THE EFFECT OF MODELLING INSTRUCTION ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF PROJECTILE MOTION

**A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY**

BY

MİNE GÖKÇE ŞAHİN

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
SECONDARY SCIENCE AND MATHEMATICS EDUCATION**

OCTOBER 2008

Approval of the thesis:

THE EFFECT OF MODELLING INSTRUCTION ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF PROJECTILE MOTION

Submitted by **MİNE GÖKÇE ŞAHİN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy Secondary Science and Mathematics Education, Middle East Technical University** by,

Prof. Dr. Canan Özgen ___________________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Ömer Geban ___________________
Head of Department, **Secondary Science and Mathematics Education**

Prof. Dr. Ömer Geban ___________________
Supervisor, **Secondary Science and Mathematics Education**

Examining Committee Members

Prof. Dr. Ayhan Yılmaz ___________________
Secondary Science and Mathematics Education Dept., H.U.

Prof. Dr. Hamide Ertepınar ___________________
Elementary Education Dept., METU

Prof. Dr. Ömer Geban ___________________
Secondary Science and Mathematics Education Dept., METU

Assoc. Prof. Dr. Yezdan Boz ___________________
Secondary Science and Mathematics Education Dept., METU

Dr. Ömer Faruk Özdemir ___________________
Secondary Science and Mathematics Education Dept., METU

Date: 15. 10. 2008

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: MİNE GÖKÇE ŞAHİN

Signature:

ABSTRACT

THE EFFECT OF MODELING INSTRUCTION ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF PROJECTILE MOTION

Gökçe Şahin, Mine

Ph.D., Department of Secondary Science and Mathematics Education

Supervisor: Prof. Dr. Ömer Geban

October 2008, 266 pages

The purpose of this study was to investigate the effect of modeling instruction over traditionally designed physics instruction on students' understanding of projectile motion concepts and their attitudes towards physics. In addition, the effects of gender difference on their understanding of projectile motion concepts and attitudes towards physics were explored. Furthermore, students' views on the nature of science were searched.

The subjects of this study included 88 tenth grade students of four classes instructed by two teachers in a private high school. One of two classes of each teacher was randomly assigned to experimental group and other classes formed control group. The modeling instruction was applied in the experimental group to teach the topic of projectile motion, it was taught with traditionally designed physics instruction in control group. Projectile Motion Concept Test, Attitude Scale towards Physics, Science Process Skill Test, and Views on Science-Technology-Society test were administered to both groups. In addition, student interviews and classroom observations were conducted.

The hypotheses of the research were tested by using ANCOVA and two-way ANOVA. The results revealed that the mean score of experimental group students' on both concept test and attitude scale was significantly higher than the mean score of control group students. Furthermore, gender was not a significant factor affecting the concept acquisition related to projectile motion and students' attitudes towards physics. However, science process skill was determined as a strong predictor in conceptual understanding. Lastly, experimental group students had more realistic views on some basic tenets of nature of science.

Keywords: conceptual change, modeling instruction, attitude, science process skill, nature of science.

ÖZ

MODELLEME YÖNTEMİYLE ÖĞRETİMİN LİSE ÖĞRENCİLERİNİN EĞİK ATIŞ KONUSUNU ANLAMASINA ETKİSİ

Gökçe Şahin, Mine

Doktora., Orta Öğretim Fen ve Matematik Alanları Eğitimi Bölümü

Tez Yöneticisi: Prof. Dr. Ömer Geban

Ekim 2008, 266 sayfa

Bu çalışma, modelleme yönteminin 10. sınıf öğrencilerinin eğik atış konusunu anlamaları ve öğrencilerin fizik dersine karşı tutumları üzerindeki etkisini geleneksel öğretim yöntemi ile karşılaştırarak incelemeyi amaçlamaktadır. Ayrıca, cinsiyet farkının öğrencilerin eğik atış konusunu anlamalarına ve fizik dersine karşı tutumlarına etkisi araştırılmıştır. Bunun dışında çalışmaya katılan öğrencilerin bilimin doğası hakkındaki görüşleri incelenmiştir.

Çalışmanın örneklemi, fizik dersleri iki öğretmen tarafından yürütülen ve olduğu gibi korunan dört ayrı sınıftaki 88 öğrenciyi kapsamaktadır. Her öğretmenin birer sınıfı rastgele deney grubu, diğer sınıfı kontrol grubu olarak atanmıştır. Eğik atış konusu, deney grubunda modelleme yöntemiyle, kontrol grubunda ise geleneksel fizik öğretimi yöntemiyle işlenmiştir. Eğik Atış Kavram Testi, Fizik Dersine Karşı Tutum Ölçeği, Bilimsel İşlem Beceri Testi ve Bilimin Doğası Hakkındaki Görüşler Anketi her iki gruba da uygulanmıştır. Ayrıca veriyi desteklemek amacıyla öğrencilerle görüşmeler ve sınıf gözlemleri gerçekleştirilmiştir.

Araştırmanın hipotezleri ANCOVA ve iki yönlü ANOVA kullanılarak sınanmıştır. Sonuçlar, modelleme yöntemiyle öğretilen öğrencilerin hem Eğik Atış Kavram Testindeki hem de Fizik Dersine Karşı Tutum Ölçeğindeki ortalama puanlarının, geleneksel yöntemle öğretilen öğrencilere göre istatistiksel olarak anlamlı biçimde yüksek olduğunu göstermiştir. Buna ek olarak cinsiyetin, eğik atış ile ilgili kavram kazanımına ve öğrencilerin fizik dersine karşı tutumlarına anlamlı bir etkisinin olmadığı saptanmıştır. Ancak, bilimsel işlem becerisinin öğrencilerin eğik atışla ilgili kavram kazanımına istatistiksel olarak anlamlı bir katkısı olduğu belirlenmiştir. Son olarak, deney grubu öğrencilerinin bilimin doğası konusunda bazı temel ilkelerle ilgili daha gerçekçi görüşlere sahip oldukları görülmüştür.

Anahtar Kelimeler: kavramsal değişim, modelleme yöntemiyle öğretim, tutum, bilimsel işlem becerisi, bilimin doğası.

To my son, TUNA

and to my husband, AHMET.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the precious suggestions, constructive criticism and continuous encouragement of my supervisor Prof. Dr. Ömer Geban throughout the research.

I wish to express my special thanks to Hanife Can Şen for her unwavering support in every stage of my study, for being near to me whenever I needed and for her invaluable friendship.

I am grateful to my dear friend Çiğdem İş Güzel for her suggestions and contributions to my study. I am also thankful to Beril Yılmaz Senem for her openhearted friendship and for her hearty care on my son whenever I needed.

I wish to extend my gratitude to teachers who devoted their time for this study and all the students participated in this study for their enthusiastic cooperation and contributions.

I am particularly thankful to my parents, Fatma and Ömer Gökçe, for their moral support and their faith.

Lastly, I wish to express my deep appreciation to my husband Ahmet Şahin for his extraordinary amount of patience, support and encouragement throughout this study and for his excellent fatherhood to our son, Tuna.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF SYMBOLS

SYMBOLS

ASTP: Attitude Scale towards Physics

DV: Dependent Variable

FCI: Force Concept Inventory

Ho: Null Hypothesis

IV: Independent Variable

MI: Modeling Instruction

PMCT: Projectile Motion Concept Test

SP: Sub-Problems

SPST: Science Process Skill Test

TI: Traditional Instruction

VOSTS: Views of Science-Technology-Society Test

CHAPTER I

INTRODUCTION

Students do not come to classroom as an empty page that the teacher will fill with knowledge or they are not recorders that you push a button and make them to record what teacher says. In their daily life they construct mental models in order to understand, explain and predict their surrounding world and its phenomena (Greca and Moreira, 2000). They bring these models to classroom. When they are learning a new concept they use their previous learning, beliefs, attitudes, interests, etc. When students engage in the tasks of learning a specific topic within a science domain, they have to deal with two main obstacles; missing information and prior conceptions about the domain. This prior knowledge is often incorrect when compared to the formal knowledge and is usually impedes the learning of formal knowledge with deep understanding (Chi, 2000; Chi and Roscoe, 2002). This kind of conceptions may exist even in advanced physics students (Cohen, et al., 1983; Peters, 1981). They can proficiently memorize laws, formulae and technique to solve some kinds of problems without a deep conceptual understanding and they can pass the exams by this memorized knowledge. Thus, when they memorize problem solutions, they think that they learned how to solve these problems. But when they are questioned on the conceptual bases and asked to connect their knowledge to real life situations or process their own mistakes in problem solving, they may fail because of their conceptual mismatch (Hestenes, 2006; Klammer, 1998). For the meaningful learning students should relate new knowledge what they already know. Some of the possible sources of students' informal knowledge that is not in harmony with the scientific facts are their own experiences in physical and social world, misplaced metaphors ingrained in the language, curriculum (Klammer, 1998) and text books (Cho, Kahle and Nordland, 1985).

Furthermore, the instruction may accidentally promote these conceptions or even they may be created during the instruction

The researches on students' pre-instructional knowledge and their roles in learning and teaching science have been conducted for more than three decades. In this literature, scientists looking from different perspectives have named these conceptions in different ways and made varying explanations for conceptual change process. While Vosniadou (2002) name them as misconceptions, some of the scientists prefer to use pre-conception, alternative-conception or naïve-conception. Halloun and Hestenes (1985) use common sense beliefs to identify them. Some scientists distinguish these terms from each other on the basis of their sources and how to repair them. For instance, Chi and Roscoe (2002) examine naïve knowledge into two main categories. The first type, which they refer as preconceptions, can be revised through instruction. But other type is categorized into an ontologically inappropriate category and highly resistant to change. Chi and Roscoe (2002) refer these concepts as misconceptions. Clement (2000) uses "preconception" in a general meaning and this term includes two kinds of conceptions: "alternative conceptions" which are in conflict with the scientific model and "useful conceptions" that are compatible with scientific models and that can be used for developing them. A common belief in all perspectives is that students' existing knowledge, no matter how they are called, has a crucial role in their meaningful learning and they should be remedied in order to promote deep understanding.

