 piece): 1 TL
  Total cost is 2 TL.
- Thermometers: It will be supplied by school laboratory.
- Water (5 L): 3 TL
  Total cost is 6 TL.
- Kettle/Water heater: It will be supplied by school laboratory.
- Nylon bag (1 packet) (It is shared between groups.)
  Total cost is 10 TL
- Compasses (1 piece):1 TL
  Total cost is 2 TL.
- Ruler (1 piece):1 TL
  Total cost is 2 TL.
- Stretch Film (15 m) (It is shared between groups.)
  Total cost is 10 TL
- Cork Stopper with various sizes
  Total cost is 10 TL.
- Chronometers: It will be supplied by mobile phones.

All total cost of all materials is 140 TL (for 2 groups).

10. Resources and References

MEB (2018), High School Mathematics Course Curriculum.

MEB (2018), High School Physics Course Curriculum.

MEB (2018), High School Visual Arts Course Curriculum.

MEB (2018), Primary and Middle School Mathematics Curriculum.

NGSS Lead States., (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Partnership for 21st Century Skills (2010). Framework for 21st Century Learning.

B.2. Revised Heat and Temperature STEM PBL Activity Teacher Activity Guide Sheet

TEACHER ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 11 lesson hours**

Heat and Temperature STEM PBL Activity

COFFEE TIME

In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95 ° C to 60 ° C (ideal coffee drinking temperature) within 1 hour. The size of broken thermos was 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter of thermos, and 0.2 cm ± 0.1 cm in thickness of materials. Also, the broken thermos was very good in terms of health and taste and you could bring with it wherever you went. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60 ° C and above up to 15 minutes before the end of your study like as your old thermos?

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

Note: All prototypes must meet the minimum requirements in this table.

To explain the evaluation criteria, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured when the water is filled in the thermos and teacher writes the measurement. After 60 minutes, teacher will measure the temperature of water and take notes. All measurements will be written in the evaluation table.

Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and take note it. All measurements will be written in the evaluation table.

Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table.

Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused.

Note: After all prototypes meet the minimum requirements in the table, the criteria of evaluation table are checked. All groups will start to measure at the same time and all measurements are taken at the same time. Teacher will observe and control the measurements and results of the groups. The teacher selects the group that meets the minimum requirements in the table.

Note: Teachers and students can predict the time to stay at the desired temperature with these measurements. Considering the heat loss of the coffee within 15 minutes, the heat loss within 1 hour will be measured.

Day 1: 115 minutes

Read the problem to the students "In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95 ° C to 60 ° C (ideal coffee drinking temperature) within 1 hour. The size of broken thermos was 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter of thermos, and 0.2 cm ± 0.1 cm in thickness of materials. Also, the broken thermos was very good in terms of health and taste and you could bring with it wherever you went. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60 ° C and above up to 15 minutes before the end of your study like as your old thermos? "

Separate students into two groups (Every group has 3 students.) and say "In your group, you will determine the need. Every student in each group has the same responsibility to the activity. You share duties within your own groups."
Then, ask "What are the minimum requirements and evaluation criteria that this thermos should have?" Also, discuss this question with students and the expected answer come from the students. Say "Fill the table" and says "Considerations in the evaluation are as follows. You will determine the desired time and desired temperature for the coffee to remain hot and quantity of water from the problem. Length of thermos is 25 cm ± 0.1 cm. Width/Diameter of thermos is 8 cm ± 0.1 cm. For heat loss, although the thermos is max sizes, there will be minimum heat loss.

You need to carry for 15 minutes with bare hands. Thickness of materials is 0.2 cm ± 0.1 cm. Efficacy is related to how many times thermos can be reused. Health and taste is important. It will be assessed in terms of materials that come into contact with coffee.” and add “Accordingly, in the evaluation, the first to keep the coffee hot for the longest time will be selected.”

Minimum requirements to be observed
Evaluation Criteria

Then, ask “Does the problem have a need?” and adds “What is the need?” After that, teacher says “I am a guide to you. If there are any question, I will guide you.” and adds “You have 10 minutes to think.”

While during 10 minutes, distribute the student activity sheet to the students and says “During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet.” Teacher observes the students while reading and discussing the problem.

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Say “Considerations in the evaluation are as follows. You will determine the desired time and desired temperature for the coffee to remain hot and quantity of water from the problem. Length of thermos is 25 cm ± 0.1 cm. Width/Diameter of thermos is 8 cm ± 0.1 cm. For heat loss, although the thermos is max sizes, there will be minimum heat loss. You need to carry for 15 minutes with bare hands. Thickness of materials is 0.2 cm ± 0.1 cm. Efficacy is related to how many times thermos can be reused. Health is important. It will be assessed in terms of materials that come into contact with coffee.” and adds “Accordingly, in the evaluation, the first to keep the coffee hot for the longest time will be selected.”

Ask “What is the need? Write the need on the second space in the activity sheet.” Write the need on the board. If the students do not give this answer, guide the students until the answer comes.

2.

The need is that a thermos is developed to keep 750 mL coffee hot to drink in the library by considering in 1 hour and at 60 °C for the coffee to remain hot, 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter, being max sizes with minimal heat loss, able to carry for 15 min with bare hands, 0.2 cm ± 0.1 cm in thickness of materials, being efficacy according to reused, being healthy according to come into contact with coffee.

Ask “Have you ever designed a thermos before in your life?” Say “If you have encountered, you can benefit from your experience.” and “If you have not encountered, you will learn what you can do if you encounter such a situation.” Ask “What would you do if such a situation happened to you? Now, you have 10 minutes to discuss it. I want you to generate ideas by talking.” Ask “What should you consider when designing this thermos?" and add "What can you do to keep your coffee warm?" Continue until the response from the students is expected to say that a cover or some insulation materials can be used and continue brainstorming until students receive this answer.

Say "Now, I will give you 5 minutes to think what you need to search. After, you will share what you thought" After 5 minutes, ask "What did you think?" Students are expected to receive the following answer that heat-temperature issues, the material that keeps coffee hot for the longest time, the factors that affect the heat conduction rate, how to make a thermos are needed to investigate to keep coffee warm. Students are guided until these answers come from the students.

Say "Now, it's time to do search. During this search, you can find the answers of these questions "Did you make a thermos before?", "Are these thermoses like thermoses you need?", "How are these thermoses made?", "What solutions have been found?" For your search, you need some books and computers with Internet. I prepare you 2 9^{th} grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 45 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search in the third space in the activity sheet." Share what students write on the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate.

3.

Heat and Temperature

Energy Transmission Ways

Energy Transmission Rate

Ask “Which resources did you use and what did you find?” and “Which materials are used in making thermoses?” Expect the answer of students which explaining the working principle of a thermos and which materials this thermos is composed. Get the answers from the students that some people make thermos from paper cups, plastic cups, Styrofoam. Then, ask “Is the use of these materials one or more? Are these materials same size or not?” Teacher expect the answers from students that generally, two nested materials are used and they are not same size because there is double glazing to provide thermal insulation in our homes. If same sizes of cups to make a thermos are used, there will be no space between the cups as in double glazing. Write these on the board.

Ask “Which disciplines do you need for the solution of this?” Expect the answers physics, mathematics, engineering and technology. Ask “Which chapters will you need to know about in these lessons’ content?” Expect the answers the lesson content as disciplines which are Heat and Temperature in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a thermos. Also, direct students until these answers get. Tell them “Write these on the fourth space in the activity sheet.” Write the answers on the board. Also, ask students “Which subtitles of chapters are useful for your problem-solving?” Heat and Temperature, and Energy Transmission Ways and Energy Transmission Rate are expected answers, so guide the students until these answers get. Tell them “Write it on the fourth space in the activity sheet.” Then, write the answers on the board.

4.

Lessons: Physics, Mathematics, Engineering and Technology

Unit: Heat and Temperature in physics

Chapters: Heat and Temperature, Energy Transmission Ways and Energy Transmission Speed in physics

Chapters: Graphics, Algebra in mathematics

Write the answers on the board and associate the problem and the need on the board by brainstorming with students.

If students cannot find heat and temperature, give them the following example from everyday life "Why do we wear a few clothes on us in winter?"

Says "I will give you 10 minutes to think how the product will be evaluated. After, we will discuss."

Ask "What information does the problem give us?", "Does the problem put restrictions and limitations on us?", "What are the criteria of the problem?" "Write these to your findings in the fifth space in the activity sheet."

Then, teacher asks "What information does the problem give us?", "Does the problem put restrictions and limitations on us?", "What are the criteria of the problem?" The purpose in doing so is the problem can be analyzed easily.

Then, discuss for 10 minutes. Write the most common answers of the questions ones are written on the board.

Continue the discussion until the following answers from the students that designing a thermos that managed to keep coffee hot, minimum heat loss, carrying for 15 minutes with bare hands, health and taste, and efficiency criteria, measuring coffee temperature at regular intervals, keeping the 750 mL coffee hot at 60°C and above up to 15 minutes before the end of study, length of thermos, width/diameter of thermos, thickness of materials, measuring coffee temperature at regular intervals, materials are from real life (at least two) are restrictions and limitations. Then, write the all shared information by the students on the board. Then, say "Write these to your findings on the fifth space in the activity sheet."

5.

Criteria:

-Keeping coffee hot

-Minimum heat loss

-Carry for 15 minutes with bare hands

-Health and Taste

-Efficiency

Restrictions-Limitations:

- Length of thermos

- Width/diameter of thermos

- Thickness of materials

-Measuring coffee temperature at regular intervals

-Keeping the 750 mL coffee up to 60°C and above up to 15 minutes before the end of study

Say them "Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them on the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it."

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Continue brainstorming until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a thermos is and helps them work with them.

Ask them “How did you decide on these possible solutions?” Ask the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the variables affecting the energy transmission rate in matters; they are surface area, thickness, temperature, types of matter; representation of mathematical inferences on graphs such as the relationship temperature-time, and the use of technology and engineering skills in the design part. The discussion continues until these answers come.

Say “Which of the criteria (number of cups, types of cups, thickness of cups, etc.) mentioned in the assessment change your choice? When these are considered, how to make a thermos? Let's look at this and decide the best solution.”

Then, ask “Which solution you have chosen as the best possible solution?” Developing a thermos by using the variables affecting the energy transmission rate in matters is expected answer from the students. Another answer from the students that the surface area, thickness, temperature, types of materials will be examined. To determine the surface area, the materials which students will use in the activity mathematically will be compared and computed which is the expected answer from the students. For thickness, more thickness, less heat loss; to determine the thickness, expected answer from the students that materials which students will use in the activity mathematically will be compared and computed. For temperature, expected answer from the students is that temperature variable will not affect their study because they will study in the same environment at constant temperature. The answer that different materials provide different thermal insulation is expected one. In addition, another expected example from students that considering the example of double glazing, the use of two glazing instead of one glazing increases the thermal insulation. So, putting two cups instead of one is expected answer because of number of cups. Therefore, make students aware of trying different types of cups because all of them will have different heat conduction. In addition, the amount of water that can be taken inside the thermos is 750 mL. Therefore, make students aware of developing a thermos whose internal volume will be at these dimensions; and next is the cup on the outside of the thermos. Also, the expected answer is that if students put two cups of the same size together, this time they cannot provide thermal insulation as in the case of double glazing; so they are going to have to leave some space. In addition to this, another expected answer is that if they do not leave a space, they can use a hollow material. Then, write the students answers on the board. Then, say "Write the board to in the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons."

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After these, ask students "Is there any variable in the problem? If yes, what are they?" Expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant." Then, write the variables on the board and tells them "Write it on the eighth space in the activity sheet."

8.

- *Dependent variables:* water temperature change
- *Independent variables:* types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials
- *Control-constant variables:* amount of water, temperature of environment, the initial temperature of water

Then, ask "When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a thermos with desired features? Are the materials you mentioned before sufficient to develop a thermos with desired features?"

In order to design a thermos with the desired characteristics, students choose their own materials and share it with the teacher.

Foreseen Materials that are expected to request by students after material discussion:

Paper cup, plastic cup with various sizes

Glass cup with various sizes

Styrofoam

Cotton

Paper

Cardboard

Pen

Aluminum foil

Fiber

Adhesive

Sponge

Scissors

Band

Thermometer

Water

Kettle/Water heater

Nylon bag

Compasses

Ruler

Stretch Film

Cork Stopper

Chronometer

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, say “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

Day 2: 325 minutes

Bring and separate materials to the groups. Say “Here are your determined materials.”

Then, add “Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There should be the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, kettle, hot water, socket. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, scissors is dangerous product. When you need to use it, you will come and take it from me and bring it back to me.”

Ask “What were the dependent, independent, and control variables that you previously defined?” The expected answer is that water temperature change is dependent, types of cups, sizes of cups, number of cups, types of insulation materials, amount of insulation materials are independent, and amount of water, temperature of environment, the initial temperature of water are control-constant. Then, say “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, give them as an example with the blanks in the table. For example, if they first look at the changes of types of cups, they write to the table as follows. (The sample table is shown on the board.)

Say "Write the other variables in the table in the ninth space in the activity sheet."

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	water temperature change	types of cups	-sizes of cups, -types of insulation materials, -amount of insulation materials, -number of cups **Always be kept under control:** -amount of water -temperature of environment -the initial temperature of water	

Then, tell "Time has come to produce/develop a prototype. Here you can make a 750-milliliter thermos."

For redevelop part, tell "You modify and redo the criteria that do not meet the evaluation criteria table. Then, you check again until you meet all the criteria. Then, if your prototype works with all criteria, you skip this step to go to step 10."

Say "Test and control the prototype whether it works effectively or not. You apply your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is working, skip redevelop and go to share your prototype. Second, if the prototype does not work, try again by changing which criterion does not meet in the evaluation criteria table. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work."

Explain why the prototype does not work when the second and third options are encountered. Ask them the problems they observe in the prototype.

Say "You develop your prototypes, therefore we can control whether they work or not." and add "Both groups start their measurements at the same time. At first, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured at the beginning and after 60 minutes by making 2 measurements with 750 milliliters water at 95 degree. First, teacher will put 750 milliliters water at 95 degree in the thermos and measure the temperature of the water with a thermometer. Teacher notes the value read on the thermometer. Teacher will then take a measurement after 60 minutes using a chronometer and takes note. All measurements will be written in the evaluation table. Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Then, teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and takes note it. All measurements will be written in the evaluation table. Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused." and remind "All groups will start to measure at the same time and all measurements are taken at the same time. I will observe and control the measurements and results of the groups. After, I select the group that meets the minimum requirements in the table.

After the measurements, interpret the prototypes and say "The thermos of both groups passed the criteria, but the thermos of this group were better than the thermos of the other group. This group has developed a thermos that provides minimum requirements in the table, minimal heat loss, can be carried with bare hands for 15 minutes, uses the least harmful material in contact with coffee and has several times usability in use."