In this extent literature, there exist many researches on informal conceptions of students related to physics concepts. As a school subject physics is not an easy course for meaningful learning to construct. As mentioned earlier, students' existing knowledge has an important role in this process. They face with many physical phenomena in their daily life and they develop their own theories to explain these phenomena. Projectile motion is one of them. It is the parabolic motion of particles moving through air in two dimensions near the earth surface

(Giancoli, 2005). If two components of motion are examined separately, the underlying abstract model of its vertical component is particle with constant acceleration and the model of horizontal component is particle with constant velocity. The research literature shows that students develop many misconceptions about the projectile motion (Caramazza, McCloskey and Green, 1981; Clement, 1981 and 1982; Cromley and Mislevy, 2005; Gilbert, Watts and Osborne, 1982; Halloun and Hestenes, 1985; Hestenes, Wells and Swackhamer, 1992; Hope, 1994; Kinematics, n. d.; Leboutet-Barrell, 1976; McCloskey, 1983 (a and b); Millar and Kragh, 1994; Peters, 1981; Planinic et al., 2006; Prescott, 2004; Prescott and Mitchelmore, 2005; Reif and Allen, 1992; Rowlands, Graham and McWilliam, 2004; Tao and Gunstone, 1999; Vosniadou, 1994). For instance, one of the common misconceptions between students is that objects fired horizontally from a certain height fall straight down or in right angle or circular arcs. These students do not realize that these objects moves horizontally at a constant speed and vertically under the force of gravity, therefore they move in parabola (Cromley and Mislevy, 2005). Furthermore, students think that there exists a force other than gravity exerted on a projectile. Because they believe that if an object is moving, then there should be a force in the direction of motion. Because force as a kind of fuel or energy that sustains the motion (Halloun and Hestenes, 1985; Prescott, 2004; Tao and Gunstone, 1999; Vosniadou, 1994).

The results of the many cognitive researches provide the evidence that traditional instructional methods, including lecturing, demonstrating and traditional lab studies, fails to notice the crucial influence of students' personal naïve believes on what they learn (Hestenes, 1997). In addition, the outcomes of lecture and demonstration type instruction are uniformly poor for all teachers even independent of their experience and academic background. Therefore, instructional methodology constitutes more serious problem than teacher competence in teaching (Wells, Hestenes and Swackhamer, 1995). In these kinds of instruction students are seen passive receivers of knowledge regardless of the effects of cognitive and motivational factors on their learning. When they come to classroom, new conceptual models are introduced to them and they are expected to construct mental models that are copies of these conceptual models. But if the new conceptual model can not be constructed in consistency with the prior knowledge student get, it might be just memorized by the student (Greca and Moreira, 2000). Students' existing interrelated network of concepts that influence the selection of a new concept playing a central and organizing role in thought is called conceptual ecology (Vosniadou and Stathopoulou, 2007). Posner et al. (1982) postulated four conditions for a successful conceptual change to occur in the learner's conceptual ecology. At first (a) there must be dissatisfaction with existing conceptions; students are unlikely to make major conceptual changes until they believe that less radical changes will not work. Besides, (b) the new conception must be intelligible; the individual must be able to grasp how experience can be structured by a new conception sufficiently to explore the possibilities inherent in it, (c) it must be initially plausible; any new conception adopted must appear to have the capacity to solve the problems generated by its predecessors and be consistent with other knowledge and experience, in order that it appears a plausible choice and (d) it must be fruitful; it should have the potential to be extended, to open up new areas of inquiry and to have technological and/or explanatory power.

As students use their prior conceptions to understand how the world works and they are confident in them, they would not replace them with new ones willingly. They should be convinced that their views are inaccurate. Varying instructional techniques, such as refutational/conceptual change texts (Chambers and Andre,1997; Guzetti et al.,1993), bridging analogies and anchoring intuitions (Clement,1993), demonstration (Hynd, Alvermann, and Qian, 1997), scientific argument (Nussbaum, Sinatra and Poliquin,2008), class activities combined with discussion (Nussbaum and Novick, 1982; Van Zee et al., 2001), using anomalous data (Chinn and Mahlotra, 2002), integration, differentiation, exchange and conceptual bridging (Hewson and Hewson,1983) have been developed and tested by scientists to overcome students' misconceptions and foster conceptual change. In this study, a modeling method which was adapted to scientific inquiry by

Malcolm Wells (Wells, Hestenes and Swackhamer, 1995) was tested for this purpose. This method has a student centered design, that is, students are actively engaged in the activities to develop models for the asked phenomena. Constructive approaches put stress on that learners' themselves should participate and be intellectually active in constructing qualitative models that they can use to understand relationships and differences among concepts (McDermott, 1993). The conceptual change strategy suggested by Dykstra et al., (1992) supports this approach. They suggest the following steps for re-conceptualization; (1) find some phenomenon which is easy to produce, not part of normal everyday experience, but close enough that students will feel confident predicting its outcome, and whose outcome differs in some significant way with their predictions, (2) have the students predict the outcome and discuss their justifications for those predictions, (3) have them test their predictions against the actual outcome, and (4) establish a "town meeting", a facilitating environment which supports the student community in a discussion to develop and test new ideas in order to resolve perceived discrepancies between the predictions and their justifications and the actual outcome of the experiment.

Hestenes (1987) displays a similar approach with Dykstra (1992) et al. and names the process by which new ideas about the real world are tested, accepted and integrated into a conceptual framework as "dialectic process" that simply involves the provoking the 'cognitive conflict' between the new and prior concept and induce student to resolve the conflict by rational means. He recommends a dialectical teaching strategy with the following elements: (1) explicit formulation (students should be engaged in considering systems of explicitly formulated common sense beliefs), (2) check for external validity (students should be induced to check the beliefs to consistency with empirical evidence), (3) check for internal validity (students should be induced to check the beliefs for mutual consistency among beliefs) and (4) comparison with alternative beliefs (students should be induced to compare and decide between conflicting beliefs and beliefs systems, including relevant scientific beliefs). Modeling instruction takes students in such an environment of activities and discourse in which they perform reflective thinking about physical phenomena that are likely to evoke their misconceptions (Hestenes, 2006).

Though Wells developed the inquiry-based version of modeling method which was tested in this study, in physics education research, the word "model" is associated with David Hestenes, professor of physics. He and collaborates has been studying for the development of modeling method of high school physics instruction for more than 20 years. The instruction they developed is organized into modeling cycles each of which involves two stages; model development (including the four steps; description, formulation, ramification and validation) and model deployment. At the beginning of the cycle, instructor employs the students in developing scientific model for the asked phenomena. He/she guides the students to an investigation. Students identify the variables, design an experiment to reach the model that explain the phenomena, perform the experiment, use the data to produce several representations of the model they developed and present their result to the class. At the end of the process, class as whole arrives at a consensus about the model. As a result, students successively internalize the steps of scientific investigation, so they become more independent of teacher and ready for deeper insights into physics (Hestenes, 1997, 1999).

In brief to sum up, modeling instruction is based on the fundamental principles of the scientific method and students are assisted with constructing physics knowledge and enabling ownership of their learning process through this instruction (Vesenka, 2005). It aims to correct many weaknesses of traditional instruction, such as student passivity, incoherence of knowledge and persistence of misconceptions. It works through modeling activities to engage students in developing their own explanations and models for basic physical phenomena; modeling discourse to engage students in articulating and comparing their explanations; and modeling tools such as graphs, diagrams and equations that help students to simplify their models (Hestenes, 1997, 2006). Malone (2007) claims that there are a number of possible abilities which the students instructed through modeling cycles can develop but the students instructed traditionally can not. Some examples of these skills are using multiple representations to solve problems, identifying the method of solution via models instead of equations, completing a breadth search of knowledge structure instead of a depth search using metacognitive skills continuously (setting goals, monitoring, and evaluating) and produce fewer physics errors.

The classroom discourse is most critical aspect of the modeling instruction. It lays the ground work for formulation, evaluation and application of models. Students are provided with the opportunity to express their ideas, compare them with others, be aware of their misconceptions, test their predictions and develop new ideas during the discussion .When the activity is guided skillfully, the most significant learning may occur in the post lab discourse conducted at the end of model development stage (Wells, Hestenes and Swackhamer, 1995). Researches on conceptual change also shows that types of class activities combined with discussion are effective in identifying students' misconceptions prior to the instruction and improving their conceptual understanding (Nussbaum and Novick, 1982; Nussbaum, Sinatra and Poliquin, 2008; Van Zee et al., 2001).

The conceptual change approaches of learning and teaching developed recent years emphasizes the influences of affective measures in conceptual change learning. According to Vosniadou and Stathopoulou (2007) process of students' understanding of physics does not involve only the cognitive factors. It is also influenced by other significant components including the motivational and affective variables such as personal beliefs and attitudes. Sinatra and Pintrich (2003, cited in Duit and Treagust, 2003) studied on intentional conceptual change and they brought out the importance of affective factors in conceptual change. Similarly, Pintrich, Marx and Boyle (1993) see conceptual change more than a cold, rational process regarding the influence of affective variables and value beliefs.