Then, say "Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search."

Then, say "Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineering, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future."

B.3. Revised Heat and Temperature STEM PBL Activity Student Activity Guide Sheet

STUDENT ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 11 lesson hours**

Heat and Temperature STEM PBL Activity

COFFEE TIME

In the afternoon, you will go to the library for 1 hour to study. You like to drink coffee while studying. Since you don't like cold coffee very much, you would like to keep coffee hot in thermos. But when you go to make coffee, you notice that your thermos is broken. Before your thermos broke, which is 750 milliliter, brings the boiled water at 95 ° C to 60 ° C (ideal coffee drinking temperature) within 1 hour. The size of broken thermos was 25 cm ± 0.1 cm in length, 8 cm ± 0.1 cm in width/diameter of thermos, and 0.2 cm ± 0.1 cm in thickness of materials. Also, the broken thermos was very good in terms of health and taste and you could bring with it wherever you went. Since you will drink coffee no later than 45 minutes before you get up. Also, it takes 15 minutes to go to the library from the dormitory. How can you keep your coffee hot at 60 ° C and above up to 15 minutes before the end of your study like as your old thermos?

Fill the table.

Minimum requirements to be observed
Evaluation Criteria

Write on the first space whether the problem has a need, and what the need is.

1.

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Write what the need on the second space in the activity sheet.

2.

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Write on the third space what you have found during your search about whether thermos is made of before, whether these thermoses are like the thermos you need, how these thermos are made, and what solutions have been found.

3.

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Write which courses are necessary for the solution of the problem in the fourth space below.

4.

Lessons:

Unit:

Chapters:

Chapters:

Write your findings on the fifth space about what information the problem gives us, whether the problem puts restrictions and limitations on us, what criteria of the problem are.

5.

Criteria:

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Restrictions and Limitations:

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Create at least 3 possible solutions and write them in the sixth space.

6.

1.

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2.

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3.

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Write which solution you have chosen as the best possible solution in the seventh space.

7.

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Write what they are on the eighth space if there is a variable (dependent, independent, control-constant) in the problem.

8.

- *Dependent variables:*
- *Independent variables:*

- *Control-constant variables:*

Note: The application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Be careful while using scissors, snap blade knife, wire. When you need to use them, you will come and take them from the teacher and bring it back to the teacher.

Try the information you use and obtain it quickly. Observe how variables affect to develop a prototype.

Write the other variables in the table on the ninth space.

9.

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	water temperature change	types of cups	-sizes of cups, -types of insulation materials, -amount of insulation materials, -number of cups **Always be kept under control:** -amount of water -temperature of	

			environment -the initial temperature of water	

After developing prototype, test it according to the criteria in the evaluation. You have 3 options. First, if the prototype is finished, you can share it with all class. Second, if the prototype does not work, go back and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.

After developing your prototypes, control whether they work or not.

Both groups start their measurements at the same time. At first, heat loss will be determined by temperature change of coffee. In purpose of this, although the thermos is max sizes and has minimum requirements (it is mentioned in the table), there will be minimal heat loss. While checking, the temperature change of the water (water can be used instead of coffee to check the criterion) will be measured at the beginning and after 60 minutes by making 2 measurements with 750 milliliters water at 95 degree. First, teacher will put 750 milliliters water at 95 degree in the thermos and measure the temperature of the water with a thermometer. Teacher notes the value read on the thermometer. Teacher will then take a measurement after 60 minutes using a chronometer and takes note. All measurements will be written in the evaluation table. Second criterion is to carry the thermos 15 minutes with bare hand; therefore, there should be minimum temperature change of outer material of thermos. In the first criterion, teacher who measures the temperature of the water will also measure the temperature of outer material of thermos at the same time. Teacher who will note the value read on the thermometer in the first criterion also note the value read on the thermometer in here. Then, teacher will then take another measurement after 15 minutes by using a chronometer. At that point, teacher will measure the temperature of the outer material of thermos and takes note it. Third criterion is health and taste. It will be assessed in terms of materials that come into contact with coffee. The materials will be written in the evaluation table. Fourth criterion is efficiency. It will be evaluated in terms of how many times thermos can be reused." and remind "All groups will start to measure at the same time and all measurements are taken at the same time. I will observe and control the measurements and results of the groups. After, I select the group that meets the minimum requirements in the table.

C.1. Revised Motion and Force STEM PBL Activity Lesson Plan

STEM PBL ACTIVITY LESSON PLAN

1. Grade Level: 9

2. Lesson: Physics

3. Unit: MOTION AND FORCE

4. Objectives:

The following objectives are the maximum number of objectives that students can integrate to the solution of the problem.

At the end of the lesson, students are able;

Physics (MEB (2018), High School Physics Course Curriculum.)

9.1.2.1. To relate the application areas of physics with its sub-branches and other disciplines. **(S.O.1)**

b. To give examples from daily life with the relationship between physics and philosophy, biology, chemistry, technology, engineering, art, sports and mathematics. **(S.O.2)**

9.3.1.3. To relate the concepts of position, velocity and time for uniform linear motion. **(S.O.3)**

a. To collect data by experiment or simulations, draw position-time and velocity-time graphs, interpret them and make conversions between the graphs drawn. **(S.O.4)**

b. To draw and interpret mathematical models related to motion by using graphs. **(S.O.5)**

9.3.1.5. To associate the concept of acceleration with acceleration and deceleration events. **(S.O.6)**

9.3.4.1. To analyze the variables to which friction force depends. **(S.O.7)**

a. To make inferences from the data obtained from experiments or simulations and determine the relationship between variables. **(S.O.8)**

d. To give examples of advantages and disadvantages of friction force in daily life. **(S.O.9)**

e. To explain the direction of friction force in bodies moving in a sliding and rotating with examples. **(S.O.10)**

Mathematics (MEB (2018), High School Mathematics Course Curriculum)

9.5.2.2. To interpret the data groups reflecting the real life situation by representing them with appropriate graph types. **(M.O.1)**

Mathematics (MEB (2018), Primary and Middle School Mathematics Curriculum.)

M.7.1.1.5. To solve problems that require operations with integers **(M.O.2)**

M.8.2.2.3. To express how one of the two variables, which have linear relations, changes depending on the other with tables and equations. **(M.O.3)**

a. To use expression in the form of ordered pairs in the representations made with the table. **(M.O.4)**

b. To examine how the value of one of the two variables changes according to the value of the other variable and in which case, which is dependent and which is independent. **(M.O.5)**

M.8.2.2.5. To create and interpret equations, tables and graphs of real life situations involving linear relationships. **(M.O.6)**

M.8.2.2.6. To explain the slope of line with models, associate linear equations and graphs with slope. **(M.O.7)**

c. To utilize appropriate information and communication technologies when necessary. **(M.O.8)**

M.8.4.1.1. To interpret line and column graphs of up to three data groups. **(M.O.9)**

Technology-Engineering (NGSS Lead States (2013), Engineering Design Cycle. NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.)

1. To detail in the problem. **(T.E.O.1)**
2. To create different solution ways. **(T.E.O.2)**
3. To determine criteria and constraints. **(T.E.O.3)**
4. To reach the best solution with necessary technological tools. **(T.E.O.4)**
5. To test the solution ways under different conditions. **(T.E.O.5)**
6. To use mathematics and computers for solution ways. **(T.E.O.6)**
7. To create a prototype. **(T.E.O.7)**
8. To optimize the solution. **(T.E.O.8)**

Visual Arts (MEB (2018), High School Visual Arts Course Curriculum.)

1. To create original products using traditional and contemporary materials. **(V.A.O.1)**
2. To reflect their imagination on their works/studies. **(V.A.O.2)**

21st Century Skills (Partnership for 21st Century Skills (2010). Framework for 21st century learning.)

1. Learning and Innovation Skills
    - Critical Thinking and Problem Solving **(L.I.S.1)**
    - Creativity and Innovation **(L.I.S.2)**
    - Collaboration **(L.I.S.3)**
    - Communication **(L.I.S.4)**
2. Life and Career Skills
    - Flexibility and Adaptability **(L.C.S.1)**
    - Initiative and Self-Direction **(L.C.S.2)**
    - Social and Cross-Cultural Skills **(L.C.S.3)**
    - Productivity and Accountability **(L.C.S.4)**
    - Leadership and Responsibility **(L.C.S.5)**
3. Information, Media and Technology Skills
    - Information Literacy **(I.M.T.S.1)**

Media Literacy **(I.M.T.S.2)**

ICT (Information, Communications and Technology) Literacy **(I.M.T.S.3)**

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

Problem: You're invited to your friend's birthday party. There's a toy car race on his birthday. Everyone has to design their own car and come to the competition. The car that is able to complete the 150 centimeter road as soon as possible will be selected as the fastest car. The mass of the car should be between 50 grams and 250 grams, the total height of the car from the ground (distance from the bottom of the wheel to the highest point of the car) should be between 5 cm and 20 cm, the length of the car (distance between the front and rear ends of the wheels) should be between 10 cm and 20 cm, the width of the car (distance between the outer ends of the wheels) should be between 10 cm and 15 cm and the car should have 4 wheels. Competition rules are as follows. All cars will start racing on a straight whiteboard with a 45 degree incline with the ground. They will start the race with their first wheels at the level of the line on the inclined plane without initial velocity. The length of the inclined plane is 50 cm and the width of the inclined plane is 40 cm. The road will continue as a concrete surface (ground) after the inclined surface is finished. The length of the horizontal plane is 1 meter. The car that managed to complete the 150 centimeter as soon as possible will win the competition. You should design a car that meets all these rules. Come on, start!

Note: All prototypes must meet the minimum requirements. Prototypes will not be considered if their minimum requirements are not met.

To explain the evaluation criterion, the race will have equal conditions for both groups. The teacher places the whiteboard at a 45-degree angle to the floor. For the students to start the race from the whiteboard to the ground, a 50 cm path is determined and a horizontal line is drawn by teacher. The teacher then draws a horizontal line to the concrete floor, where the race ends, so that the inclined plane can be moved 100 cm from where it ends. The aim is to start the race without initial velocity and take the 150-centimeter path as soon as possible. The group that will achieve this will be the first group.

In the competition section, the teacher places the car with the front wheels of the car just behind the line on the inclined plane and leaves the car. As soon as teacher leaves the car, teacher starts the chronometer. The car then stops the chronometer while it crosses the line in the horizontal plane. In this case, he looks at the chronometer and takes notes on the paper. The teacher repeats the same process for both groups. The car that takes the same path as soon as possible wins the race.

Note: In order for the cars to be evaluated on equal terms, the mechanism to be created shall be prepared by the teacher.

5. Topical Outline, Planning and Timing (2 days – 6.5 lesson hours: 260 min)

- 1. Identify the need (15 min)
- 2. Generate ideas/Brainstorm (15 min)
- 3. Searching for the answer (45 min)
- 4. Associate the disciplines (15 min)
- 5. Determine the criteria, materials, restrictions, limitations of the problem (15 min)
- 6. Examine possible solutions (15 min)
- 7. Choose the best possible/applicable/probable/feasible solution (10 min)
- 8. Develop or redevelop a prototype (100 min)

- 9. Test and evaluate the prototype by individual group (15 min)
- 10. Share (15 min)

8. Presentation of STEM PBL Lesson

Day 1: 130 min

1. Identify the need

At the beginning of the lesson, teacher gives the problem to the students. Teacher says “Here is a problem. The problem is that you're invited to your friend's birthday party. There's a toy car race on his birthday. Everyone has to design their own car and come to the competition. The car that is able to complete the 150 centimeter road as soon as possible will be selected as the fastest car. The mass of the car should be between 50 grams and 250 grams, the total height of the car from the ground should be between 5 cm and 20 cm, the length of the car should be between 10 cm and 20 cm, the width of the car should be between 10 cm and 15 cm and the car should have 4 wheels. Competition rules are as follows. All cars will start racing on a straight whiteboard with a 45 degree incline with the ground. They will start the race with their first wheels at the level of the line on the inclined plane without initial velocity. The length of the inclined plane is 50 cm and the width of the inclined plane is 40 cm. The road will continue as a concrete surface (ground) after the inclined surface is finished. The length of the horizontal plane is 1 meter. The car that managed to complete the 150 centimeter as soon as possible will win the competition. You should design a car that meets all these rules. Come on, start!” and “Now, I will separate you into two groups. Every group has 3 students. In your group, you will determine the need” Teacher says **“**Every student in each group has the same responsibility to the activity. You share duties within your own groups.” **(L.I.S.3) (L.C.S.3) (L.C.S.5)**

Then, teacher asks “What are the minimum requirements and evaluation criteria that this toy car should have?” Also, teacher discusses this question with students and the expected answer come from the students. Teacher says “Fill the table” and says “Considerations in the evaluation are as follows. The total road to be completed of the cars is 150 cm. The initial velocity of cars is 0 m/s. The mass of cars is between 50 g - 250 g. The total height of the cars off the ground is between 5 cm - 20 cm. Length of the cars is between 10 cm - 20 cm and width of the cars is between 10 - 15 cm. All cars should have 4 wheels." and adds "Accordingly, in the evaluation, the fastest car according to the car that completes the 150 cm road as soon as possible will be selected as first group."

Minimum requirements to be observed
Evaluation Criteria

Then, teacher asks some questions "Does the problem have a need?" and adds "What is the need?" After that, teacher says "I am a guide to you. If there are any question, I will guide you." and adds "You have 15 minutes to think."

While during 15 minutes, teacher distributes the student activity sheet to the students and says "During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet." Teacher observes the students while reading and discussing the problem.

After that, teacher asks students "What is the need?" Teacher expects the following answer from the students "*The need* is that a toy car is developed to win the race as quickly as possible that complete the 150 cm road by considering 0 m/s in initial velocity, having between 50 g - 250 g in mass, between 10 cm - 20 cm in total height of the car off the ground in length, between 10 - 15 cm in width, 4 wheels." If the students do not give this answer, the teacher will guide the students until the answer comes.

Then, teacher says "Write the need on the second space in the activity sheet." Then, teacher writes the need on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.1)**

2. Generate ideas/Brainstorm

After writing the need on the board, teacher asks to students "Have you ever designed a toy car before in your life?" Teacher says "If you have encountered, you can benefit from your experience." and "If you have not encountered, you will learn what you can do if you encounter such a situation." Then teacher says "What would you do if such a situation happened to you? Now, you have 15 minutes to discuss it. I want you to generate ideas by talking." Teacher asks "What should you consider when designing this car?" and adds "Should the mass of the car be large or small?" The response from the students is expected to say "A certain mass can contribute to movement" and teacher continues brainstorming until students receive this answer. Then, teacher asks "Does the height of the car change anything?" Students are expected to say that "Very high cars can both tip over and cause problems in terms of aerodynamics." and teacher continues brainstorming until students receive this answer. Moreover, teacher asks "How should the wheels be? Should they are big or small? Should the wheel be thin or thick?" Teacher expects the answer "The size of the wheel is about speed and comfort. The width of the wheel is about getting in the ground. Therefore, the wheels of cars are small; the wheels of trucks are big." from the students. Then, teacher asks "What should be the surface of the wheel? Should the friction between the wheel and the ground be large or small? Should the friction between the shaft in the wheel and the car be large or small?" The answer from the students "Friction between the wheel and the shaft should be minimum." Also, teacher asks "What is the shape of the wheel?" The answer from the students should be "It should be circle." Then, teacher asks "How should the surface of the circle contact with the ground?" The answer from the students may be rubber. **(L.C.S.2) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.4) (I.M.T.S.2)**

3. Searching for the answer

Teacher says "Now, I will give you 5 minutes to think what you need to search. After, you will share what you thought" After 5 minutes, teacher asks "What did you think?" Students are expected to receive the following answer that motion-forces issues, the material of wheels that moves fastest on the floor, the factors that affect the friction force, how to design a toy car to design a fastest car. Students are guided until these answers come from the students.

Teacher says "Now, it's time to do search. During this search, you can find the answers of these questions "Did you make a toy car before?", "Are these toy cars like the toy cars you need?", "How are these toy cars made?", "What solutions have been found?" For your search, you need some books and computers with Internet. I prepare you 2 9^{th} grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 40 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search in the third space in the activity sheet." Teacher shares what students write on the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Motion, and Friction Force. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.3) (L.I.S.4)**

After the search, teacher asks “Which resources did you use and what did you find?” and “Which materials are used in making toy cars?” Teacher expects the answer of students which explaining the working principle of a toy car and which materials this toy car is composed. Teacher gets the answers from the students that some people make cars from plastic water bottles, water bottle covers and paper cups. Then, teacher asks “Is the use of these materials one or more?” Teacher expects the answers from students that generally, four covers for wheels are used. Teacher writes these on the board. **(T.E.O.4) (T.E.O.6) (I.M.T.S.2) (I.M.T.S.3)**

4. Associate the disciplines

Then, teacher asks “Which disciplines do you need for the solution of this?” Teacher expects the answers physics, mathematics, engineering and technology. Teacher asks “Which chapters will you need to know about in these lessons’ content?” Teacher expects the answers the lesson content as disciplines which are Motion and Force in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a toy car. Also, teacher directs students until these answers get. Teacher tells them “Write these in the fourth space in the activity sheet.” Teacher writes the answers on the board. Also, teacher asks students “Which subtitles of chapters are useful for your problem-solving?” Motion and Friction Force are expected answers, so teacher guide the students until these answers get. Teacher tells them “Write it in the fourth space in the activity sheet.” Then, teacher writes the answers on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (T.E.O.1)**

Then, teacher and students associate the problem and the need on the board by brainstorming. If students do not find the motion and friction force, teacher asks them why chains are attached to the tire of cars in winter. Thus, students discover the relationship between motion and friction force.

5. Determine the criteria, materials, restrictions, limitations of the problem

Teacher says “I will give you 15 minutes to think how the product will be evaluated. After, we will discuss.”

Then, teacher asks "What information does the problem give us?", "Does the problem put restrictions and limitations on us?", "What are the criteria of the problem?" The purpose in doing so is the problem can be analyzed easily.

Then, teacher and students start to discuss for 15 minutes. Teacher writes the most common answers of the questions ones are written on the board.

Discussion continues until the following answers from the students that designing a car that managed to complete the 150 centimeter as soon as possible is a criterion, mass of car, the total height of the car off the ground, length of car, width of car, number of wheels are restrictions and limitations. In addition to all these answers, students are expected to pay attention to the environment in which the race will take place and say that the environment in which the race will take place should have the following characteristics: initial velocity, material of inclined plane, angle between inclined plane and floor, length of inclined plane, width of inclined plane, material of inclined plane, length of horizontal plane and a horizontal line on the inclined plane. Then, teacher writes the all shared information by the students on the board. Then, teacher says "Write these to your findings in the fifth space in the activity sheet." **(T.E.O.1) (T.E.O.3) (L.I.S.1)**

6. Examine possible solutions

Teacher says them "Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them in the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it." **(T.E.O.2) (L.I.S.4) (I.M.T.S.2) (L.I.S.3)**

After brainstorming, brainstorming continues until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a car is and helps them work with them.

Teacher asks them “How did you decide on these possible solutions?” Teacher asks the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the effects of friction on objects, representation of mathematical inferences on graphs, and the use of technology and engineering skills in the design part. The discussion continues until these answers come. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.1) (T.E.O.6) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1)**

7. Choose the best possible/applicable/probable/feasible solution

Teacher says “Which of the criteria (mass of cars, height of car, length of car, etc.) mentioned in the assessment change your choice? When these are considered, how to make a toy car? Let's look at this and decide the best solution.”

Then, teacher asks “Which solution you have chosen as the best possible solution?” The expected answers from students are what variables affecting friction force are. Also, teacher expects the following answers that friction force depends on magnitude of vertical force acting on the surface and types of friction surfaces; and does not depend on size of friction surfaces. Teacher expects the reasons of these answers that vertical force acting on the surface is related to mass of car and this is between 50 g – 250 g, so a certain mass can help to motion. Moreover, teacher expects the following answers that material and thickness of wheels are related to types of friction surfaces, but size of wheels does not affect the friction force. Teacher waits for the student to capture the following detail that friction force between the shaft inside the wheel and the wheel should be minimum; and the minimum force required for the car to move must be greater than the frictional force between the car and the ground.

Then, teacher writes the students’ answers on the board. Then, teacher says “Write the board to in the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons.” **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5)**

(S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (T.E.O.1) (L.I.S.1) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1) (L.C.S.2)

After these, teacher asks students “Is there any dependent variable, independent variable, control-constant variable in the problem explicitly? If yes, what are they?”

Students are expected to say that time taken of the groups to finish the race is dependent, mass of car, the type of the wheels (material of the wheels), the surface of the wheels, size of the wheels, and the thickness of the wheels, the material of the shaft inside the wheel, the size of the shaft inside the wheel, total height of the car off the ground, length of car, width of car are independent, and initial velocity of cars, number of wheels are control-constant. Also, teacher expects the following answers that for race and measurement environment; material of inclined plan, angle between inclined plane and floor, length of inclined plane, width of inclined plane, material of horizontal plane, length of horizontal plane, a horizontal line on the inclined plane can be accepted as control-constant because all cars will race under the same conditions. The discussion continues until all these answers come.

Then, teacher writes the dependent, independent and control-constant variables on the board and tells them “Write it in the eighth space in the activity sheet.”

Then, teacher asks “When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a toy car with desired features? Are the materials you mentioned before sufficient to develop a toy car with desired features?”

In order to design a toy car with the desired characteristics, students choose their own materials and share it with the teacher.

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher. The teacher asks the students questions like “What materials are required for this activity?”, "What other materials can we use in this activity?", "So, if cutting is necessary, how and with what material will you provide it?", "How do you plan to attach the materials?" to determine the materials in this process.

Foreseen Materials that are expected to request by students after material discussion:

Paper cup and plastic cup with various sizes

Styrofoam

Paper

Cardboard

Pen

Pencil

Fiber

Adhesive

Sponge

Scissors

Band

Ruler

Sticks and pieces of woods with various sizes

Rubber Band

Measuring Tape

Rope

Chronometer

Bendable wire

Match box

Cardboard box

Toilet paper roll

Plastic water bottles with different size

Water bottle cover with various sizes

Pipette

Dynamometer

Snap blade knife

Thin glass bottle

Fruit juice cans with various sizes
Tin box with various sizes

CD

Gel

Liquid oil

Machine oil

Hair clip

Toothpick

Glass bottle cap (metal)

Soda can

Soda cover:

Barbeque sticks

Tongue depressors

Paper tower roll

Sewing spool

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, teacher says "I will bring the materials tomorrow. Therefore, we will continue tomorrow."

Day 2: 130 min

8. Develop or redevelop a prototype

At the beginning of the lesson, teacher brings and separated materials to the groups. Teacher says "Here are your determined materials."

Then, teacher adds "Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There should be the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, snap blade knife, wire. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, snap blade knife is dangerous product. When you need to use it, you will come and take it from me and bring it back to me."

Then, teacher says "Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers."

Before students writes the variables they have determined for their chosen solution to the table, teacher gives them as an example with the blanks in the table. For example, if they first look at the changes of type of the wheel, they write to the table as follows. (The sample table is shown on the board.)

Teacher says "Write the other variables in the table on the ninth space in the activity sheet."

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	Time taken of the groups to finish the race	-the type of the wheel (material of the wheel)	-mass of car -the surface of the wheel -size of the wheels -the thickness of the wheel -the material of the shaft inside the wheel -the size of the shaft inside the wheel -total height of the car off the ground	

			-length of car - width of car **Always be kept under control:** -initial velocity of cars -number of wheels are control-constant	

(T.E.O.5)

Then, teacher tells “Time has come to develop a prototype.” **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.6) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.1) (L.I.S.2) (L.I.S.3) (L.C.S.4)**

In redevelop part, teacher says “You modify the criteria that do not meet the evaluation criteria table and redesign your prototype. Then, you check again until you meet all the criteria. Then, if your prototype works with all criteria, you go to step 10.” **(T.E.O.5) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.2) (L.I.S.3) (L.C.S.1) (L.C.S.4)**

9. Test and evaluate the prototype by individual group

After that, students test and control the prototype whether it works effectively or not.

Teacher says them “You develop your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is finished, go to step 10. Second, if the prototype does not work, go to step 8 and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to step 10 when prototypes work"

Also, the teacher explains why the prototype does not work when the second and third options are encountered. Teacher asks them the problems they observe in the prototype.

10. Share

The teacher places the whiteboard at a 45-degree angle to the floor. For the students to start the race from the whiteboard to the ground, a 50 cm path is determined and a horizontal line is drawn by teacher. The teacher then draws a horizontal line to the concrete floor, where the race ends, so that the inclined plane can be moved 100 cm from where it ends. The aim is to start the race without initial velocity and take the 150-centimeter path as soon as possible. The group that will achieve this will be the first group.

In the competition section, the teacher places the car with the front wheels of the car just behind the line on the inclined plane and leaves the car. As soon as teacher leaves the car, teacher starts the chronometer. The car then stops the chronometer while it crosses the line in the horizontal plane. In this case, teacher looks at the chronometer and takes notes on the paper. The teacher repeats the same process for both groups. The car that takes the same path as soon as possible wins the race.

Then, the teacher will choose the car that goes the 150 centimeter road as soon as possible. After the measurements, teacher interprets the prototypes and says "The toy cars of both groups passed the criteria, but the toy car of this group were better than the toy car of the other group according to the time. This group has developed a toy car that provides minimum requirements in the table, and to go the 150 cm road as soon as possible. Therefore, the first group is this group; the second group is the other group." Then, teacher says "Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search."

Then, teacher says "Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineers, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future."

9. Budget

This budget is planned according to 2 groups. It can be changed as number of group.

- Paper cup and plastic cup with various sizes (100 ml – 200 ml – 300 ml): *(It is shared between groups.)*
  Total cost is 10 TL. (It is shared between groups.)
- Styrofoam (2 cm x 10 cm x 10 cm – 1 piece): 5 TL (It is shared between groups.)
  Total cost is 10 TL.
- Paper (1 pack): *(It is shared between groups.)*
  Total cost is 18 TL
- Cardboard (1 piece): 1 TL
  Total cost is 2 TL.
- Pen (1 piece): 1 TL
  Total cost is 2 TL
- Pencil (1 piece): 0.5 TL
  Total cost is 2 TL.
- Fiber (200 gr - 1 packet) *(It is shared between groups.)*

Total cost is 8 TL.

- Adhesive (1 piece): 1 TL

  Total cost is 2 TL.
- Sponge (1 piece): 2 TL

  Total cost is 4 TL.
- Scissors (1 piece): 1 TL

  Total cost is 2 TL.
- Band (1 piece): 1 TL

  Total cost is 2 TL.
- Ruler (1 piece):1 TL

  Total cost is 2 TL.
- Sticks and pieces of woods with various sizes

  Total cost is 0 TL. (It will be supplied by garden.)
- Rubber Band (100 pieces in 1 packet): (It is shared between groups.)

  Total cost is 3 TL
- Measuring Tape (1.5 m): 3 TL

  Total cost is 6 TL.
- Rope (2 m - 1 piece): 3 TL

  Total cost is 6 TL.
- Chronometer (It will be supplied by cellphone.)
- Bendable wire (1.4 mm, 25 meter in 1 packet) (It is shared between groups.)

  Total cost is 12 TL
- Match box (10 pieces - 1 packet): 4 TL

  Total cost is 8 TL.
- Cardboard box with different sizes (It will be supplied by markets.)
- Toilet paper roll (It will be supplied by homes.)
- Plastic water bottle (0.5 liter): 0.5 TL

  Total cost is 3 TL.
- Plastic water bottle (1 liter): 0.75 TL

Total cost is 3 TL.

- Water bottle cover with various sizes (It will be supplied by homes.) (It is shared between groups.)
- Snap blade knife: 3 TL

  Total cost is 6 TL.
- Pipette (100 pieces - 1 packet) *(It is shared between groups.)*

  Total cost is 10 TL.
- Dynamometer (It will be supplied by laboratory.)
- Thin glass bottle: 2 TL

  Total cost is 4 TL.
- Fruit juice cans with various sizes

  Total cost is 10 TL.
- Tin box with various sizes

  Total cost is 10 TL.
- CD (It will be supplied by homes)
- Gel (It will be supplied by homes)
- Liquid oil (It will be supplied by homes)
- Machine oil (50 mL in a bottle)

  Total cost is 2 TL.
- Hair clip (It will be supplied by homes)
- Toothpick (1 packet)

  Total cost is 5 TL.
- Glass bottle cap (metal)
- Soda can (6 bottle in 1 packet)

  Total cost is 5 TL.
- Soda cover: 5 TL

Total cost is 5 TL.

- Barbeque sticks (1 packet)

  Total cost is 2 TL.

- Tongue depressors (1 packet)

  Total cost is 5 TL.

- Paper tower roll (It will be supplied by homes)
- Sewing spools: 3 TL

  Total cost is 24 TL.

All total cost of all materials is 195 TL (for 2 groups).

10. Resources and References

MEB (2018), High School Mathematics Course Curriculum

MEB (2018), High School Physics Course Curriculum.

MEB (2018), High School Visual Arts Course Curriculum.

NGSS Lead States., (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Partnership for 21st Century Skills (2010). Framework for 21st Century Learning.