One of the other crucial factors in science teaching is the students' perception about the epistemology and nature of science. Duit and Treagust (1998) conclude that science learning closely concerns the both students' and teachers' conceptions of science content, the nature of science conceptions and the aims and nature of the learning process. The nature of science should become one of the instructional objectives of science courses. Because students need to understand nature of science in order to make sense of science and menage the technical processes in their daily life. In addition understanding nature of science is necessary to achieve informed decision-makings on socio-scientific issues and to appreciate the value of science as part of contemporary culture (Lederman, 2007). Besides, these instructional objectives would be effective on some educational problems such as lack of motivation and learning, female non-participation, cultural gaps, public antipathy towards science and inadequate understanding of place of science in history, culture and society (Matthews, 1998).

Finally, this study was conduct to investigate the effectiveness of modeling instruction and gender of students in overcoming 10^{th} grade students' misconceptions on the issues related to projectile motion by making references to the traditionally designed physics instruction. In addition, it strived to analyze the effect of modeling instruction and gender of students on their' attitudes towards physics as a school subject. And also it concerns the views of students on the nature of science conceptions.

CHAPTER 2

REVIEW OF RELATED LITERATURE

This chapter consists of nine headlines that are allowed for the description of theoretical bases, presentation of different approaches to subjects concerned by the study and illustration of related researches conducted by the scientists.

Under the first title, different perspectives on the definition and nature of misconceptions and conceptual change process were stated. Whereupon, the primary goals of conceptual change instructions and varying instructional techniques developed and tested by scientists to overcome students misconceptions were illustrated under the second topic.

One of the methods that were examined in the context of conceptual change is modeling instruction. Similarly, its effectiveness on students understanding of physics concepts was examined in this research. Therefore, an elaborate study on modeling instruction is presented under the following titles of this chapter. This starts in the third title with the explanation of what the model and the types of models are. Fourth title serves the steps and basic points of modeling methodology. Under the fifth topic, the objectives and stages of modeling instruction are explained by details. At the end, the conceptual change function of modeling instruction is discussed and exemplified by related researches under a separate heading. In the present research, the physics subject selected to test this function of modeling instruction was projectile motion. Therefore the misconceptions related to projectile motion are listed under the seventh title.

In the scope of this research, the effects of modeling instruction on students' understanding of nature of science and their attitudes towards physics were also analyzed. Because of that, the last two titles of the chapter are devoted for these concepts.

2.1 Misconceptions and Conceptual Change

Mark Twain, famous American humorist and novelist, says that it is not what you don't know that hurts you; it is what you know that ain't so. Johnson-Liard (1983) comments on Twain's words and explains that individuals' views of the world depend on both the way world is and the way individuals are. In other words, individuals' knowledge of the world is subject to their ability to construct models of it.

"Students, in order to understand their surrounding world and its phenomena, construct internal representations - mental models - that will allow them to learn, explain, and/or predict it", "... these models of physical phenomena constitute the prior knowledge that the students bring to the classroom" (Greca and Moreira, 2000, p 8). Their pre-instructional knowledge might not be in harmony with the scientific facts and even they might be in contrast to them. These naïve conceptions may be accidentally promoted by the instruction or even they may be created during the instruction.

The preconceptions of students that may not be in accordance with scientific views have been studied since 1970's. Conceptual change is a concept investigated in the different core fields such as history and philosophy of science, learning and teaching process of science and science education. (Lattery and Hewson, 2006, p.6). Scientists looking from different perspectives have named these conceptions in different ways and have made varying explanations for conceptual change process.

Klammer (1998) uses the term “alternate conception” for all kind of preconceptions that might interfere with future learning and indicates three main sources of alternate conceptions of students, their own experiences, the language (misplaced metaphors ingrained in language) and the curriculum of truth (instructions that give just end products to students without full logical development process of ideas). He claims that these alternate conceptions can even exist in advanced physics students and they prevent the integration and acceptance of new knowledge. Perkins (1992, cited in Klammer, 1998) refers to this kind of knowledge as “inert knowledge”. He calls students’ alternate knowledge which students retain even after a considerable instruction as “naïve knowledge”. Sneider and Ohadi (1998) prefer to use the pre-conception, alternative-conception or naïve-conception instead of misconception, since the ideas expressed by the students are logical in their view.

Chi and Roscoe (2002) states that when students engage in the tasks of learning a specific topic within a science domain, they have to deal with two main obstacles; missing information and naïve knowledge (prior conceptions) about the domain. Especially, naïve knowledge, which is often incorrect, is usually impedes the learning of formal knowledge with deep understanding. They examine naïve knowledge into two main categories. The first type, which they refer as “preconceptions”, can be revised through instruction. But other type is highly resistant to change and Chi and Roscoe refer these robust concepts, categorized into an ontologically inappropriate category, as “misconceptions”. All naïve knowledge requires do correcting and revising to foster deep understanding. They call the process of repairing misconceptions as “conceptual change” and the process of repairing preconceptions as “conceptual reorganization”. Radical changes occur within or between existing knowledge structures, involving a shift between two epistemologically distinct categories during the conceptual change process. They (2002, p. 4) affirm that “conceptual shift process is not inherently difficult, but is instead challenging mainly when students lack awareness of their misconceptions and/or lack the alternatives categories to which they should reassign their misconceptions”.

Vosniadou (2002, p. 62) have used the term of “misconception” to describe the students’ conceptions that ‘produce systematic patterns of error’. He and Brewer (1992) describes the conceptual change process as a process of creating conflict by acquiring inconsistent new knowledge and then building internally consistent models, that is, the mental model of learner changes during conceptual change. The Learner having misconception is exposed to new knowledge that is inconsistent with her/his existing mental representations. Since learner assimilates new knowledge with existing one, she/he forms “synthetic meanings”. These are incoherent and unstable. At the end, the process of resolving internal inconsistencies, which results in progression of mental models, occurs.

Duit and Treagust (2003) used the term conceptual change for the reconstruction of pre-instructional conceptual structures of learners in order to allow acquisition of intended concepts. ‘Conceptual change denotes learning pathways from students’ pre-instructional conceptions to the science concepts to be learned’ according to him (p. 673). Read (2004) makes a similar description and defines conceptual change as reorganization of common sense understanding of the world (existing knowledge) which is incompatible with accepted scientific explanations (or knowledge taught in schools).

diSessa (2002) mentions about complex knowledge system (conceptual ecology) that consists of a large number of conceptual pieces combined and modified in complex ways. Learning is the construction of this system. At the beginning learner has a small, simple and plentiful intuitive knowledge that diSessa call p-prism (phenomenological primitives). During the conceptual change course, this knowledge is integrated into more complex explanatory systems, that is, they become a part of conceptual ecology. In contrast to many other views, it is not a replacement process but a process of integration and reorganization in diSessa's view.

Ivarsson, Schoultz and Saljö (2002) claims that cognition is the use of intellectual and physical tools and learners are tool users in social context. In contrast to other researchers, they assert that conceptual change does not take place within individuals' minds, since it occurs as a result of interaction between learner, tool and other people. Conceptual change happens through the learner's participation in using intellectual and physical tools within relevant social activities, which are called collective cultural practices by them. In other words conceptual change occurs through interacting with society in situation that the individual needs to use intellectual and physical tools.

Mayer (2002) compares and contrasts four views of conceptual change; synthetic meaning view of Vosniadou, misconception repair view of Chi and Roscoe, knowledge-in-pieces view of diSessa and socio-cultural view of Ivarsson, Scholuts and Saljö. He synthesizes these competing views for the purpose of reconciling and concludes that they all agree on that conceptual change is a cognitive process in which the learner performs to construct coherent and useful knowledge for an organized and functional mental representation. And also in each of the theories, learner is an active sense-maker. He brings these views together in such a definition that conceptual change is "replacing incorrect conceptions that form a larger mental model (as suggested by Chi), as organizing one's prior experiences (as suggested by diSessa), as reorganizing one's old and new knowledge (as suggested by Vosniadou) or as becoming in increasingly proficient in using cognitive tools (as suggested by Ivarsson, Schoultz and Saljö) (p. 109).

Piagets theory of cognitive development describes the conditions necessary conceptual change. He states that there are two kinds of learning, assimilation and accommodation. Assimilation is the integration of information into existing schema. Accommodation is the modification of a schema to be consistent with new information. Posner et al. (1982) claim that when a cognitive dissonance between students' internal conceptions and a new observation occurs, either students use their existing concepts to deal with new phenomena, or if their conceptions are insufficient to deal with it they modify their conceptual framework. He refers to first alternative as assimilation and second radical change of entire framework as accommodation. Pupils' misconceptions are so permanent to resist scientific facts and they have a great influence on the way of acquisition of new scientific concepts. The conceptual ecology is the learner's existing interrelated network of concepts that influence the selection of a new concept playing a central and organizing role in thought (Vosniadou and Stathopoulou, 2007) and Posner et al. postulated four conditions for a successful conceptual change (accommodation) to occur in the learner's conceptual ecology. These four conditions, which have received wide acceptance with some minor revisions by the scientific community, are that:

1. There must be dissatisfaction with existing conceptions. Scientists and students are unlikely to make major conceptual changes until they believe that less radical changes will not work.

2. A new conception must be intelligible. The individual must be able to grasp how experience can be structured by a new conception sufficiently to explore the possibilities inherent in it.