MEB (2018), Primary and Middle School Mathematics Curriculum.

C.2. Revised Motion and Force STEM PBL Activity Teacher Activity Guide Sheet

TEACHER ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 6.5 lesson hours**

Motion and Force STEM PBL Activity

BE THE FIRST!

You're invited to your friend's birthday party. There's a toy car race on his birthday. Everyone has to design their own car and come to the competition. The car that is able to complete the 150 centimeter road as soon as possible will be selected as the fastest car. The mass of the car should be between 50 grams and 250 grams, the total height of the car from the ground (distance from the bottom of the wheel to the highest point of the car) should be between 5 cm and 20 cm, the length of the car (distance between the front and rear ends of the wheels) should be between 10 cm and 20 cm, the width of the car (distance between the outer ends of the wheels) should be between 10 cm and 15 cm and the car should have 4 wheels. Competition rules are as follows. All cars will start racing on a straight whiteboard with a 45 degree incline with the ground. They will start the race with their first wheels at the level of the line on the inclined plane without initial velocity. The length of the inclined plane is 50 cm and the width of the inclined plane is 40 cm. The road will continue as a concrete surface (ground) after the inclined surface is finished. The length of the horizontal plane is 1 meter. The car that managed to complete the 150 centimeter as soon as possible will win the competition. You should design a car that meets all these rules. Come on, start!

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

Note: All prototypes must meet the minimum requirements.

To explain the evaluation criterion, the race will have equal conditions for both groups. The teacher places the whiteboard at a 45-degree angle to the floor. For the students to start the race from the whiteboard to the ground, a 50 cm path is determined and a horizontal line is drawn by teacher. The teacher then draws a horizontal line to the concrete floor, where the race ends, so that the inclined plane can be moved 100 cm from where it ends. The aim is to start the race without initial velocity and take the 150-centimeter path as soon as possible. The group that will achieve this will be the first group.

In the competition section, the teacher places the car with the front wheels of the car just behind the line on the inclined plane and leaves the car. As soon as teacher leaves the car, teacher starts the chronometer. The teacher stops the chronometer while car crosses the line in the horizontal plane. In this case, teacher looks at the chronometer and takes notes on the paper. The teacher repeats the same process for both groups. The car that takes the same path as soon as possible wins the race.

Note: After all prototypes meet the minimum requirements in the table, the criteria of evaluation table are checked. Teacher will observe and control the measurements and results of the groups. The teacher selects the group that meets the minimum requirements in the table and finished the race as soon as possible from the evaluation criteria table as the first group.

Note: In order for the cars to be evaluated on equal terms, the mechanism to be created shall be prepared by the teacher.

Day 1: 130 min

Read the problem to the students. Then, separate students into two groups. Say that every group has 3 students. Also, say that in their group, they will determine the need. Add that every student in each group has the same responsibility to the activity; they share duties within their own groups.

Then, ask "What are the minimum requirements and evaluation criteria that this toy car should have?" Also, discuss this question with students and the expected answer come from the students. Say "Fill the table" and say "Considerations in the evaluation are as follows. The total road to be completed of the cars is 150 cm. The initial velocity of cars is 0 m/s. The mass of cars is between 50 g - 250 g. The total height of the cars off the ground is between 5 cm - 20 cm. Length of the cars is between 10 cm - 20 cm and width of the cars is between 10 – 15 cm. All cars should have 4 wheels." Then, say "Accordingly, in the evaluation, the fastest car according to the car that completes the 150 cm road as soon as possible will be selected as first group."

Minimum requirements to be observed

Evaluation Criteria

Ask “Does the problem have a need?” and add “What is the need?” Say “I am a guide to you. If there are any question, I will guide you.” and add “You have 15 minutes to think.”

While during 15 minutes, distribute the student activity sheet to the students and say “During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet.” Also, observe the students while reading and discussing the problem.

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Ask “What is the need?”

2. ***The need*** is that a toy car is developed to win the race as quickly as possible that complete the 150 cm road by considering 0 m/s in initial velocity, having between 50 g - 250 g in mass, between 10 cm - 20 cm in total height of the car off the ground in length, between 10 - 15 cm in width, 4 wheels, using real life materials.

If the students do not give this answer, guide the students until the answer comes. Write the need on the board.

Ask “Have you ever designed a toy car before in your life?” Say “If you have encountered, you can benefit from your experience.” and “If you have not encountered, you will learn what you can do if you encounter such a situation.”

Ask “What would you do if such a situation happened to you? Now, you have 15 minutes to discuss it. I want you to generate ideas by talking.”

Ask “What should you consider when designing this car?” and add “Should the mass of the car be large or small?” Wait that the response from the students is expected to say "A certain mass can contribute to movement" and continue brainstorming until students receive this answer. Ask “Does the height of the car change anything?” Wait that students are expected to say that “Very high cars can both tip over and cause problems in terms of aerodynamics.” and continue brainstorming until students receive this answer. Moreover, Ask “How should the wheels be? Should they are big or small? Should the wheel be thin or thick?” Expect the answer “The size of the wheel is about speed and comfort. The width of the wheel is about getting in the ground. Therefore, the wheels of cars are small; the wheels of trucks are big.” from the students. Then, ask “What should be the surface of the wheel? Should the friction between the wheel and the ground be large or small? Should the friction between the shaft in the wheel and the car be large or small?” The answer is from the students "Friction between the wheel and the shaft should be minimum.” Also, ask “What is the shape of the wheel?” The answer from the students should be “It should be circle.” Then, ask “How should the surface of the circle contact with the ground?” The answer from the students may be rubber.

Say “Now, I will give you 5 minutes to think what you need to search. After, you will share what you thought” After 5 minutes, ask “What did you think?” Students are expected to receive the following answer that motion-forces issues, the material of wheels that moves fastest on the floor, the factors that affect the friction force, how to design a toy car to design a fastest car. Students are guided until these answers come from the students.

Say “Now, it’s time to do search. During this search, you can find the answers of these questions “Did you make a toy car before?”, “Are these toy cars like the toy cars you need?”, “How are these toy cars made?”, “What solutions have been found?” For your search, you need some books and computers with Internet. I prepare you 2 9th grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 40 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search in the third space in the activity sheet.” Teacher shares what students write in the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Motion, and Friction Force.

3.

Motion, Friction Force

Using different materials like paper cups, plastic cups, water bottle cover, water bottle

Four covers for wheels

Wheel type and size related with friction

Ask “Which disciplines do you need for the solution of this?” Teacher expects the answers physics, mathematics, engineering and technology. Ask “Which chapters will you need to know about in these lessons’ content?” Expect the answers the lesson content as disciplines which are Motion and Force in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design a toy car. Also, direct students until these answers get. Tell them “Write these in the fourth space in the activity sheet.” Write the answers on the board. Also, ask students “Which subtitles of chapters are useful for your problem-solving?” Motion and Friction Force are expected answers, so guide the students until these answers get. Tell them “Write it on the fourth space in the activity sheet.” Then, write the answers on the board.

Then, associate the problem and the need with the students on the board by brainstorming. If students do not find the motion and friction force, teacher asks them why chains are attached to the tire of cars in winter. Thus, students discover the relationship between motion and friction force.

4.

Lessons: Physics, Mathematics, Engineering and Technology

Unit: Motion and Force in physics

Chapters: Motion, Friction Force in physics

Chapters: Graphics, Algebra in mathematics

Says “I will give you 15 minutes to think how the product will be evaluated. After, we will discuss.”

Ask “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?”, “What are the criteria of the problem?” “Write these to your findings on the fifth space in the activity sheet.”

Write the most common answers on the board.

5.

Criteria:

- Designing the car which as quickly as possible motion (fastest car)

Restrictions and Limitations:

-Time of race

-Initial velocity of car

-Mass of car

-The total height of the car off the ground

-Length of car

-Width of car

-Number of wheels

-Size and type of the wheel

Say “Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them on the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it.”

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After brainstorming, brainstorming continues until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a car is and helps them work with them.

Ask them “How did you decide on these possible solutions?” Ask the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the effects of friction on objects, representation of mathematical inferences on graphs, and the use of technology and engineering skills in the design part. The discussion continues until these answers come.

Say “Which of the criteria (number of cups, types of cups, thickness of cups, etc.) mentioned in the assessment change your choice? When these are considered, how to make a toy car? Let's look at this and decide the best solution.” “Which solution you have chosen as the best possible solution? Write the board to in the seventh space in the activity sheet.”

The expected answers from students are what variables affecting friction force are. Also, expect the following answers that friction force depends on magnitude of vertical force acting on the surface and types of friction surfaces; and does not depend on size of friction surfaces. Expect the reasons of these answers that vertical force acting on the surface is related to mass of car and this is between 50 g – 250 g, so a certain mass can help to motion. Moreover, expect the following answers that material and thickness of wheels are related to types of friction surfaces, but size of wheels does not affect the friction force. Wait for the student to capture the following detail that friction force between the shaft inside the wheel and the wheel should be minimum; and the minimum force required for the car to move must be greater than the frictional force between the car and the ground.

Then, write the students’ answers on the board. Then, say “Write the board to on the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons.”

7.

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Write the answers on the board.

After these, ask students "Is there any dependent variable, independent variable, control-constant variable in the problem explicitly? If yes, what are they?"

Students are expected to say that time taken of the groups to finish the race is dependent, mass of car, the type of the wheels (material of the wheels), the surface of the wheels, size of the wheels, and the thickness of the wheels, the material of the shaft inside the wheel, the size of the shaft inside the wheel, total height of the car off the ground, length of car, width of car are independent, and initial velocity of cars, number of wheels are control-constant. Also, teacher expects the following answers that for race and measurement environment; material of inclined plan, angle between inclined plane and floor, length of inclined plane, width of inclined plane, material of horizontal plane, length of horizontal plane, a horizontal line on the inclined plane can be accepted as control-constant because all cars will race under the same conditions. The discussion continues until all these answers come.

Then, teacher writes the dependent, independent and control-constant variables on the board and tells them "Write it in the eighth space in the activity sheet."

8.

- *Dependent variables:* time taken of the groups to finish the race
- *Independent variables:* mass of car, the type of the wheel (material of the wheel), the surface of the wheel, the width-narrowness of the wheel, size of

the wheels, and the thickness of the wheel, the material of the shaft inside the wheel, the size of the shaft inside the wheel, length of car, width of car

- *Control-constant variables:* initial velocity of cars, number of wheels

Write the variables on the board.

Then, ask “When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a toy car with desired features? Are the materials you mentioned before sufficient to develop a toy car with desired features?”

In order to design a toy car with the desired characteristics, students choose their own materials and share it with the teacher.

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher. Ask the students questions like “What materials are required for this activity?”, "What other materials can we use in this activity?", "So, if cutting is necessary, how and with what material will you provide it?", "How do you plan to attach the materials?" to determine the materials in this process.

Foreseen Materials that are expected to request by students after material discussion:

Paper cup and plastic cup with various sizes

Styrofoam

Paper

Cardboard

Pen

Pencil

Fiber

Adhesive

Sponge

Scissors

Band

Ruler

Sticks and pieces of woods with various sizes

Rubber Band

Measuring Tape

Rope

Chronometer

Bendable wire

Match box

Cardboard box

Toilet paper roll

Plastic water bottles with different size

Water bottle cover with various sizes

Pipette

Dynamometer

Snap blade knife

Thin glass bottle

Fruit juice cans with various sizes

Tin box with various sizes

CD

Gel

Liquid oil

Machine oil

Hair clip

Toothpick

Glass bottle cap (metal)

Soda can

Soda cover

Barbeque sticks

Tongue depressors

Paper tower roll

Sewing spool

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, say “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

Day 2: 130 min

Bring and separate materials to the groups.

Say “Here are your determined materials.”

Say “Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There is the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, snap blade knife, wire. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, snap blade knife is dangerous product. When you need to use it, you will come and take it from me and bring it back to me.”

Say “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, give them as an example with the blanks in the table. For example, if they first look at the changes of type of the wheel, they write to the table as follows. (The sample table is shown on the board.)

Say “Write the other variables in the table on the ninth space in the activity sheet.”

9.

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	Time taken of the groups to finish the race	-the type of the wheel (material of the wheel)	-mass of car -the surface of the wheel -size of the wheels -the thickness of the wheel -the material of the shaft inside the wheel -the size of the shaft inside the wheel -total height of the car off the ground -length of car - width of car **Always be kept under control:** -initial velocity of cars -number of wheels are control-constant	

Say “Time has come to produce/develop a prototype.”

Say “Test and control the prototype whether it works effectively or not. You apply your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is finished, skip redevelop and go to share your prototype. Second, if the prototype does not work, try again by changing which criterion does not meet in the evaluation criteria table. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.”

Explain why the prototype does not work when the second and third options are encountered. Ask them the problems they observe in the prototype.

Say “You develop your prototypes, therefore we can control whether they work or not.” Place the whiteboard at a 45-degree angle to the floor. For the students to start the race from the whiteboard to the ground, a 50 cm path is determined and a horizontal line is drawn by teacher. Draw a horizontal line to the concrete floor, where the race ends, so that the inclined plane can be moved 100 cm from where it ends. The aim is to start the race without initial velocity and take the 150-centimeter path as soon as possible. The group that will achieve this will be the first group.

In the competition section, place the car with the front wheels of the car just behind the line on the inclined plane and leave the car. As soon as leave the car, start the chronometer. Stop the chronometer while car crosses the line in the horizontal plane. In this case, look at the chronometer and take notes on the paper. Repeat the same process for both groups. The car that takes the same path as soon as possible wins the race.

Then, choose the car that goes the 150 centimeter road as soon as possible. After the measurements, interpret the prototypes and say “The toy cars of both groups passed the criteria, but the toy car of this group were better than the toy car of the other group according to the time. This group has developed a toy car that provides minimum requirements in the table, and to go the 150 cm road as soon as possible. Therefore, the first group is this group; the second group is the other group.”

Then, say “Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search.”

Then, say “Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineers, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future.”

C.3. Revised Motion and Force STEM PBL Activity Student Activity Guide Sheet

STUDENT ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 6.5 lesson hours**

Motion and Force STEM PBL Activity

BE THE FIRST!

You're invited to your friend's birthday party. There's a toy car race on his birthday. Everyone has to design their own car and come to the competition. The car that is able to complete the 150 centimeter road as soon as possible will be selected as the fastest car. The mass of the car should be between 50 grams and 250 grams, the total height of the car from the ground (distance from the bottom of the wheel to the highest point of the car) should be between 5 cm and 20 cm, the length of the car (distance between the front and rear ends of the wheels) should be between 10 cm and 20 cm, the width of the car (distance between the outer ends of the wheels) should be between 10 cm and 15 cm and the car should have 4 wheels. Competition rules are as follows. All cars will start racing on a straight whiteboard with a 45 degree incline with the ground. They will start the race with their first wheels at the level of the line on the inclined plane without initial velocity. The length of the inclined plane is 50 cm and the width of the inclined plane is 40 cm. The road will continue as a concrete surface (ground) after the inclined surface is finished. The length of the horizontal plane is 1 meter. The car that managed to complete the 150 centimeter as soon as possible will win the competition. You should design a car that meets all these rules. Come on, start!