3. A new conception must be initially plausible. Any new conception adopted must appear to have the capacity to solve the problems generated by its predecessors and be consistent with other knowledge and experience, in order that it appears a plausible choice.

4. A new concept should be fruitful. That is, it should have the potential to be extended, to open up new areas of inquiry and to have technological and/or explanatory power

Based on their research, their experience in the classroom and conceptual changes described in the literature, Dykstra et al. (1992) have identified what they believe to be three types of conceptual change; differentiation, class extension and re-conceptualization.

They (p. 669) conclude that the general strategy for inducing differentiation is:

1) the use of and the development of trust in tools that extend the senses and

2) the concomitant additional exposure to the phenomena, then

3) a focus on inducing disequilibration via these new tools based on a contrast between the reports of the tools and the students' previous conceptions

4) establishing a "town meeting", a facilitating environment which supports the student community in a discussion to develop and test new ideas in order to resolve perceived discrepancies.

The general treatment strategy for class extension type of conceptual change is (p. 670):

1) present an example of the phenomenon to be considered, preferably one that is going to have widely differing explanations by students in the classroom, then

2) solicit explanations and the reasoning behind those explanations,

3) establish a "town meeting", a facilitating environment which supports the student community in a discussion to develop and test new ideas to resolve the differences between the explanations.

The general treatment strategy for re-conceptualization is (p. 671):

1) find some phenomenon which is easy to produce, not part of normal everyday experience, but close enough that students will feel confident predicting its outcome, and whose outcome differs in some significant way with their predictions,

2) have the students predict the outcome and discuss their justifications for those predictions,

3) have them test their predictions against the actual outcome,

4) establish a "town meeting", a facilitating environment which supports the student community in a discussion to develop and test new ideas in order to resolve perceived discrepancies between the predictions and their justifications and the actual outcome of the experiment.

According to classical conceptual change approach the cognitive conflict created in student's mind automatically leads to dissatisfaction with the existing conception. But in this view, important motivational and contextual factors are neglected. Dissatisfaction is only one of the motivating factors for the learners to put in an effort for conceptual change. (Dole and Sinatra, 1998, cited in Read, 2004).The conceptual change approaches of learning and teaching developed in recent years focused on context and process of conceptualization rather than the change of isolated concepts. And also they emphasized the influences of effective measures and learners' metacognitive awareness in conceptual change learning. Sinatra and Pintrich (2003, cited in Duit and Treagust, 2003) studied on intentional conceptual change and they brought out the importance of affective factors in conceptual change. Pintrich, Marx and Boyle (1993) describes motivational constructs, such as goal orientation, self efficacy, beliefs, values, that can serve to mediate the process of conceptual change. They see conceptual change more than a cold, rational process regarding the influence of affective variables and value beliefs. And they argue that classroom context has a big influence on motivational and cognitive components and their interactions. According to Palmer (2005) motivation should be recognized as an important factor in the construction of knowledge and the process of conceptual change too. According to Vosniadou and Stathopoulou (2007) process of students' understanding of physics does not involve only the cognitive factors. It is also influenced by other significant components such as the physics-related epistemological beliefs of students, motivational and affective variables such as personal beliefs and attitudes, the kind of new information, physical and social/cultural context from which the information is picked up and the way in which new information is interpreted. Researches on the dynamics of conceptual change showed the importance of learners' epistemological beliefs in changes in knowledge representation. (Carey et al., 1989; Duschl and Hamilton, 1998; Nussbaum, Sinatra, and Poliquin, 2008; Schauble, Klopfer and Raghavan, 1990) Qian and Alverman (1995) have studied on the role of beliefs about the nature of knowledge and learning in knowledge restructuring by text reading. They studied with high school students having alternative conceptions on motion. They used texts about the Newtonian theory of motion in the treatment. At the end of the research, they found that epistemological beliefs of students play an important role on revise students' conceptions. Their beliefs were significant predictors of conceptual change.

The researches related to students' misconceptions and conceptual change strategies resulted in varying instructional techniques that aim to overcome students' misconceptions. Some of the instructional methods and guidelines to teach for conceptual change are presented below.

2.2 Conceptual Change Instruction

Confronting a conflict situation is a crucial step for the conceptual change. Dreyfus et al. (1990) suggests that in order to create highly meaningful conflicts, instructors should use and relate students' own experiences into the learning process by using materials where both the conflict and the solution are meaningful to the students. Varying instructional techniques have been developed and tested by scientists to overcome students' misconceptions and foster conceptual change.

In the instructional strategy proposed by Nussbaum and Novick (1982) teachers are expected to guide their students through three stages;

1. Engaging students in an exposing event which they will interpret based upon their existing conceptions

2. Engaging students in a discrepant event which will create a conflict between exposed preconceptions and newly observed phenomena, which can not be explained

3. Provide them with a learning support system to help their search for a solution and encourage emerging accommodation.

Hewson, Beeth and Thorley (1998) suggest the guidelines for teaching for conceptual change which are supported by and elaborated with illustrations from the literature.

1. The range of ideas related to the topic held by different students is made explicit. This process makes students to be aware of the ideas that they had not considered seriously and makes them the part of classroom discourse as their ideas are valued. Different methods of eliciting students' conceptions

were stated in literature. Pre-instructional quizzes and small group posters are two examples.

2. Metacognition and metaconception are guidelines of teaching for conceptual change. They are inheriting in the process of conceptual change. According to Gunstone (1994) students should be metacognitive to go through the conceptual change process. Literature involves different strategies of leading the metacognition such as asking students to consider their own recorded responses to some form of pretest, engaging students in discussing whether two situations are analogous to one another and direct questioning that involves students that reflecting on their learning experiences.

3. "The status of an idea is an indication of the degree to which the person holding it, knows it, accepts it and finds it useful." (p. 207). Three aspects of status are intelligibility, plausibility and fruitfulness. The techniques such as classroom discourse and direct questioning can be used to determine status of students' conceptions. Activities aimed at rising the status of acceptable ideas and lowering the status of inadequate ideas are the part of teaching for conceptual change.

4. In conceptual change learning students should decide the status of new ideas for them. This justification process of their conceptual ecology should be the part of conceptual change instruction.

Guzetti et al. (1993) used refutational texts for making students aware of the inadequacy of their intuitive ideas to explain the certain phenomena and helping them to understand and apply the target scientific concept through the use of explanation and examples. Chambers and Andre (1997) investigated the effects of conceptual change texts on students' understanding of concepts related to electricity. They concluded that conceptual change text approach leads to better conceptual understanding of electrical concepts than traditional didactic text.

Hynd, Alvermann, and Qian, (1997) used only refutation texts and refutation texts combined with demonstration to investigate the change in preservice elementary school teachers' conceptions about projectile motion. They found that using texts with demonstration was effective for short-term changes and using only text was effective for long-term assessment.

Hewson and Hewson (1983) investigated four possible teaching strategies for conceptual change learning; integration, differentiation, exchange and conceptual bridging. They concluded that taking into account of students' alternative conceptions was worthwhile since they adversely influence meaningful understanding of the learners. Clement (1993) used bridging analogies and anchoring intuitions to deal with students' preconceptions in physics.

Nussbaum, Sinatra and Poliquin (2008, p. 1) explains the scientific argument that refers to "the application of scientific standards to arguments for the purpose of understanding scientific phenomena" as a conceptual change technique and they conclude that engaging students in consideration of alternative points of view and evaluation of alternative conceptions throughout an argumentation can promote conceptual change in their minds.

Another one of the instructional strategies designed for the conceptual change is the induction of cognitive conflict through anomalous data. The results of the researches of Chinn and Mahlotra (2002) provide the evidence that when presented with anomalous data in a scientific debate, students may nevertheless resist changing their points of view (conceptual change) by discounting anomaly.

Types of class activities combined with discussion were also found to be effective in identifying students' misconceptions prior to the instruction and improving their conceptual understanding (Nussbaum and Novick, 1982; Van Zee et al., 2001). The argumentative structures, the quality of these structures and the identities that students take on during discussions are critical in influencing student learning and achievement in science (Cross et al., 2008). One of the innovative instructional methods where both classroom and group instructions loom large is modeling instruction. Classroom discourse is organized within the context of modeling instruction in order to disclose students' different ideas at the beginning and to get their ideas together for a consensus at the end. Group discussions provide students with opportunity to work out and evaluate their scientific claims. The results of many educational researches provided evidence that this is an effective method on eliminating students' misconceptions (Brewe, 2006; Hestenes, 2006; McLaughlin, 2003; Schwaz and Gwekwerere, 2007; Wells, Hestenes and Swackhamer, 1995). The current research was also concerning the effectiveness of modeling instruction on students' conceptual understanding of physics. Therefore, an elaborated study on modeling instruction is presented under the further titles. This starts under the next topic with the detailed description of what the model and modeling are.

2.3 What is A Model?

Physicists use the words "model" and "modeling" frequently. These terms were pronounced in physics by Rene Descartes firstly and now they became popular subjects for the new researches in science education. It is possible to see them in numerous papers in the most important journals of area. And we meet with varying definitions of model in these papers. Some of these definitions that approach the concept for the purpose of instruction are touched on here.

In physics education research, the word "model" is associated with David Hestenes, professor of physics. He and collaborates has been studying for the development of modeling method of high school physics instruction for more than 20 years (Modeling Instruction, n. d.). He (1987, p. 441) defined a model in the following way: "a model in physics is a surrogate object, a conceptual representation of a real thing", in other words "a model is a representation of structure in a physical system and/or its properties" (1997, p. 943). Ingham and Gilbert (1991, p. 195) stated a general definition that was similar to Hestenes' one; "a model is a simplified representation of a system, which concentrates attention on specific aspects of the system". These aspects can be illustrated with objects, events, processes and ideas (Gilbert, 1995). According to Gilbert and Boulter (1998, p. 54), a model is "an intermediary between the abstractions of theory and the concrete actions of experiment".

In spite of defining model in a different way, Etkina, Warren and Gentile (2006, p. 34) list several common ideas about model shared by the existing definitions;

a) a model is a simplified version of an object or process under study; a scientist creating the model decides what features to neglect

b) a model can be descriptive or explanatory; explanatory models are based on analogies—relating the object or process to a more familiar object or process

c) a model needs to have predictive power

d) a model's predictive power has limitations

Mental models are the people's personal knowledge and they differ from conceptual models that represent scientifically acceptable knowledge. Gobert and Buckley (2000) define mental models as personal internal representations of the target system being modeled. For Johnson-Liard (1983), a mental model is a structural analog of a real world or imaginary situation, event or process that the mind constructs in reasoning. Wu, Dale, and Bethel (1998, p. 292) express mental model as the 'conceptual representation of an abstract concept or a physical system that provides predictive and explanatory powers to a person in trying to understand the concept or the system and guides their interaction with it'. According to de

Kleer and Brown (1983), mental models can be considered as mental simulations and these simulations involve two steps: Envisioning (a topological representation of the system components) and running (execution of the causal model based on basic operational rules and on general scientific problems).

The main purpose of mental models is to allow its builder explain and make predictions about the physical system represented by it (Greca and Moreira, 2000). In other words, people construct mental models to understand how the world is working. They recognize patterns in their experiences and represent them by the use of metaphors, analogies and models (Hestenes, 1999, part 4). These are dynamic representations (Johnson-Liard, 1983). That is, they are not complete and they continue to be enlarged as new information is embraced (Greca and Moreira, 2000). Norman (1983) characterizes mental models as unstable, unscientific, parsimonious and having not a well-defined limit.

Conceptual models are simplified representations, which are coherent with scientifically accepted knowledge of real objects, phenomena and situations (Greca and Moreira, 2000; Norman, 1983). They provide an appropriate representation of a target system, that is, they are accurate, consistent, and complete and a useful tool for the understanding or teaching of the system (Wu, Dale, and Bethel, 1998).

Hestenes (2006) express the crucial distinction between mental models and conceptual models. He defines mental models as 'private constructions in the mind of an individual' (p. 10). And a conceptual model is 'a concept with the additional stipulation that the structure of its referent be encoded in its representation by a symbolic construction, or figure, or some other inscription' (p. 12). He presents the distinction and interaction of two types of models in the following Figure.

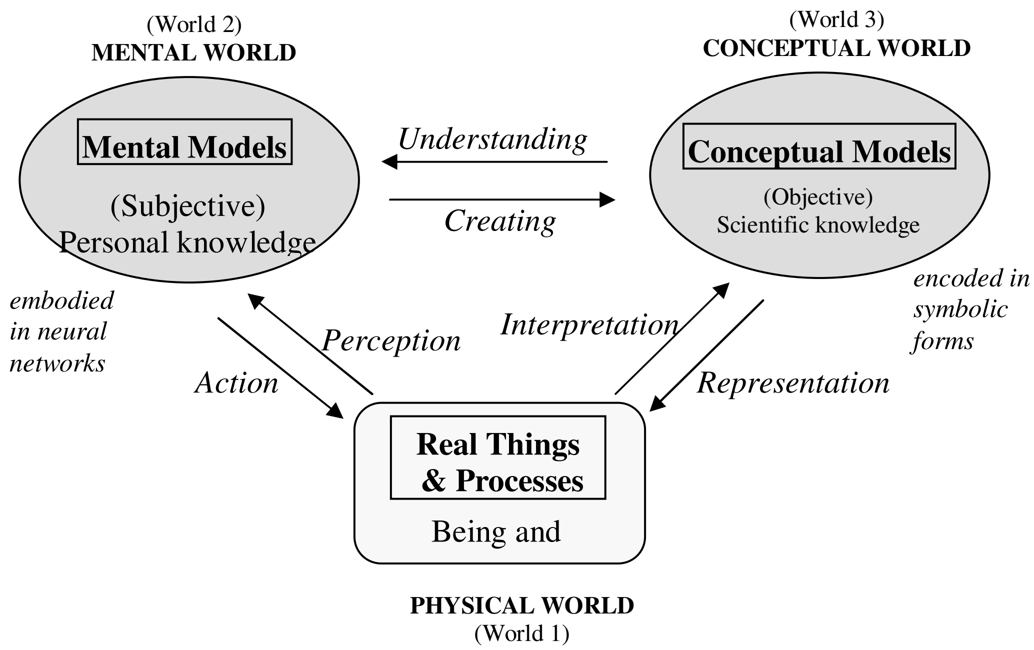


Figure 2.1 Mental Models vs. Conceptual Models (Hestenes, 2006, p. 10)

On the basis of this basic summary of the research literature on models, Chittleborough, and others (2005, p. 196) relates different types of models and presents the role of each type of model in learning. “The scientific models and teaching models provide input into students’ understanding; mental models are the product of the students’ learning that can be regarded as output. A student’s expression of his or her own mental model is referred to as the expressed model.”

The physical properties in models are represented by quantitative properties. Therefore, the models in physics are mathematical models. (Hestenes, 1997) Therefore mathematical modeling should be the central subject matter of the physics instruction. A mathematical model has four components; a set of names for the object in model, a set of descriptors (which represent the properties of object and which can be in three types: object variable, state variable and interaction variable), equations of the model and interpretation of descriptors (Hestenes, 1987).

2.4 Modeling Methodology

Modeling methodology has a series of steps followed to identify the elements of a system and to evaluate the chosen model obeying the distinct rules (Halloun, 1996). Nersessian (1995, p. 204) explains this procedure as "an integrative reasoning process that employs analogical and visual modeling and thought experimentation in creating and transforming informational representations of problems". Another description comes from Gobert and Buckley (2000); model formation is the process of integrating pieces of information about the structure, behaviour, and causal mechanism of the phenomenon and mapping from analogous systems or through induction to construct a model for that phenomenon. Etkina, Waren and Gentile (2006) suggest that four components of phenomena should be simplified to make a model; the objects in the phenomena, the interaction between objects, the systems of objects together with their interactions and the processes both qualitative and quantitative.

Modeling forms the heart of scientific method. Therefore, a detailed analysis of modeling modes provides a rich characterization of the scientific method. Hestenes (1999) specifies three major modeling modes: model construction, model analysis and model validation. The system and its properties are identified and the variables that represent these properties are investigated during the model construction. Model analysis includes the investigation of structure and implications of model. In the validation mode the reality of the model is examined, that is, the model is compared with the real system.

Hestenes defines models as representations of structures in physical systems. He (2006) reveals four types of structures specified by the models: systematic structures, geometric structures, interaction structures and temporal (event) structures. The models represent the structures that are relevant to the purpose, not necessarily including all types. To represent systematic structures the diagrammatic tools called system schema are used. Hestenes (1997, p. 944) express that “to construct a system schema from a given physical situation, or even from an artificially simple situation described in a "word problem," can be deceptively difficult; for it requires a judicious choice of system, identification of relevant properties and suppression of irrelevant information. It is actually a complex skill requiring extensive modeling to develop to a high level”. Firstly, the composition (parts that the system made out of) and the environment (external agents linked to the system) of the system should be identified. Then, the connections between these two should be specified. Geometrical structure refers to spatial location and the configuration (geometric relations among the parts) of the system. Geometric structure relevant to the model has been extracted from the situation map and represented in a motion map. A motion map, for example, for a particle in oblique motion is a diagram of its trajectory in position space, with vector or scalar labels for kinematical variables only. The vectors indicate velocity, acceleration and position of the object. Temporal structure of the system specifies the structure of its behaviour in time. Two kinds of model for temporal structure are distinguished: descriptive and causal. While the descriptive models give the state variables as explicit functions of time. The causal models explain the change of state by equations. The interaction structure describes the interactions in the system on an interaction map or by a set of interaction laws (mixed representations exist). For example, on the interaction map for a particle in trajectory the forces acting on a particle at key points on its trajectory are represented. While the kinematical diagrams indicating velocity and acceleration are drawn in the motion map, the force diagrams are shown in the interaction map. Specialized modeling tools have been developed to represent different kinds of structures in models. For example, force and energy diagrams and bar charts are especially valuable for representing interaction structure and state transition diagrams and motion maps are for temporal structure. Graphs, of course, are valuable for geometric structure. And system schemas are used to represent systematic structure (Hestenes, 1987, 1997 and 1999).

It is not easy to decide what to neglect while simplifying an object or a system for modeling process, or whether the chosen model is appropriate, or how to use model to make predictions, etc. Etkina, Waren and Gentile (2006, p. 36, 37) give steps that can be followed for modeling and that make modeling process more explicit;

1. When we choose to investigate a physical phenomenon, we first identify the objects involved. We then decide how we will simplify these objects.

2. When there are multiple objects involved, we need to consider interactions between those objects. We make decisions to neglect some interactions and take others into account.

3. By combining the models of objects and interactions for a physical system, we get a model of the system.

4. Due to the interactions between the objects in a system or with objects outside a system, the system may change in some manner. We will refer to a model that describes the changes in a system as a process model.

5. When we quantify our models of systems and processes, we get mathematical expressions that we call state equations and causal equations. A state equation describes how one or more properties of a system vary in relation to each other, but the cause of the change is unspecified. A causal equation, however, describes how the properties of a system are affected by its interactions with the environment.