Fill the table.

Minimum requirements to be observed
Evaluation Criteria

Write on the first space whether the problem has a need, and what the need is.

1.

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Write what the need on the second space in the activity sheet.

2.

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Write in the third space what you have found during your search about whether toy car is made of before, whether these toy cars are like the toy cars you need, how these toy cars are made, and what solutions have been found.

3.

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Write which courses are necessary for the solution of the problem in the fourth space below.

4.

Lessons:

Unit:

Chapters:

Chapters:

Write your findings in the fifth space about what information the problem gives us, whether the problem puts restrictions and limitations on us, what criteria of the problem are.

5.

Criteria:

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Restrictions and Limitations:

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Create at least 3 possible solutions and write them in the sixth space.

6.

1.

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2.

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3.

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Write which solution you have chosen as the best possible solution in the seventh space.

7.

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Write what they are in the eighth space if there is a variable (dependent, independent, control-constant) in the problem.

8.

- *Dependent variables:*
- *Independent variables:*
- *Control-constant variables:*

Note: The application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Be careful while using scissors, snap blade knife, wire. When you need to use them, you will come and take them from the teacher and bring it back to the teacher.

Try the information you use and obtain it quickly. Observe how variables affect to develop a prototype.

Write the other variables in the table on the ninth space.

9.

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	Time taken of the groups to finish the race	-the type of the wheel (material of the wheel)	-mass of car -the surface of the wheel -size of the wheels -the thickness of the wheel -the material of the shaft inside the wheel -the size of the shaft inside the wheel -total height of the car off the ground -length of car	

			- width of car **Always be kept under control:** -initial velocity of cars -number of wheels are control-constant	

After developing prototype, test it according to the criteria in the evaluation. You have 3 options. First, if the prototype is finished, you can share it with all class. Second, if the prototype does not work, go back and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.

After developing your prototypes, control whether they work or not.

Both groups start their measurements at the same time. The teacher places the whiteboard at a 45-degree angle to the floor. For the students to start the race from the whiteboard to the ground, a 50 cm path is determined and a horizontal line is drawn by teacher. The teacher then draws a horizontal line to the concrete floor, where the race ends, so that the inclined plane can be moved 100 cm from where it ends. The aim is to start the race without initial velocity and take the 150-centimeter path as soon as possible. The group that will achieve this will be the first group.

In the competition section, the teacher places the car with the front wheels of the car just behind the line on the inclined plane and leaves the car. As soon as teacher leaves the car, teacher starts the chronometer. The teacher stops the chronometer while car crosses the line in the horizontal plane. In this case, teacher looks at the chronometer and takes notes on the paper. The teacher repeats the same process for both groups. The car that takes the same path as soon as possible wins the race.

D.1. Revised Properties of Matter STEM PBL Activity Lesson Plan

STEM PBL ACTIVITY LESSON PLAN

1. Grade Level: 9

2. Lesson: Physics

3. Unit: PROPERTIES OF MATTER

4. Objectives:

The following objectives are the maximum number of objectives that students can integrate to the solution of the problem.

At the end of the lesson, students are able;

Physics (MEB (2018), High School Physics Course Curriculum.)

9.1.2.1. To relate the application areas of physics with its sub-branches and other disciplines. **(S.O.1)**

b. To give examples from daily life with the relationship between physics and philosophy, biology, chemistry, technology, engineering, art, sports and mathematics. **(S.O.2)**

9.2.2.1. To explain the concept of strength. **(S.O.3)**

a. To calculate the concept of strength related to ratio of cross-sectional area to volume of uniform geometric shape body such as cube, rectangles prism, cylinder and sphere. **(S.O.4)**

Mathematics (MEB (2018), High School Mathematics Course Curriculum.)

9.5.2.2. To interpret the data groups reflecting the real life situation by representing them with appropriate graph types. **(M.O.1)**

Mathematics (MEB (2018), Primary and Middle School Mathematics Curriculum.)

M.7.1.1.5. To solve problems that require operations with integers **(M.O.2)**

M.8.2.2.3. To express how one of the two variables, which have linear relations, changes depending on the other with tables and equations. **(M.O.3)**

a. To use expression in the form of ordered pairs in the representations made with the table. **(M.O.4)**

b. To examine how the value of one of the two variables changes according to the value of the other variable and in which case, which is dependent and which is independent. **(M.O.5)**

M.8.2.2.5. To create and interpret equations, tables and graphs of real life situations involving linear relationships. **(M.O.6)**

M.8.2.2.6. To explain the slope of line with models, associate linear equations and graphs with slope. **(M.O.7)**

c. To utilize appropriate information and communication technologies when necessary. **(M.O.8)**

M.8.4.1.1. To interpret line and column graphs of up to three data groups. **(M.O.9)**

Technology-Engineering (NGSS Lead States (2013), Engineering Design Cycle. NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.)

1. To detail in the problem. **(T.E.O.1)**
2. To create different solution ways. **(T.E.O.2)**
3. To determine criteria and constraints. **(T.E.O.3)**
4. To reach the best solution with necessary technological tools. **(T.E.O.4)**
5. To test the solution ways under different conditions. **(T.E.O.5)**
6. To use mathematics and computers for solution ways. **(T.E.O.6)**
7. To create a prototype. **(T.E.O.7)**
8. To optimize the solution. **(T.E.O.8)**

Visual Arts (MEB (2018), High School Visual Arts Course Curriculum.)

1. To create original products using traditional and contemporary materials. **(V.A.O.1)**
2. To reflect their imagination on their works/studies. **(V.A.O.2)**

21st Century Skills (Partnership for 21st Century Skills (2010). Framework for 21st century learning.)

1. Learning and Innovation Skills

Critical Thinking and Problem Solving **(L.I.S.1)**

Creativity and Innovation **(L.I.S.2)**

Collaboration **(L.I.S.3)**

Communication **(L.I.S.4)**

2. Life and Career Skills

Flexibility and Adaptability **(L.C.S.1)**

Initiative and Self-Direction **(L.C.S.2)**

Social and Cross-Cultural Skills **(L.C.S.3)**

Productivity and Accountability **(L.C.S.4)**

Leadership and Responsibility **(L.C.S.5)**

3. Information, Media and Technology Skills

Information Literacy **(I.M.T.S.1)**

Media Literacy **(I.M.T.S.2)**

ICT (Information, Communications and Technology) Literacy **(I.M.T.S.3)**

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.

Problem: You started working at a buffet for a summer vacation. Your boss ordered too much water. Each water pack contains 12 water bottles, and each of which is 0.5 liters. You can't keep your water packets out of the buffet because the weather is too hot, and all the refrigerators are full of ice cream. That's why you need to keep the water bottles in the buffet. However, the area you can allocate for water bottles is only 2500 square centimeters. For the top material of the table, the boss wants to use the 0.3 cm thick decota sheet, which he used in the signboard last month and remain a residual material. You cannot put the water bottles in direct contact with the ground because it can be used in buffet, bakery and so on where are certain conditions for keeping food and beverages in places. According to these conditions, you should keep food and beverages at a height from the ground between minimum 8 centimeters and maximum 20 centimeters from the ground. Your boss wants to make a table with choosing one of the materials of 15 toilet paper rolls, 15 paper towel rolls, 20 cardboard cups and various sized cardboard boxes. How can you design a table to keep water bottles from tipping over under these circumstances?

Note: All prototypes must meet the minimum requirements.

To explain the evaluation criterion, most strength table will be determined. In purpose of this, a bucket is given to the groups and this bucket is placed at the center of the tables. After this, 0.5 liter water bottle is left in the bucket one by one. When the number of bottles reaches 12, a pack of 12 bottles of water is placed in the bucket. Packs of water will be placed on the tables. All measurements will be taken by teacher. The table that carries the most water bottles will be selected as the most strength table.

5. Topical Outline, Planning and Timing (2 days – 6 lesson hours: 240 min)

- 1. Identify the need (10 min)
- 2. Generate ideas/Brainstorm (10 min)
- 3. Searching for the answer (30 min)
- 4. Associate the disciplines (5 min)
- 5. Determine the criteria, materials, restrictions, limitations of the problem (15 min)
- 6. Examine possible solutions (15 min)
- 7. Choose the best possible/applicable/probable/feasible solution (10 min)

- 8. Develop or redevelop a prototype (110 min)
- 9. Test and evaluate the prototype by individual group (20 min)
- 10. Share (15 min)

8. Presentation of STEM PBL Lesson

Day 1: 95 min

1. Identify the need

At the beginning of the lesson, teacher gives the problem to the students. Teacher says "Here is a problem. The problem is that you started working at a buffet for a summer vacation. Your boss ordered too much water. Each water pack contains 12 water bottles, and each of which is 0.5 liters. You can't keep your water packets out of the buffet because the weather is too hot, and all the refrigerators are full of ice cream. That's why you need to keep the water bottles in the buffet. However, the area you can allocate for water bottles is only 2500 square centimeters. For the top material of the table, the boss wants to use the 0.3 cm thick decota sheet, which he used in the signboard last month and remain a residual material. You cannot put the water bottles in direct contact with the ground because it can be used in buffet, bakery and so on where are certain conditions for keeping food and beverages in places. According to these conditions, you should keep food and beverages at a height from the ground between minimum 8 centimeters and maximum 20 centimeters from the ground. Your boss wants to make a table with choosing one of the materials of 15 toilet paper rolls, 15 paper towel rolls, 20 cardboard cups and various sized cardboard boxes. How can you design a table to keep water bottles from tipping over under these circumstances?**"** and "Now, I will separate you into two groups. Every group has 3 students. In your group, you will determine the need" Teacher says **"**Every student in each group has the same responsibility to the activity. You share duties within your own groups." **(L.I.S.3) (L.C.S.3) (L.C.S.5)** Then, teacher asks "What are the minimum requirements and evaluation criteria that this table should have?" Also, teacher discusses this question with students and the expected answer come from the students. Teacher says "Fill the table" and says

“Considerations in the evaluation are as follows. The area reserved for water bottles is 2500 square centimeter. Height of table legs from the ground is between 8 cm and 20 cm. Table top material is dekota sheet. Number of table top material is 1 piece. Thickness of table top material is 0.3 cm. Materials that can be used for the legs of the table are max 15 paper towel rolls, max 15 toilet paper rolls, 20 cardboard cups, cardboard boxes of various sizes. You can choose one group material from these materials.” and adds “Accordingly, in the evaluation, the most strength table according to the table that carries the max number of water bottles will be selected as first group.”

Minimum requirements to be observed
Evaluation Criteria

Then, teacher asks some questions “Does the problem have a need?” and adds “What is the need?” After that, teacher says “I am a guide to you. If there are any question, I will guide you.” and adds “You have 10 minutes to think.”

While during 10 minutes, teacher distributes the student activity sheet to the students and says “During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet." Teacher observes the students while reading and discussing the problem.

After that, teacher asks students "What is the need?" Teacher expects the following answer from the students "*The need* is that a table which carries max number of water bottles developed as the most strength table by considering max 2500 square centimeter in area reserved for water bottle table, having height of table legs from the ground is between 8 cm and 20 cm, having dekota sheet table top material, having 1 piece of table top material, having thickness of table top material is 0.3 cm, using one type of materials that can be used for the legs of the table are 15 toilet paper rolls, 15 paper tower rolls, 20 cardboard cups and various sized cardboard boxes for legs of table." If the students do not give this answer, the teacher will guide the students until the answer comes.

Then, teacher says "Write the need in the second space in the activity sheet." Then, teacher writes the need on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.1)**

2. Generate ideas/Brainstorm

After writing the need on the board, teacher asks to students "Have you ever designed a table before in your life?" Teacher says "If you have encountered, you can benefit from your experience." and "If you have not encountered, you will learn what you can do if you encounter such a situation." Then teacher says "What would you do if such a situation happened to you? Now, you have 10 minutes to discuss it. I want you to generate ideas by talking." Teacher asks "What should you consider when designing this table?" adds "Should the height of the leg of the table be tall or short?" The expected response from the students is that shorter one can have more strength. Teacher continues brainstorming until students receive this answer. Then, teacher asks "Does the shape of the leg of the table change anything?" Students are expected to say that tables with different shape of legs can have different strength. Teacher continues brainstorming until students receive this answer. Moreover, teacher asks "How should the legs be? Should the legs be thin or thick?" Teacher expects the answer from the students which is the size of the legs is about shape and every uniform geometric shape has different sizes. Then, teacher asks "What should be the shape of the legs of the table for the first option?" Teacher expects the answer that the most strength uniform geometric shape is sphere. **(L.C.S.2) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.4) (I.M.T.S.2)**

3. Searching for the answer

Teacher says "Now, I will give you 5 minutes to think what you need to search. After, you will share what you thought" After 5 minutes, teacher asks "What did you think?" Students are expected to receive the following answer that they need to investigate strength issues, the shape of the legs of the table, how to design a table." Students are guided until these answers come from the students.

Teacher says "Now, it's time to do search. During this search, you can find the answers of these questions "Did you make a table to carry water bottles before?", "Are these tables like the tables you need?", "How are these tables made?", "What solutions have been found?" For your search, you need some books and computers with Internet. I prepare you 2 9^{th} grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 25 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search in the third space in the activity sheet." Teacher shares what students write in the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected search and reach information about Strength. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.3) (L.I.S.4)**

After the search, teacher asks "Which resources did you use and what did you find?" and "Which materials are used in making tables?" Teacher expects the answer of students which explaining the working principle of a table and which materials this table is composed. Teacher gets the answers from the students that some people create a table with the materials available like cardboard box, wood pieces, paper tower rolls, and plastic. Then, teacher asks “Is the use of these materials one or more?” Teacher expects the answers from students that generally, four legs for tables are used. Teacher asks “Are there any different uses?” and adds “How are these legs used?” Teacher expects the following answers that for balance, there are some extra legs in several positions. Teacher asks “What can we do in this case?” The expected answer is that the odd number of legs can be used. Teacher writes these on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (T.E.O.4) (T.E.O.6) (I.M.T.S.2) (I.M.T.S.3)**

4. Associate the disciplines

Then, teacher asks “Which disciplines do you need for the solution of this?” Teacher expects the answers physics, mathematics, engineering and technology. Teacher asks “Which chapters will you need to know about in these lessons’ content?” Teacher expects the answers the lesson content as disciplines which are Properties of Matter in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design the table to carry the water bottles. Also, teacher directs students until these answers get. Teacher tells them “Write these in the fourth space in the activity sheet.” Teacher writes the answers on the board. Also, teacher asks students “Which subtitles of chapters are useful for your problem-solving?” Strength is expected answer, so teacher guide the students until these answers get. Teacher tells them “Write it in the fourth space in the activity sheet.” Then, teacher writes the answers on the board. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (T.E.O.1)**

Then, teacher and students associate the problem and the need on the board by brainstorming. If students do not find the strength, teacher asks them whether it is possible that the dimensions of the gorillas we see in the movies can be several times the size of people.

5. Determine the criteria, materials, restrictions, limitations of the problem

Teacher says “I will give you 15 minutes to think how the product will be evaluated. After, we will discuss.”

Then, teacher asks “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?”, “What are the criteria of the problem?” The purpose in doing so is the problem can be analyzed easily.

Then, teacher and students start to discuss for 15 minutes. Teacher writes the most common answers of the questions ones are written on the board.

Discussion continues until the following answers from the students that designing a table that managed to carry the maximum number of water bottles without tipping over is a criterion, area reserved for water bottles, height of table legs from the ground, table top material, number of table top material, thickness of table top material, materials that can be used for the legs of the table are restrictions and limitations. In addition to all these answers, students are expected to pay attention to the environment in which the water bottles will be put in the bucket to prevent tipping over. Then, teacher writes the all shared information by the students on the board. Then, teacher says “Write these to your findings in the fifth space in the activity sheet.” **(T.E.O.1) (T.E.O.3) (L.I.S.1)**

6. Examine possible solutions

Teacher says them “Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them in the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it.” **(T.E.O.2) (L.I.S.4) (I.M.T.S.2) (L.I.S.3)**

After brainstorming, brainstorming continues until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a table is and helps them work with them.

Teacher asks them “How did you decide on these possible solutions?” Teacher asks the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the strength of uniform geometric shapes, representation of mathematical inferences on graphs, and the use of technology and engineering skills in the design part. The discussion continues until these answers come. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.1) (T.E.O.6) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1)**

7. Choose the best possible/applicable/probable/feasible solution

Teacher says “Which of the criteria (number of paper tower rolls and etc., sizes of paper tower rolls and etc., thickness of paper tower rolls and etc., etc.) mentioned in the assessment change your choice? When these are considered, how to make a table? Let's look at this and decide the best solution.”

Then, teacher asks “Which solution you have chosen as the best possible solution?” The expected answers from students are strength of uniform geometric shapes and the balance of the table. Also, teacher expects the following answers that as the height of the table's legs increases, the table's strength decreases so we should design a table with not very high legs. The most strength uniform geometric shape is sphere. However, the design of the sphere is not very suitable for the table leg. Therefore, at this point they should choose legs in the form of a cube or rectangular prism. At the same time, it is not enough to place the legs on only four corners of the lower part of the table top material, because they will add the water bottles into the bucket in the middle, this time the table is broken very quickly in the middle. Therefore, they must place one in the middle of the table for the table legs. All above are students’ expected answers.

Then, teacher writes the students’ answers on the board. Then, teacher says “Write the board to in the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons.” **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (T.E.O.1) (L.I.S.1) (L.I.S.3) (I.M.T.S.1) (I.M.T.S.3) (L.C.S.1) (L.C.S.2)**

After these, teacher asks students “Is there any dependent variable, independent variable, control-constant variable in the problem explicitly? If yes, what are they?”

Students are expected to say that max number of water bottles for tables is dependent, height of table legs from the ground, materials that can be used for the legs of the table, size of the legs, shape of the legs, and number of legs are independent, area reserved for water bottles, table top material, number of table top material, thickness of table top material are control-constant. Also, teacher expects the following answers that a bucket will be used for measurement in the activity. The discussion continues until all these answers come.

Then, teacher writes the dependent, independent and control-constant variables on the board and tells them “Write it in the eighth space in the activity sheet.”

Then, teacher asks “When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a table with desired features? Are the materials you mentioned before sufficient to develop a table with desired features?”

In order to design a table with the desired characteristics, students choose their own materials and share it with the teacher.

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher. The teacher asks the students questions like “What materials are required for this activity?”, "What other materials can we use in this activity?", "So, if cutting is necessary, how and with what material will you provide it?", "How do you plan to attach the materials?" to determine the materials in this process.

Foreseen Materials that are expected to request by students after material discussion:

Dekota sheet

Water bottles (0.5 liters)

Bucket

Cardboard cups with various sizes

Rope

Adhesive

Scissors

Band

Ruler

Bendable wire

Cardboard box with different sizes

Toilet paper roll
Snap blade knife
Paper tower roll

Sewing spools

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, teacher says “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

Day 2: 145 min

8. Develop or redevelop a prototype

At the beginning of the lesson, teacher brings and separated materials to the groups. Teacher says “Here are your determined materials.”

Then, teacher adds “Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There should be the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, snap blade knife, wire. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, snap blade knife is dangerous product. When you need to use it, you will come and take it from me and bring it back to me.”

Then, teacher says “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, teacher gives them as an example with the blanks in the table. For example, if they first look at the changes of number of legs (for example; paper tower rolls), they write to the table as follows. (The sample table is shown on the board.)

Teacher says "Write the other variables in the table in the ninth space in the activity sheet."

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	Strength of table (carrying max number of water bottles)	-the number of legs (for example; paper tower rolls)	-height of table legs from the ground -types of materials (materials that can be used for the legs of the table) -the size of legs -shape of legs **Always be kept under control:** -area reserved for water bottles -table top material -number of table top material -thickness of table top material	

(T.E.O.5)

Then, teacher tells “Time has come to develop a prototype.” **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (M.O.1) (M.O.2) (M.O.3) (M.O.4) (M.O.5) (M.O.6) (M.O.7) (M.O.8) (M.O.9) (T.E.O.6) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.1) (L.I.S.2) (L.I.S.3) (L.C.S.4)**

In redevelop part, teacher says “You modify and redo the criteria that do not meet the evaluation criteria table. Then, you check again until you meet all the criteria. Then, if your prototype works with all criteria, you go to step 10.” **(T.E.O.5) (T.E.O.7) (V.A.O.1) (V.A.O.2) (L.I.S.2) (L.I.S.3) (L.C.S.1) (L.C.S.4)**

9. Test and evaluate the prototype by individual group

After that, students test and control the prototype whether it works effectively or not.

Teacher says them “You develop your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is finished, go to step 10. Second, if the prototype does not work, go to step 8 and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to step 10 when prototypes work”

Also, the teacher explains why the prototype does not work when the second and third options are encountered. Teacher asks them the problems they observe in the prototype.

10. Share

Most strength table will be determined. In purpose of this, a bucket is given to the groups and this bucket is placed at the center of the tables. After this, 0.5 liter water bottle is left in the bucket one by one. When the number of bottles reaches 12, a pack of 12 bottles of water is placed in the bucket. Packs of water will be placed on the tables. All measurements will be taken by teacher. The table that carries the most water bottles will be selected as the most strength table.

Teacher carries out the process for both group and notes how many water bottles the tables can carry.

After the measurements, teacher interprets the prototypes and says “The tables of both groups passed the criteria, but the table of this group was better than the table of the other group according to the carrying the water bottles. This group has developed a table that carries max number of water bottles with minimum requirements in the table. Therefore, the first group is this group; the second group is the other group.” Then, teacher says “Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search.”

Then, teacher says “Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineers, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future.”

9. Budget

This budget is planned according to 2 groups. It can be changed as number of group.

- *Dekota sheet (1 piece: 25 TL)*
  Total cost is 50 TL.
- *Water bottles (0.5 liters): 20 TL*
  Total cost is 20 TL.
- *Bucket (1 piece: 10 TL)*
  Total cost is 20 TL.
- *Cardboard cups with various sizes*
  Total cost is 15 TL.
- *Rope: It will be supplied by homes.*

- *Adhesive (1 piece): 1 TL*
  Total cost is 2 TL.
- *Scissors (1 piece): 1 TL*
  Total cost is 2 TL.
- *Band (1 piece): 1 TL*
  Total cost is 2 TL.
- *Ruler (1 piece):1 TL*
  Total cost is 2 TL.
- *Bendable wire (1.4 mm, 25 meter in 1 packet) (It is shared between groups.)*
  Total cost is 12 TL
- *Cardboard box with different sizes (It will be supplied by markets.)*
- *Toilet paper roll (It will be supplied by homes.)*
- *Snap blade knife: 3 TL*
  Total cost is 6 TL.
- *Paper tower roll (It will be supplied by homes)*
- *Sewing spools: 3 TL*
  Total cost is 24 TL.

All total cost of all materials is 155 TL (for 2 groups).

10. Resources and References

MEB (2018), High School Mathematics Course Curriculum

MEB (2018), High School Physics Course Curriculum.

MEB (2018), High School Visual Arts Course Curriculum.

NGSS Lead States., (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Partnership for 21st Century Skills (2010). Framework for 21st Century Learning.

MEB (2018), Primary and Middle School Mathematics Curriculum.

D.2. Revised Properties of Matter STEM PBL Activity Teacher Activity Guide Sheet

TEACHER ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 6 lesson hours**

Properties of Matter STEM PBL Activity

TABLE FOR WATER BOTTLES!

You started working at a buffet for a summer vacation. Your boss ordered too much water. Each water pack contains 12 water bottles, and each of which is 0.5 liters. You can't keep your water packets out of the buffet because the weather is too hot, and all the refrigerators are full of ice cream. That's why you need to keep the water bottles in the buffet. However, the area you can allocate for water bottles is only 2500 square centimeters. For the top material of the table, the boss wants to use the 0.3 cm thick decota sheet, which he used in the signboard last month and remain a residual material. You cannot put the water bottles in direct contact with the ground because it can be used in buffet, bakery and so on where are certain conditions for keeping food and beverages in places. According to these conditions, you should keep food and beverages at a height from the ground between minimum 8 centimeters and maximum 20 centimeters from the ground. Your boss wants to make a table with choosing one of the materials of 15 toilet paper rolls, 15 paper towel rolls, 20 cardboard cups and various sized cardboard boxes. How can you design a table to keep water bottles from tipping over under these circumstances?

The hereinafter of this lesson plan may change according to class dynamics between students and teacher.
Note: All prototypes must meet the minimum requirements.

To explain the evaluation criterion, most strength table will be determined. In purpose of this, a bucket is given to the groups and this bucket is placed at the center of the tables. After this, 0.5 liter water bottle is left in the bucket one by one. When the number of bottles reaches 12, a pack of 12 bottles of water is placed in the bucket. Packs of water will be placed on the tables. All measurements will be taken by teacher. The table that carries the most water bottles will be selected as the most strength table.

Day 1: 95 min

Read the problem to the students. Then, separate students into two groups. Say that every group has 3 students. Also, say that in their group, they will determine the need. Add that every student in each group has the same responsibility to the activity; they share duties within their own groups.

Then, ask “What are the minimum requirements and evaluation criteria that this table should have?” Also, discuss this question with students and the expected answer come from the students. Say “Fill the table” and Say “Considerations in the evaluation are as follows. The area reserved for water bottles is 2500 square centimeter. Height of table legs from the ground is between 8 cm and 20 cm. Table top material is dekota sheet. Number of table top material is 1 piece. Thickness of table top material is 0.3 cm. Materials that can be used for the legs of the table are 15 paper towel rolls, 15 toilet paper rolls, 20 cardboard cups, cardboard boxes of various sizes. You can choose one group material from these materials.” and add “Accordingly, in the evaluation, the most strength table according to the table that carries the max number of water bottles will be selected as first group.”

Minimum requirements to be observed
Evaluation Criteria

Ask “Does the problem have a need?” and add “What is the need?” Say “I am a guide to you. If there are any question, I will guide you.” and add “You have 10 minutes to think.”

While during 10 minutes, distribute the student activity sheet to the students and say “During the activity, you will write what you find to this sheet. Now, while discussing, you can write what you find on the first space in the activity sheet.” Also, observe the students while reading and discussing the problem.

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Ask “What is the need?”

2. ***The need*** is that a table which carries max number of water bottles developed as the most strength table by considering max 2500 square centimeter in area reserved for water bottle table, having height of table legs from the ground is between 8 cm and 20 cm, having dekota sheet table top material, having 1 piece of table top material, having thickness of table top material is 0.3 cm, using one type of materials that can be used for the legs of the table are 15 paper towel rolls, 15 toilet paper rolls, 20 cardboard cups, cardboard boxes of various sizes for legs of table.

If the students do not give this answer, guide the students until the answer comes. Write the need on the board.

Ask “Have you ever designed a table before in your life?” Say “If you have encountered, you can benefit from your experience.” and “If you have not encountered, you will learn what you can do if you encounter such a situation.”

Ask “What would you do if such a situation happened to you? Now, you have 10 minutes to discuss it. I want you to generate ideas by talking.”

Ask “What should you consider when designing this table?” add “Should the height of the leg of the table be tall or short?” The expected response from the students is that shorter one can have more strength. Continue brainstorming until students receive this answer. Then, ask “Does the shape of the leg of the table change anything?” Students are expected to say that tables with different shape of legs can have different strength. Continue brainstorming until students receive this answer. Moreover, ask “How should the legs be? Should the legs be thin or thick?”

Expect the answer from the students which is the size of the legs is about shape and every uniform geometric shape has different sizes. Then, ask "What should be the shape of the legs of the table for the first option?" The expected answer is the most strength uniform geometric shape is sphere.

Say "Now, I will give you 5 minutes to think what you need to search. After, you will share what you thought" After 5 minutes, ask "What did you think?" Students are expected to receive the following answer that they need to investigate strength issues, the shape of the legs of the table, how to design a table." Students are guided until these answers come from the students.

Say "Now, it's time to do search. During this search, you can find the answers of these questions "Did you make a table before?", "Are these tables like the tables you need?", "How are these tables made?", "What solutions have been found?" For your search, you need some books and computers with Internet. I prepare you 2 9^{th} grade MEB physics books and 2 computers. Therefore, you can benefit them for your search. You can ask me very specific questions. You have 25 minutes to search. During the search, if you need help, I will be all around. Also, write what you have found during your search in the third space in the activity sheet." Teacher shares what students write in the third space in the activity sheet. Therefore, they can learn what they do during their search and what solutions they produce.

Students are expected to search and reach information about Motion, and Friction Force. **(S.O.1) (S.O.2) (S.O.3) (S.O.4) (S.O.5) (S.O.6) (S.O.7) (S.O.8) (S.O.9) (S.O.10) (T.E.O.1) (I.M.T.S.1) (I.M.T.S.3) (L.I.S.3) (L.I.S.4)**

3.