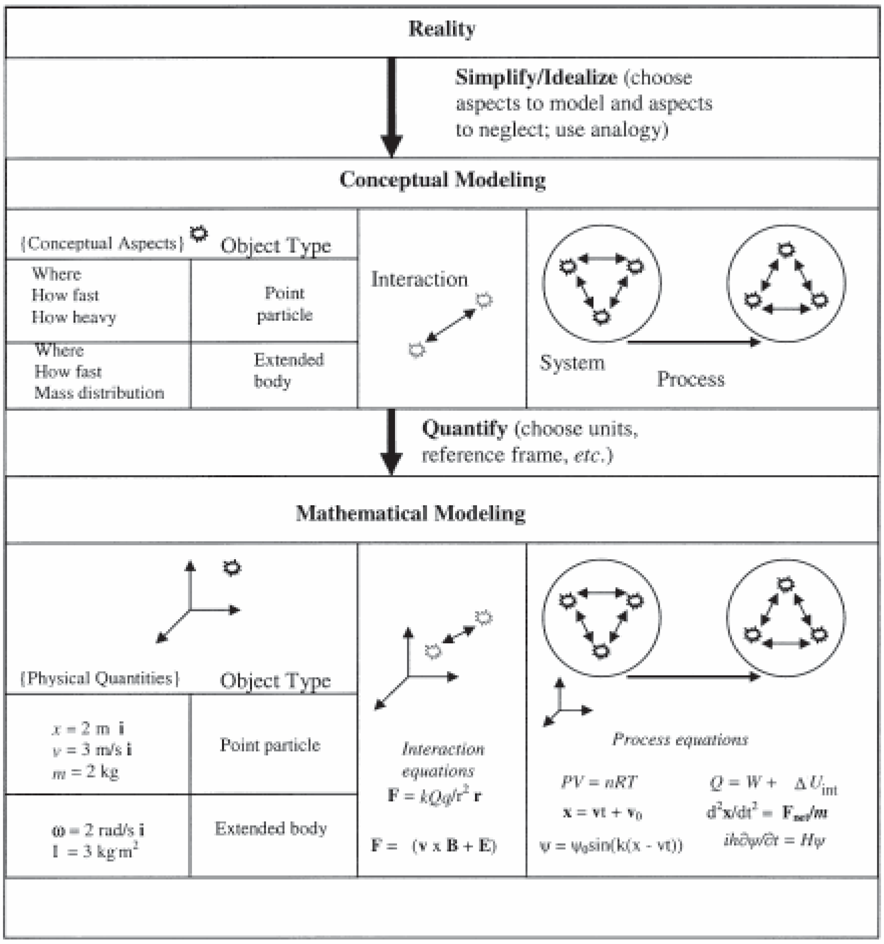


Figure 2.2 Etkina, Waren and Gentile's (2006, p. 35) figure that summarizes the process of constructing a quantifiable model.

The model construction is followed by the evaluation and use of model. In these steps it might be needed to revise, elaborate or even reject the model completely. Model revision involves the modification of some parts of model and model elaboration involves the making additions to model so that it better explains the observed situation (Gobert and Buckley, 2000).

In the recent related researches, we meet with the studies on application of modeling strategies as an instructional method. The researches conducted by David Hestenes and collaborate for the development of modeling method of high school physics instruction are the important examples. The modeling instruction elaborated by them and also investigated in this study is described by detail under the following heading.

2.5 Modeling Instruction

A modeling instruction is designed into "modeling cycles" which have two phases, model development and model deployment. Students are engaged in developing a mathematical model to investigate general physical principles, evaluating their model, applying it in new situations and acquisition of modeling skills through these phases. Roughly speaking, model development includes the design and execution of an experiment with its oral presentation and critique of results. The deployment phase encompasses the application of model in new situations to analyze, explain and solve problems in these situations. While the model development stage is responsible for exploration and invention, deployment stage is accountable for discovery. The phases of modeling cycle have a generic and flexible format which the instructors can easily adapt in their course level, topic and student ability (Hestenes, 1997; Modeling Cycle, n. d.).

Hestenes and collaborates (The Modeling Method, n. d.) lists six main instructional objectives of modeling;

- To engage students in understanding the physical world by constructing and using scientific models to describe, to explain, to predict and to control physical phenomena.
- To provide students with basic conceptual tools for modeling physical objects and processes, especially mathematical, graphical and diagrammatic representations.
- To familiarize students with a small set of basic models as the content core of physics.
- To develop insight into the structure of scientific knowledge by examining how models fit into theories.

- To show how scientific knowledge is validated by engaging students in evaluating scientific models through comparison with empirical data.
- To develop skill in all aspects of modeling as the procedural core of scientific knowledge.

Two phases of modeling cycle, model development and model deployment have been investigated and elaborated by Hestenes and collaborates for years (Halloun and Hestenes, 1985; Hestenes, 1987, 1997, 1999 and 2006; Hestenes, Jackson, Halloun, Dukerich, and Swackhamer, 2002; Hestenes, and Wells, 1992; Hestenes, Wells, and Swackhamer, 1992; Modeling Cycle, n. d.; Modeling Instruction, n. d.; The Modeling Method, n. d.; Wells, Hestenes, and Swackhamer, 1995). Their descriptions about the stages of a modeling cycle were summarized below.

MODEL DEVELOPMENT

In the model development stage students are not presented with the target model by the instructor. On the contrary, they are expected to design and perform an experiment and obtain data to invent and evaluate a model for themselves. Instructor plays the roles of Socratic inquisitor, moderator, activity facilitator and arbiter. For a good performance, the instructor should have an agenda and specific objectives including the concepts and terminology to be introduced, conclusions to be reached, issues to be raised and misconceptions to be addressed.

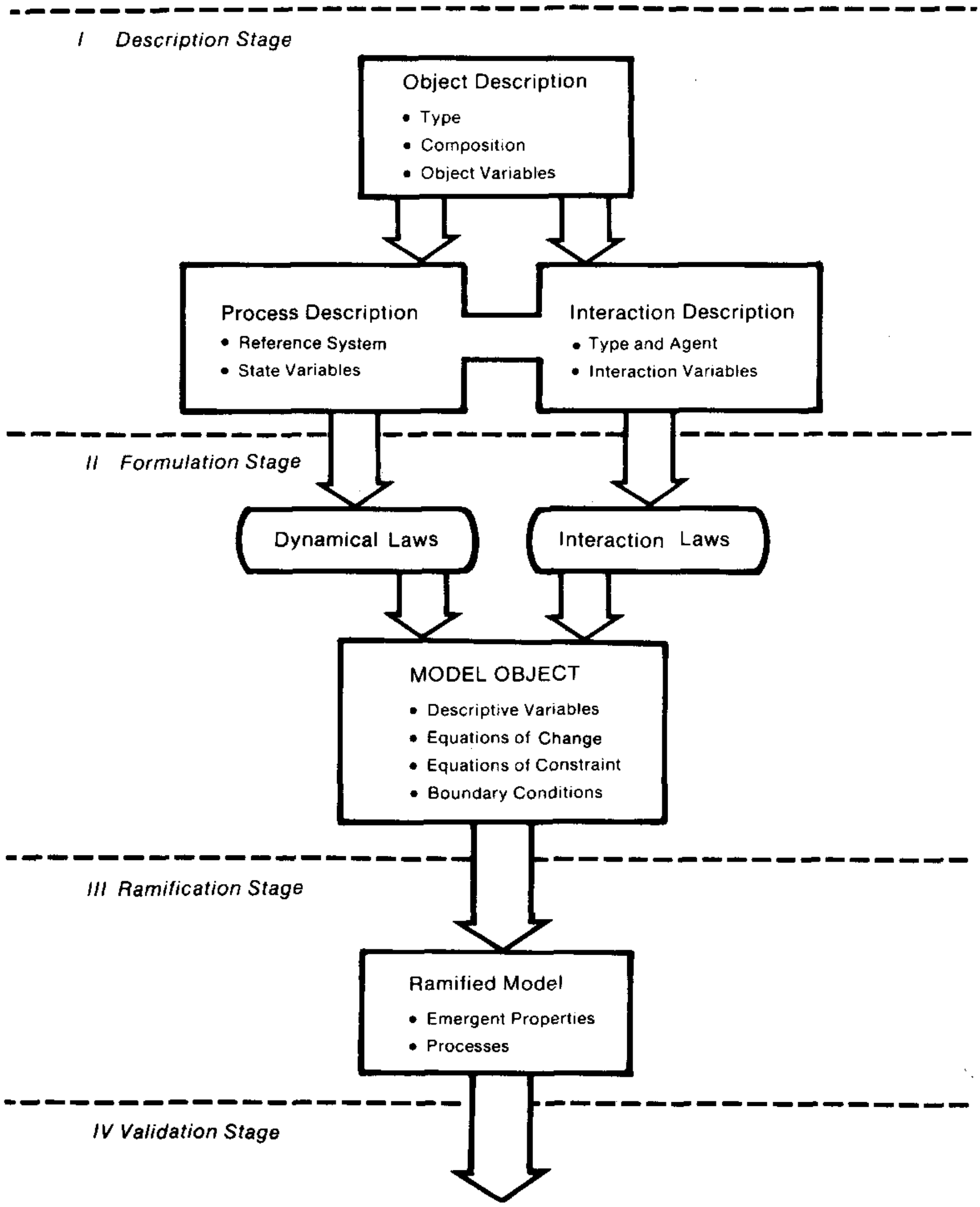


Figure 2.3 General model development synopsis by Hestenes (1987, p. 447)

During the model development, students accomplish four main phases: description, formulation, ramification and validation.