Strength

After the search, ask "Which resources did you use and what did you find?" and "Which materials are used in making tables?" Expect the answer of students which explaining the working principle of a table and which materials this table is composed. Get the answers from the students that some people create a table with the materials available like cardboard box, wood pieces, paper tower rolls, and plastic. Then, ask “Is the use of these materials one or more?” Expect the answers from students that generally, four legs for tables are used. Ask “Are there any different uses?” and add “How are these legs used?” Expect the following answers that for balance, there are some extra legs in several positions. Ask “What can we do in this case?” The expected answer is that the odd number of legs can be used. Write these on the board.

Then, ask “Which disciplines do you need for the solution of this?” Expect the answers physics, mathematics, engineering and technology. Ask “Which chapters will you need to know about in these lessons’ content?” Expect the answers the lesson content as disciplines which are Properties of Matter in physics discipline, graphics and algebra in mathematics discipline, engineering and technology disciplines to design the table to carry the water bottles. Also, direct students until these answers get. Tell them “Write these in the fourth space in the activity sheet.” Write the answers on the board. Also, ask students “Which subtitles of chapters are useful for your problem-solving?” Strength is expected answer, so guide the students until these answers get. Tell them “Write it in the fourth space in the activity sheet.” Then, write the answers on the board.

Then, associate the problem and the need with the students on the board by brainstorming. If students do not find the strength, ask them whether it is possible that the dimensions of the gorillas we see in the movies can be several times the size of people

4.

Lessons: Physics, Mathematics, Engineering and Technology

Unit: Properties of Matter in physics

Chapters: Strength in physics

Chapters: Graphics, Algebra in mathematics

Says “I will give you 15 minutes to think how the product will be evaluated. After, we will discuss.”

Ask “What information does the problem give us?”, “Does the problem put restrictions and limitations on us?”, “What are the criteria of the problem?” “Write these to your findings on the fifth space in the activity sheet.”

Then, start to discuss for 15 minutes with students. Write the most common answers of the questions ones are written on the board.

Discussion continues until the following answers from the students that designing a table that managed to carry the maximum number of water bottles without tipping over is a criterion, area reserved for water bottles, height of table legs from the ground, table top material, number of table top material, thickness of table top material, materials that can be used for the legs of the table are restrictions and limitations. In addition to all these answers, students are expected to pay attention to the environment in which the water bottles will be put in the bucket to prevent tipping over. Then, write the all shared information by the students on the board. Then, say “Write these to your findings in the fifth space in the activity sheet.”

5.

Criteria:

- Designing a table that managed to carry the maximum number of water bottles without tipping over

Restrictions and Limitations:

-Area reserved for water bottles

-Height of table legs from the ground

-Table top material

-Number of table top material

-Thickness of table top material

-Materials that can be used for the legs of the table

Say "Now, you have 15 minutes to brainstorm your possible solutions. Create at least 3 possible solutions and write them on the sixth space in the activity sheet. After that, we will discuss it on the board. Then, you choose the best possible solution and concentrate on it."

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After brainstorming, brainstorming continues until at least 3 possible solutions come from the students. Students are directed to propose 3 different solutions. If even one of the students doesn't come up with a solution, teacher asks them what the most essential feature of a table is and helps them work with them.

Ask them "How did you decide on these possible solutions?" Ask the students how they decide on these possible solutions and asks where to use the four disciplines. The following answers are expected from students; the strength of uniform geometric shapes, representation of mathematical inferences on graphs, and the use of technology and engineering skills in the design part. The discussion continues until these answers come.

Say “Which of the criteria (number of paper tower rolls and etc., sizes of paper tower rolls and etc., thickness of paper tower rolls and etc., etc.) mentioned in the assessment change your choice? When these are considered, how to make a table? Let's look at this and decide the best solution.” “Which solution you have chosen as the best possible solution? Write the board to in the seventh space in the activity sheet.”

The expected answers from students are strength of uniform geometric shapes and the balance of the table. Also, expect the following answers that as the height of the table's legs increases, the table's strength decreases so we should design a table with not very high legs. The most strength uniform geometric shape is sphere. However, the design of the sphere is not very suitable for the table leg. Therefore, at this point they should choose legs in the form of a cube or rectangular prism. At the same time, it is not enough to place the legs on only four corners of the lower part of the table top material, because they will add the water bottles into the bucket in the middle, this time the table is broken very quickly in the middle. Therefore, they must place one in the middle of the table for the table legs. All above are students’ expected answers.

Then, write the students’ answers on the board. Then, say “Write the board to on the seventh space in the activity sheet. Do not forget to write these possible solutions with their reasons.”

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Write the answers on the board.

After these, ask students "Is there any dependent variable, independent variable, control-constant variable in the problem explicitly? If yes, what are they?"

Students are expected to say that max number of water bottles for tables is dependent, height of table legs from the ground, materials that can be used for the legs of the table, size of the legs, shape of the legs, and number of legs are independent, area reserved for water bottles, table top material, number of table top material, thickness of table top material are control-constant. Also, teacher expects the following answers that a bucket will be used for measurement in the activity. The discussion continues until all these answers come.

Then, teacher writes the dependent, independent and control-constant variables on the board and tells them "Write it in the eighth space in the activity sheet."

8.

- *Dependent variables:* max number of water bottles for tables
- *Independent variables:* height of table legs from the ground, materials that can be used for the legs of the table, size of the legs, shape of the legs, and number of legs
- *Control-constant variables:* area reserved for water bottles, table top material, number of table top material, thickness of table top material

Write the variables on the board.

Then, ask "When you consider all these restrictions-limitations, the materials you mentioned earlier and your most likely solution, which materials can we choose to develop a table with desired features? Are the materials you mentioned before sufficient to develop with desired features?"

In order to design a table with the desired characteristics, students choose their own materials and share it with the teacher.

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher. The teacher asked the students questions like “What materials are required for this activity?”, "What other materials can we use in this activity?", "So, if cutting is necessary, how and with what material will you provide it?", "How do you plan to attach the materials?" to determine the materials in this process.

Foreseen Materials that are expected to request by students after material discussion:

Dekota sheet

Water bottles (0.5 liters)

Bucket

Cardboard cups with various sizes

Rope

Adhesive

Scissors

Band

Ruler

Bendable wire

Cardboard box with different sizes

Toilet paper roll
Snap blade knife
Paper tower roll

Sewing spools

Note: These materials and the materials that can be used in parallel with these materials (materials that can be used for the same purpose) are determined by the students under the guidance of the teacher.

Note: If a material request is received other than foreseen materials, the teacher's actions are as follows:

1. If the materials are intended and accessible, the teacher will bring the materials to the groups.

2. If the materials are not intended for the purpose of the study, the teacher directs the students to a material that is more suitable for their prototypes.

3. If the materials are intended for study purposes but are not accessible, the teacher directs the students to other materials that perform the same operation.

Then, say “I will bring the materials tomorrow. Therefore, we will continue tomorrow.”

Day 2: 145 min

Bring and separate materials to the groups.

Say “Here are your determined materials.”

Say “Material/Activity development process can have some problems, I have some prevention to be taken against the foreseen problems. There is the application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem. Materials can cause emergency problems e.g. scissors, snap blade knife, wire. For preventions to be taken against the unforeseen problems, I will keep you supervise during the activity. For example, snap blade knife is dangerous product. When you need to use it, you will come and take it from me and bring it back to me.”

Say “Let's try the information we use and obtain it quickly. Let's observe how variables affect to develop a prototype. You may have found the answer from the literature review. So, let's do these experiments quickly to verify if you've found the answers, find out if you haven't found the answers.”

Before students writes the variables they have determined for their chosen solution to the table, give them as an example with the blanks in the table. For example, if they first look at the changes of number of legs (for example; paper tower rolls), they write to the table as follows. (The sample table is shown on the board.)

Say “Write the other variables in the table on the ninth space in the activity sheet.”

9.

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	Strength of table (carrying max number of water bottles)	-the number of legs (for example; paper tower rolls)	-height of table legs from the ground -types of materials (materials that can be used for the legs of the table) -the size of legs -shape of legs **Always be kept under control:** -area reserved for water bottles -table top material -number of table top material -thickness of table top material	

Say “Time has come to produce/develop a prototype.”

Say “Test and control the prototype whether it works effectively or not. You apply your prototypes according to the minimum requirements table and criteria in the evaluation table. You have 3 options. First, if the prototype is finished, skip redevelop and go to share your prototype. Second, if the prototype does not work, try again by changing which criterion does not meet in the evaluation criteria table. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.”

Explain why the prototype does not work when the second and third options are encountered. Ask them the problems they observe in the prototype.

Most strength table will be determined. In purpose of this, a bucket is given to the groups and this bucket is placed at the center of the tables. After this, 0.5 liter water bottle is left in the bucket one by one. When the number of bottles reaches 12, a pack of 12 bottles of water is placed in the bucket. Packs of water will be placed on the tables. All measurements will be taken by teacher. The table that carries the most water bottles will be selected as the most strength table.

Carries out the process for both group and note how many water bottles the tables can carry.

After the measurements, interpret the prototypes and say “The tables of both groups passed the criteria, but the table of this group was better than the table of the other group according to the carrying the water bottles. This group has developed a table that carries max number of water bottles with minimum requirements in the table. Therefore, the first group is this group; the second group is the other group.” Then, say “Your prototypes are within the boundaries you have drawn. You have done a very successful job. In doing so, you have worked quite well both as a team and as an individual. Group communication, performance, duties/tasks, taking responsibility, research skills are remarkable. You have dealt with the subject integrity while conducting search.”

Then, say “Thanks to this study, the responsibilities you take and the tasks/duties you undertake, you can all become architects, civil engineers, contractor, industrial designer, maker, physics engineer, physics teacher, or project designer in the future.”

D.3. Revised Properties of Matter STEM PBL Activity Student Activity Guide Sheet

STUDENT ACTIVITY GUIDE SHEET

Grade: 9 **Date:**

Lesson: Physics **Timing: 6 lesson hours**

Properties of Matter STEM PBL Activity

TABLE FOR WATER BOTTLES!

You started working at a buffet for a summer vacation. Your boss ordered too much water. Each water pack contains 12 water bottles, and each of which is 0.5 liters. You can't keep your water packets out of the buffet because the weather is too hot, and all the refrigerators are full of ice cream. That's why you need to keep the water bottles in the buffet. However, the area you can allocate for water bottles is only 2500 square centimeters. For the top material of the table, the boss wants to use the 0.3 cm thick decota sheet, which he used in the signboard last month and remain a residual material. You cannot put the water bottles in direct contact with the ground because it can be used in buffet, bakery and so on where are certain conditions for keeping food and beverages in places. According to these conditions, you should keep food and beverages at a height from the ground between minimum 8 centimeters and maximum 20 centimeters from the ground. Your boss wants to make a table with choosing one of the materials of 15 toilet paper rolls, 15 paper towel rolls, 20 cardboard cups and various sized cardboard boxes. How can you design a table to keep water bottles from tipping over under these circumstances?

Fill the table.

Minimum requirements to be observed
Evaluation Criteria

Write on the first space whether the problem has a need, and what the need is.

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Write what the need on the second space in the activity sheet.

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Write in the third space what you have found during your search about whether table is made of before, whether these tables are like the table you need, how these tables are made, and what solutions have been found.

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Write which courses are necessary for the solution of the problem in the fourth space below.

4.

<u>Lessons:</u>

<u>Unit:</u>

<u>Chapters:</u>

<u>Chapters:</u>

Write your findings in the fifth space about what information the problem gives us, whether the problem puts restrictions and limitations on us, what criteria of the problem are.

5.

Criteria:

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Restrictions and Limitations:

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Create at least 3 possible solutions and write them in the sixth space.

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Write which solution you have chosen as the best possible solution in the seventh space.

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Write what they are in the eighth space if there is a variable (dependent, independent, control-constant) in the problem.

8.

- *Dependent variables:*

- *Independent variables:*

- *Control-constant variables:*

Note: The application class includes first aid kit, fire tube, fire blanket, emergency button, fire bell, emergency exit instructions in the case of an emergency problem.

Be careful while using scissors, snap blade knife, wire. When you need to use them, you will come and take them from the teacher and bring it back to the teacher.

Try the information you use and obtain it quickly. Observe how variables affect to develop a prototype.

Write the other variables in the table on the ninth space.

9.

	Dependent Variables	**Independent Variables**	**Constant Variables**	**What we have found/observed**
First try	Strength of table (carrying max number of water bottles)	-the number of legs (for example; paper tower rolls)	-height of table legs from the ground -types of materials (materials that can be used for the legs of the table) -the size of legs -shape of legs **Always be kept under control:** -area reserved for water bottles -table top material -number of table top	

			material -thickness of table top material	

After developing prototype, test it according to the criteria in the evaluation. You have 3 options. First, if the prototype is finished, you can share it with all class. Second, if the prototype does not work, go back and try again by changing which criterion does not meet in the evaluation. That means you have to redevelop the prototype. Third, if you want to add or change something to your prototype, you can redevelop your prototype. After these, you go to share when prototypes work.

After developing your prototypes, control whether they work or not.

Most strength table will be determined. In purpose of this, a bucket is given to the groups and this bucket is placed at the center of the tables. After this, 0.5 liter water bottle is left in the bucket one by one. When the number of bottles reaches 12, a pack of 12 bottles of water is placed in the bucket. Packs of water will be placed on the tables. All measurements will be taken by teacher. The table that carries the most water bottles will be selected as the most strength table.

Teacher carries out the process for both group and notes how many water bottles the tables can carry.

E. Application Form

Başvuru Formu

İletişim bilgileri

Bu çalışma ücretsiz bir STEM eğitimi materyal geliştirme çalışması olup bir Orta Doğu Teknik Üniversitesi (ODTÜ) yüksek lisans çalışmasıdır. Katılımcıların eşit değerlendirilebilmeleri için bu formu eksiksiz doldurmaları gerekmektedir. Katılımcıların bilgileri gizli tutulacaktır ve hiçbir kişisel veri bir belge üzerinde yer almayacaktır.

Adınız-Soyadınız

Okulunuz

Yaşınız

Sınıfınız

Telefon Numarası

LGS Başarı Sıralaması

Ortaokul Mezuniyet Ortalaması

Ortaokul Fen Bilimleri Dersi Karne Notu (2019 Haziran Karne Notu)

F. Student Interview Questions

YARI YAPILANDIRILMIŞ ÖĞRENCİ GÖRÜŞME SORULARI

1. Hangi aktiviteye katıldınız:

2. STEM eğitimi sırasında verilen problem durumunu günlük hayat ile ilişkilendirmekte güçlük çektiniz mi? Eğer çektiyseniz, ilişkilendirmeyi sağlamak için ne gibi bir yol izlediniz?