1. Description:

This stage starts with the presentation of experimental set up. Before asking questions to the students, the necessary technical terms, operational definitions (including dependent and independent variables) and notations are served by the instructor to clarify the discussion. Then the research question and other probing questions are introduced. The purpose of these questions is to direct students to select the quantitatively measurable parameters that might be expected to exhibit some cause-effect relationship. The factors identified by the students are listed on the board and a class discussion on which ones they could effectively measure by using introduced set up is managed. At this point students learn to differentiate the important aspects of phenomena and distracters.

2. Formulation:

In this phase, students collaborate in planning and conducting experiments in small groups to develop functional relationship between variables and answers to research questions. They should elaborate experimental design including the parameters that will be measured, the ones that will be hold constant, the measurement method, the number of trials, the method of data recording, etc. Then the groups are allowed to perform their experiments.

Each member of the teams should have a lab notebook. They are asked to record raw data and note the procedure of their experiment and any changes to the procedure as they conduct the lab in their lab notebook. They are announced that they will prepare a detailed lab report in the given format in their notebook and submit these notebooks at the end of the cycle.

3. Ramification:

The teams carry out their own data analysis cooperatively, plotting necessary graphs and constructing mathematical representations of the functional relationships they posited previously (Malone, 2007).

Models have a large variety of symbolic representations of scientific phenomena they explain such as three-dimensional structures, equations, diagrams, analogies, metaphors, pictures, ideas and simulations (Chittleborough and others, 2005). Malone (2007) states four types of symbolic representations produced between the system and model; verbal, algebraic, diagrammatic and graphical representations.

4. Validation:

Students present their model representations to the rest of the class. The class as a whole arrives a consensus on the model in a class discussion. Although most of the study done cooperatively in the class, each student is responsible to prepare and submit lab notebook. Grading is done regarding the lab notebooks, group presentations and performance of students in class discussions and other activities. Hestenes (1987, p. 447) gives a synopsis of four stages of model development in a figure shown in Figure 2.3.

MODEL DEPLOYMENT

Though some of the activities may involve laboratory studies, this stage is usually carried out in the class. This is a kind of problem solving study and its purpose is abstract of the models elaborated by students thereby allowing them for disposition of models to new situations in different ways. (Malone, 2007)

Hestenes (1987, p. 446) gives some deployment tactics,

1) The attack on a problem begins by extracting the information which can be used in a model development and representing it in some schematic form. This information is of two types: about objects and their properties or about processes.

2) The initial analysis of problem is completed by formulating the goal in terms of information about objects or processes to be determined.

3) From the given information about the properties one can determine the relevant scientific theory and selected model types for the objects of interest.

4) Before generating a model description, one must decide whether to use basic or derived variables. The best decision depends on the specialized knowledge about the process in the problem.

5) After a model has been formulated, it should be check to see if the specialized information is theoretically sufficient to determine the desired information. At this point it should also be possible to identify any specified information which is contradictory or irrelevant to the goal.

6) To get most quickly to the goal, it is often best to select or drive the equations for desired variables from the laws of the model, and then proceed to solve those questions.

The research showed that discussion and the types of class activities combined with discussion are effective conceptual change strategies (Nussbaum, Sinatra and Poliquin, 2008; Nussbaum and Novick, 1982; Van Zee et al., 2001). A classroom discourse is organized within the context of modeling instruction to work out and evaluate scientific claims and this is the most critical aspect of the modeling instruction. Besides, Hestenes (1999) affirms that the reason why some teachers using the modeling instruction get better results than others is the way that discourse occurs in the classroom. The quality of discourse determines the instructional success. He (1997, 1999) states three main requirements for a scientific discourse, models for precise formulation of claims, methods to investigate the applicability of models and data to evaluate them. Different forms of discourse such as whole class discussion, small group discussion, review, presentation, critique, etc. can be used depending on the objectives of discourse. It is very important to create a climate of openness in the classroom before the discourse begins. Students should feel comfortable. Another crucial point is that when someone in class uses a word, the rest should attribute the same meaning to the word. The instructor should give the meanings of important terms, maybe equations and diagrams, at the beginning of the discourse. The questions are most important tools of instructor to lead the discourse. The questioning should attempt to reinforce key ideas, challenge misconceptions and provide students with opportunities to explain the model they developed, to extend it into new applications and represent their results verbally, diagrammatically, graphically, and mathematically.

2.6 Overcoming Misconceptions with Modeling Instruction

Many of recent cognitive researches have identified serious flaws in traditional instructional practice. Firstly, traditional instruction fails to notice the crucial influence of students' personal naïve beliefs on what they learn. Secondly, most students construe wrongly what they hear and read in traditional introductory physics (Hestenes, 1997). When students come to classroom, new conceptual models are introduced to them and they are expected to construct mental models that are copies of conceptual models introduced to them. But this does not always happen. If the new conceptual model can not be constructed in consistency with the prior knowledge student get, it might be just memorized by the student (Greca and Moreira, 2000).

The modeling instruction aims to correct many weaknesses of traditional instruction, such as student passivity, incoherence of knowledge and persistence of misconceptions (Hestenes, 1997). Malone (2007) claims that there are a number of possible abilities which the students instructed through modeling cycles can develop but the students instructed traditionally can not. Some examples of these skills are using multiple representations to solve problems, identifying the method of solution via models instead of equations, completing a breadth search of knowledge structure instead of a depth search using metacognitive skills continuously (setting goals, monitoring, and evaluating) and produce fewer physics errors.

In many conceptual change techniques somebody tells students that there is better alternative. It is better to provide students with the opportunity to recognize that there's a better alternative (Hestenes, 1999). Model building is a powerful strategy for engaging, supporting and assessing conceptual change in learners, since the activities in modeling instruction provide students with repeated opportunity to confront all serious misconceptions and test and correct their own ideas regarding the relevance and coherence with other ones (Jonassen and Strobel, 2005; Schober, 1999; Vesenka et al., 2002; Wells, Hestenes and Swackhamer, 1995).

Reviewing several instructional models, Cosgrove and Osborne (1985) suggests that,

1. The teacher requires realizing the scientist views, the children views and his or her own views in relation to the topic begin taught.

2. Children must have opportunity to explore the context of the concept within a real situation and needed to engage to clarify their own views as clearly as in the learning process.

3. Students debate their ideas with each other and teacher introduces the science view where it is necessary. This requires the teacher to make the concept intelligible and plausible by experimentation, demonstration or reference to analogy.

4. Teacher should provide opportunities for application of new ideas based on commonplace.

Hestenes (1987) names the process by which new ideas about the real world are test, accepted and integrated into a conceptual framework as “dialectic process” and introduce this process as a reflection of the self-regulation process in human cognition. He claims that a dialectic teaching strategy is appropriate when the student has misconceptions related to concepts to be taught. The strategy simply involves the provoking the ‘cognitive conflict’ between the new and prior concept and induce the student to resolve the conflict by rational means. He recommends a dialectical teaching strategy with the following elements (p. 452);

1. Explicit formulation. Students should be engaged in considering systems of explicitly formulated common sense beliefs.

2. Check for external validity. Students should be induced to check the beliefs to consistency with empirical evidence.

3. Check for internal validity. Students should be induced to check the beliefs for mutual consistency among beliefs.

4. Comparison with alternative beliefs. Students should be induced to compare and decide between conflicting beliefs and beliefs systems, including relevant scientific beliefs.

He sees the objective of dialectic teaching much more than alternation of deep-seated beliefs. The dialectic strategy should teach students objective procedures and criteria for evaluating and recognizing the flaws in common sense beliefs and justify their own beliefs. It also teaches to value of explicit and precise formulations, the need for careful empirical tests and the processes of objective evaluation. In short, they should learn scientific methods for evaluating beliefs about the physical world.

Varying educational researches have conducted to investigate the effects of modeling instruction on conceptual understanding of students. Wells, Hestenes and Swackhamer (1995) compared the effectiveness of three instructional methods, traditional instruction, cooperative inquiry and modeling instruction, on students' understanding of mechanics concepts. Traditional instruction consisted of lectures, demonstrations, problem solving activities and homework questions. In cooperative inquiry method, most of the class time (70%) was devoted to lab activities that the students were actively engaged in investigating real phenomena in collaboration with their peers under the guidance by the instructor. The modeling instruction was complementary version-which was laboratory based and adapted to scientific inquiry- of the modeling method. It consisted of general features of cooperative inquiry but it emphasized the use of models to describe and explain physical phenomena. The modeling instruction involved two main stages of model development and model deployment. The results showed that modeling method was a considerable improvement over inquiry method and clearly superior to the traditional method. The study also evinced that the results of traditional instruction was poor for all teacher regardless of their experiences and academic background.

McLaughlin (2003) conducted a study to compare traditional math instruction to instruction that was consistent with the modeling method of teaching physics and instructional suggestions from proportional reasoning research. Proportional reasoning is one of the topics of mathematics courses, but student success in secondary science is highly related to proportional reasoning ability.

In the study, control group received traditional math instruction while experimental group was taught through modeling instruction. A proportional reasoning test was conducted as pretest and posttest to both groups. The results indicated that the treatment developed the necessary reasoning required for greater success on the proportional reasoning instrument. The researcher concluded that a viable model for mathematics instruction could lead to greater success in secondary science as well as facilitate formal operational thought.