3. STEM eğitimi süresince sizi en çok zorlayan ve uygulamaya geçmekte zorlandığınız kısım neydi? Bu kısımlarda nasıl bir ilerleme sağladınız? Ne gibi bir çözüm yolu izlediniz?

4. STEM eğitimi sırasında fizik öğretmeniniz ile iletişiminiz nasıldı?

5. STEM eğitimi sırasında öngöremediğiniz bir durum oldu mu? Eğer olduysa, bu durum karşısında nasıl bir yol izlediniz?

6. STEM eğitimi sırasında en rahat ilerlediğiniz kısımlar nelerdi? Neden bu kısımlarda en rahat ilerlediğinizi düşünüyorsunuz?

7. Aktivitenin ve yürütülmesinin revizyon gerektiğini düşündüğünüz yerleri var mı? Varsa bunlar nelerdir? Ne gibi revizyonların yapılması gerektiğini düşünüyorsunuz?

G. Teacher Interview Questions

YARI YAPILANDIRILMIŞ ÖĞRETMEN GÖRÜŞME SORULARI

Kişisel Bilgiler

Öğrencilerle birlikte hangi aktiviteyi uyguladınız:

Cinsiyetiniz:

Öğretmenlik tecrübeniz:

Eğitim durumu:

Etkinlikle İlgili Sorular

1. Daha önce STEM eğitimini duymuş muydunuz?
2. Daha önce STEM eğitiminde yer almış mıydınız?
3. Derslerinizde proje tabanlı öğrenme kullanıyor musunuz?
4. Daha önce bir materyal geliştirme çalışmasında yer aldınız mı?
5. STEM eğitimi sırasında verilen problem durumunu günlük hayat ile ilişkilendirmekte güçlük çektiniz mi? Eğer çektiyseniz, ilişkilendirmeyi sağlamak için ne gibi bir çözüm yolu izlediniz?
6. STEM eğitimi süresince sizi en çok zorlayan ve uygulamaya geçmekte zorlandığınız kısım neydi? Neden bu kısımlarda zorlandığınızı düşünüyorsunuz?
7. STEM eğitimi sırasında öğrencilere rehberlik etmekte zorluk çektiniz mi? Eğer çektiyseniz, ne gibi bir çözüm yolu izlediniz?
8. STEM eğitimi sırasında öğrencilerin öngöremedikleri bir bilgiyi onlara hangi soruları yönelterek rehberlik ettiniz?
9. STEM eğitimi sırasında en rahat ilerlediğiniz kısımlar nelerdi? Neden bu kısımlarda en rahat ilerlediğinizi düşünüyorsunuz?

10. Aktivitenin ve yürütülmesinin revizyon gerektiğini düşündüğünüz yerleri var mı? Varsa bunlar nelerdir? Ne gibi revizyonların gerekli olduğunu düşünüyorsunuz?

11. Ders planı ve materyal kazanımları gerçekleştirdi mi?

Evet __ Hayır __

Cevabınız hayır ise hangi kazanımların gerçekleştirilmediğini yazınız.

H. Observation Form

GÖZLEM FORMU

Bu form, STEM aktivitelerini uygulayan fizik öğretmenlerinin uygulamalarını gözlemlemek için hazırlanmıştır.

Aktivite adı:		Tarih:	……./………../……..
Aktiviteye katılan öğrenci sayısı:		Saat:	Başlama:…………….
Gözlemcinin adı-soyadı:			Bitiş:………………… …

Aşağıdaki ifadeler, öğretmenin öğrenci merkezli bir ders sırasında göstermesi beklenen eylemleri göstermektedir. Eylem gerçekleştirilmişse "✓" gerçekleştirilmemişse "x" kullanınız.

Bu formda, "Gözlemleriniz için Durumlar" bölümü bulunmaktadır. Bu bölümde, araştırmacının, gerçekleşen ve gerçekleşmeyen durumlar ile planlanmamış ve/veya öngörülemeyen durumlar hakkında gözlemlediklerini yazabileceği bir alan bulunmaktadır. Bu alanı gözlemleriniz sırasında doldurunuz.

Derse Giriş:

Öğretmen,

	Gerçekleştiyse ✓ gerçekleşmediyse x kullanınız.	Gözlemleriniz için Durumlar:
1. Verilen problemi öğrenciler ile birlikte tartışır.		

2. Öğrencilerle birlikte dersin hedeflerini tartışır.		
3. Öğrencilerin cevaplayacakları soruyu netleştirmelerine yardımcı olur.		
4. Öğrencileri, önceki bilgileri üzerinde düşünmeye teşvik eder.		

Ders Süreci:

Öğretmen,

	Gerçekleştiyse ✓ gerçekleşmediyse x kullanınız.	Gözlemleriniz için Durumlar:
1. Öğrencileri gruplandırır.		
2. Öğrencilere cevabı direkt söylemek yerine yönlendirir.		
3.Öğrencileri grup çalışmasına teşvik eder.		

4. Öğrencilerin ders sırasındaki çalışmalarını kontrol eder.		
5. Öğrencileri prosedürleri oluşturmaya yönlendirir.		
6. Öğrencilerden varsayımları belirlemelerini ister.		
7. Öğrencileri aktif katılıma teşvik eder.		
8. Öğrencilerin sorgulamasını sağlar.		

Dersin bitimi:

Öğretmen,

	Gerçekleştiyse ✓ gerçekleşmediyse x kullanınız.	Gözlemleriniz için Durumlar:

1. Kazanımları gerçekleştirir.		
2. Öğrencilerin geliştirdikleri proje ürünlerini dikkatle inceler.		
3.Öğrencilere geri bildirimde bulunur.		

I. Table 2.2. STEM Activities Implementation Cycles

Table 2.2. *STEM Activities Implementation Cycles*

Models	The Steps for the Models											
STEM Education Cycle (MEB STEM Education TeacherHandbook, 2017)	1-Create questions (ask, identify)							2-Design product/invention (produce)	3-Test the product (does it work?, does it meet the original design con	4-Deduce (make inference) 5-Evaluate (interpret) 6-Share (share-	7-Rethink (if needed redesign)	

									straints?)	analyze)		
Improvisation Process Cycle (Papert, 1993)	1-Identify and analyze the problem (cause-effect relationship)			2-Find possible solutions and choose the best (propose, choose)		2-Find possible solutions and choose the best (propose, choose)		3-Make a sample and test this (solve, produce, test)	3-Make a sample and test this (solve, produce, test)	4-Share product (share, comments, criticism)	5-Evaluate the product and think better (evaluate, develop,redesign)	
Five Easy Steps for	1-Reflect		2-Discover	3-Imagine				4-Create		5-Share		

STEM Project (Nasa. The Imagine Mars Project)												
STEM Cycle (Çorlu, 2017)	1- Identify problem (life-based)	2- Develop ideas	3- Research	4- Limitations				5- Develop product	6- Test product	7- Share and reflect		
STEM PBL (Erdogan, Navruz, Younes &	1- Define a task with a	2- Plan before instruction	3- Research and find a sol			3- Research and find a sol		4- Create a prototype and test it	4- Create a prototype and		5- Revise	6- Present the product and find

Capraro, 2016)	problem		ution			ution			test it			ings
STEM Inquiry Based (Gencer, 2017)	1- Asking questions and using materials	2- Scientific inquiry and test variables	3- Deeping inquiry 4- Associate the activity with science and					5- Engineering practice questions/problems	6- Test a prototype	7- Evaluation		

			math									
Project Based Learning (Stix & Hrbek, 2006)	1- Set the stages with real life samples	2- Take on the role of project designers	3- Discuss and accumulate the background information	4- Negotiate the criteria for evaluating the projects	5- Accumulate the materials			6- Create the projects		7- Prepare to present the projects 8- Present the projects		9- Reflect on the process and evaluate the projects
NRC 1996 Aabilities of Technological	1- Identify a simple pro			2- Propose a solution		3- Implementing pro			4- Evaluate a product or			5- Communicate a pro

Design (NRC, 1996)	blem (explain, identify task)			(make proposal, describe, communicate, design a solution)		posed solutions (develop, demonstrate)			design (does it work?, does it meet the original design constraints?) (modify)			blem, design and solution (communicate, oral, written, pictorial)
PIRPOSAL Model	1-Problem	2-Ideation	3-Research		4-Potential	5-Optimizati		5-Optimization	6-Solution		7-Alterations	8-Learned Out

(Wells, 2016)	Identification (need, define, formulate)	(criteria, brainstorm, generate)	(explore, investigate, examine)		Solutions (analyze, visualize, select)	on (experiment, revisit, construct)		(experiment, revisit, construct)	Evaluation (test, analyze, interpret)		(identify, redesign, retest)	comes (process, iterations, justify)
EDP 1 (ITEA Standards for Technological Literacy 2000/2002/2007)	1- Defining a problem (identify)	2- Brainstorming (generate ideas)	3- Researching and gathering ideas (investiga	4- Identifying criteria and specifying restraints (dr	5- Exploring possibilities (investigate, ana	6- Selecting an approach (choose best)	7- Developing a design proposal (plan)	8- Making a model or prototype (create)	9- Testing and evaluating the design using specifications	10- Refining the design (redesign)	11- Creating or making it (redesign)	12- Communicating processes and results (evaluat

			te)	aw fra me) (pla n)	lyz e)				(do es it wor k?, doe s it me et the ori gin al des ign con stra ints ?)			e, shar e)
EDP 2 (Mass achuse tts Scienc e and Techn ology/ Engin eering Curric ulum Frame work, 2006)	1- Ide ntif y the nee d or pro ble m (as k,		2- Res ear ch the nee d or pro ble m (ex ami	3- De vel op pos sibl e sol utio n(s) (br ain stor		4- Sel ect the bes t pos sibl e sol utio n(s) (det		5- Cons truct a proto type (mod el)	6- Tes t and eva luat e the sol utio n(s) (do es it	7- Co mm uni cat e the sol utio n(s) (ma	8- Red esig n (ove rhau l)	

	analyze)		ne, explore)	m, draw, articulate, refine)		ermine)			work?, does it meet the original design constraints?)	ke presentation, discuss)		
EDP 3 (NGSS Lead States, 2013)	1- Define the problem (identify)		2- Do background research (analyze)	3- Specify requirements (define)		4- Brainstorm, evaluate, and choose solution		5- Develop and prototype solution (create)	6- Test solution (does it work?, does it meet the	7- Solution meet requirements (go step 8)		8- Communicate results (evaluate, share

						(develop process)			original design constraints?)	7- Solution meet requirements partially or not at all (go back step 4, 5, 6)		e)
EDP 4 (Mang	1- Define		2- Resear	3- Brainst	4- Analy	5- Choos		6- Create	7- Test		8- Redesig	

old & Robinson, 2013)	the problem (identify, analyze)		ch the problem (investigate more information)	or m possible solutions (generate ideas)	ze and evaluate solutions (determine features of product)	e best solution (analyze, choose)		prototype (choose material, create)	prototype (does it work?, does it meet the original design constraints?)		n if needed (overhaul)	
EDP 5 (Mangold &	1- Develop	2- Synthesis			3- Analysis			4- Construction	5- Testing			6- Evaluation

Robinson, 2013)	ment of objectives and criteria (identify)	(brainstorm)			(investigate)			(create, make a prototype)	(does it work?, does it meet the original design constraints?)			(assessment)
EDP 6 (NRC, 2013)	1- Define (analyze the pro				2- Develop solutions (divide		3- Optimize (determine criteria					

	blems, criteria, constraints)				problems into small parts individually)		, environmental effects)					
EDP 7 (NASA EDP)	1- Ask (ask, analyze)	2- Imagine (brainstorm)	3- Plan (research)					4- Create (design)	5- Test (does it work?, does it meet the origin		6- Improve (redesign, overhaul)	

									al design constraints?)			
EDP 8 (Dankenbring, Capobianco & Eichinger, 2014)	1- Identify a Standard	2- Brainstorm Ideas for Design Oriented Activities	3- Contextualize a Problem Statement Within the Design Task	4- Identify Necessary Materials, Resources, and Tools			5- Develop the Design Brief		6- Implementing the Design Task			7- Assessing Students' Engagement in Design
EDP 9	1- Pla		1- Pla	1- Pla	2- De	2- Des		2- Desi	3- Ch	3-	3-	4- Sha

(Jamer son EDP)	n (id enti fy pro ble m)		n (res ear ch)	n (li mit atio ns and req uire me nts)	sig n (ge ner ate)	ign (ch oos e bes t opti on)		gn (dev elop a proto type)	eck (tes t)	Ch eck	Che ck (mo dify)	re
EDP 10 (NRC, 2012)	1- Def ini ng and Del imi tin g an En gin eeri ng Pro ble m			1- Def inin g and Del imi ting an En gin eeri ng Pro ble m	2- De vel opi ng Po ssi ble Sol uti ons		3- Opt imi zin g the Des ign Sol utio n					
EDP 11	1- Ide	2- Sha	2- Sha				2- Sha	3- Creat	3- Cre	4- Co	5- mpr	

(Capobianco, n.d.)	ntify problem	re and develop a plan	re and develop a plan				re and develop a plan	e and test	ate and test	mmunicate results	ove and retest	
EDP 12 (Museum of Science EDP) (it is also used for Bitara-STEM module)	1- Ask	1- Ask	1- Ask		2- Imagine (generate)	2- Imagine (choose best solution)	3- Plan	4- Create	4- Create (test)	5- Improve	5- Improve	
EDP 13 (Burke, 2014)	1- Engage		2- Explore	3- Explain				4- Engineer (extend/el		5- Enrich	5- Enrich	6- Evaluate

								aborate)				
EDP 14 (Davis, 1998)	1- Identification of a problem		2- Research and the ranking of priorities that often appear to be in competition with each			2- Research and the ranking of priorities that often appear to be in competition with each			3- Tests the viability of multiple solutions through prototypes			4- The evaluation of objects against a socially mediated set of performance criteria

			h other			h other						
EDP 15 (Fortus, Dershimer, Krajcik, Marx & Mamlok-Naaman,2004)	1- Identify and define context	2- Background research	3- Develop personal and group ideas					4- Construct 2D and 3D artifacts				5- Feedback
EDP 16 (So, Zhan, Chow, & Leung, 2018)	1- Defining the problem to be solved							2- Creating and testing the solution	2- Creating and testing the solution		3- Refining the solution	
STEM -based	1- En							2- Expl	3- Ex		4- Exte	5-

5E (Capraro, Capraro, Morgan, & Scheurich,2010; Moyer & Everett, 2012; Yıldırım, & Altun, 2015).	gage							ore	plain		nd	Evaluate

J. Ethics Committee Approval Document

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21 KASIM 2019

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr.Ali ERYILMAZ

Danışmanlığını yaptığınız **Cemre TOMAÇ'ın "STEM Eğitim Materyalleri Geliştirme"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **413 ODTU 2019** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

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