Hestenes (2006) and collaborates conducted a nationwide study called Modeling Instruction Project that involved 7500 high school physics students. The teachers participated in project attended a Modeling Workshop. Naïve teachers group attended the workshops for three years but the second group involving masters in physics education attended in the last year only. Every teacher began teaching with it immediately. Researchers administered Force Concept Inventory (FCI) just before the workshops and after each year of the workshops. FCI questions are based on detailed taxonomy of common sense concepts of force and motion derived from research. Each question requires choosing one between a Newtonian concept and common sense alternatives for best explanation in given physical situation. The mean FCI pre-test scores were similar in all groups. While the average post-test scores increased to 52% for naïve modelers and to 69% for expert modelers, it was 42% for the students taught through traditional instruction. These results showed that traditional high school instruction had little impact on students' naïve beliefs. The average gain in modeling instruction applied by both naïve and expert teachers was significantly higher than traditional one. Researchers concluded that the fundamental reason of ineffectiveness of traditional instruction was that it does not even recognize common sense beliefs of students as legitimate and it neglects them. Contrarily, modeling instruction is designed to address this problem.

Brewe (2006) applied modeling theory of instruction in the university physics. Experimental classes have progressed through modeling cycles including the stages of model development, application and adaptation, extension and revision. He presented the results of his study comparing with the traditional instruction. First, he concluded that modeling instruction and traditional instruction need different curricula. While the traditional curriculum is organized into discreet topics, modeling instruction needs a curriculum organized around general models. Such a modeling curriculum helps students to construct a more effective knowledge organization and to reduce their cognitive load during the analysis of physical situations. The second benefit of modeling instruction cited by Brewe was the relationship between curriculum design and practice of science. Thirdly, he claimed that modeling instruction requires use of multiple representations in problem solving, that is, it allows students to have varied ways of analyzing physical situations including diagrams, graphs, equations, etc. Furthermore, to carry out modeling instruction teachers need to take account of students' pre-existing knowledge as it evolves throughout the instruction.

The study carried out by Schwaz and Gwekwerere (2007) aimed to investigate the effect of an instruction under modeling framework on preservice elementary teacher's science pedagogy skills and teaching orientations. They analyzed pre-service teacher's pre-post tests, classroom artifacts, peer interviews and lesson plans throughout the semester. The results revealed that the instruction enabled two thirds of the class to move their teaching orientations away from discovery or didactic approaches towards conceptual change, inquiry and guided inquiry approaches.

The present investigation was conducted to search for the influences of modeling instruction on the students' understanding of physics concepts. The physics topic selected for this study was projectile motion. Projectile motion is two-dimensional motion with uniform acceleration. Hestenes (1999) names five basic kinematics models; constant velocity, constant acceleration, simple harmonic oscillator, uniform circular motion and collisions. In his previous report he summarizes four of these models and motion maps in the table shown in Figure 2.3 (1987, p. 444):

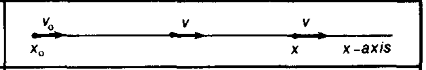
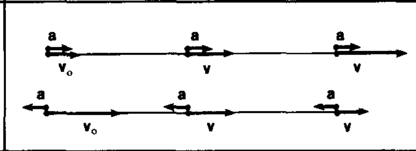
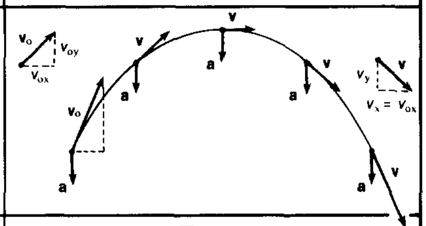
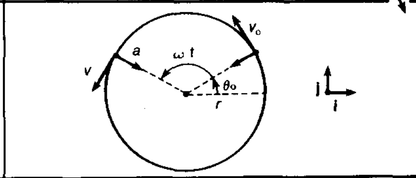
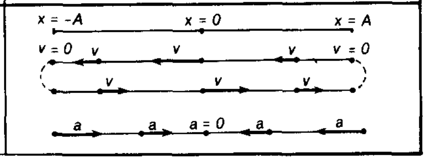
Kinematical Type	Defining equations: vectorial	Defining equations: coordinate	Solution: vectorial	Solution: coordinate	Motion Map
Uniform Velocity	$\mathbf{v} = \mathbf{v}_o$ $(\mathbf{a} = 0)$	$v = v_o$ $(a = 0)$	$\mathbf{r} = \mathbf{r}_o + \mathbf{v}t$	$x = x_o + vt$	
Uniform Acceleration 1-dim.	$\mathbf{a} = \mathbf{a}_o$ $\mathbf{a} \times \mathbf{v} = 0$	$a_x = a_{ox} = a$	$\mathbf{v} = \mathbf{v}_o + \mathbf{a}t$ $\Delta\mathbf{r} = \mathbf{v}_o t + \frac{1}{2}\mathbf{a}t^2$ $v^2 = v_o^2 + 2\mathbf{a}\cdot\Delta\mathbf{r}$ $\Delta\mathbf{r} = \mathbf{r} - \mathbf{r}_o$	$v = v_o + at$ $x = x_o + \frac{1}{2}at^2 + v_o t$ $v^2 = v_o^2 + 2a(x - x_o)$	
Uniform Acceleration 2-dim.	$\mathbf{a} = \mathbf{a}_o$ $\mathbf{a} \times \mathbf{v} \neq 0$	$a_y = a_{oy} = a$ $a_x = 0$ $v_x \neq 0$		$v_x = v_{ox}$ $x = x_o + v_{ox}t$ $v_y = v_{oy} + at$ $y = y_o + v_{oy}t + \frac{1}{2}at^2$ $v_y^2 = v_{oy}^2 + 2a(y - y_o)$	
Uniform Circular Motion	$\mathbf{a}\cdot\mathbf{v} = 0$ $a = a_o$ $v = v_o$	$r = r_o$ $\omega = \omega_o$ $\omega = \frac{d\theta}{dt}$	$\theta = \omega t + \theta_o$ $v = \omega r$ $a = \omega^2 r = \frac{v^2}{r}$ $\mathbf{r} = r(\mathbf{i}\cos\theta + \mathbf{j}\sin\theta)$ $\mathbf{v} = v(-\mathbf{i}\sin\theta + \mathbf{j}\cos\theta)$		
Simple Harmonic Motion	$\mathbf{a} = -\omega^2\mathbf{r}$ $\mathbf{a} \times \mathbf{v} = 0$	$a = -\omega^2 x$	$\mathbf{r} = \mathbf{A}\cos(\omega t + \delta)$ $\mathbf{v} = \mathbf{V}\sin(\omega t + \delta)$ $\mathbf{V} = -\omega\mathbf{A}$	$x = A\cos(\omega t + \delta)$ $v = -\omega A\sin(\omega t + \delta)$	

Figure 2.4 Kinematical Models

The underlying abstract model of projectile motion is particle with constant acceleration. The same model applies the motion of a block sliding on an incline plane. “One of the important objectives in teaching modeling is to extract the models from situation-specific applications, so that the students can learn how to see these patterns in many different situations. Then they have powerful conceptual tools for ordering their experience in a huge domain” (Hestenes, 1999, Part 5, p. 3).

Projectile motion is one of the physical phenomena students face with in their daily life and they develop their own theories to explain it. The research literature shows that students develop many misconceptions about the projectile motion. Students possible misconceptions related to projectile motion are exhibited below.

2.7 Students' Misconceptions Related to Projectile Motion

The first explicit formulations for the common sense beliefs about physical phenomena were developed by Aristotle. He organized his ideas in a coherent conceptual system and it took long time for science to detect and correct the flaws in his system. The followings can be exemplified for the common sense beliefs of projectile motion that are argued by Aristotle and are incompatible with the established scientific theories today. According to Aristotle, every object tends to move toward its natural place. This place depends on the composition of object. "Heavy bodies, composed mainly of earth and water, are endowed with the property of gravity, a centripetal tendency to move toward the center of the universe. Light bodies, composed mainly of air and fire, are endowed with the property of levity, a centrifugal tendency to flee the center of the universe." (p. 2). He also believes that a constant force produces a constant velocity and an increasing force produces acceleration. The weight of body in free fall increases as it gets closer to its natural place. This is why an object gets faster as it falls. The speed of falling object is also influenced by its weight. Aristotle claims that the heavier objects fall faster (Halloun and Hestenes, 1985).

In the 14th century, the impetus theory that rejects Aristotle's ideas and brings an alternative explanation to motion and what causes motion was developed by philosophers. Albert of Saxony described projectile motion by using this theory. The motion of a body launched horizontally was examined in three stages in his explanation. In the first stage (a), the impetus suppresses any effect of gravity and the body moves horizontally until it is weakened by air resistance. In the intermediate stage (b), the initial impetus, that causes horizontal movement, is exhausted, and in the final stage (c), the projectile falls vertically (Halloun and Hestenes, 1985).

The recent researches in literature brought out many other misconceptions of students related to projectile motion concepts (Caramazza, McCloskey and Green, 1981; Clement, 1981 and 1982; Cromley and Mislevy, 2005; Gilbert, Watts, and Osborne, 1982; Halloun and Hestenes, 1985; Hestenes, Wells and Swackhamer, 1992; Hope, 1994; Kinematics, n. d.; Leboutet-Barrell, 1976; McCloskey, 1983 (a and b); Millar, and Kragh, 1994; Peters, (1981); Planinic et al., 2006; Prescott, 2004; Prescott and Mitchelmore, 2005; Reif and Allen, 1992; Rowlands, Graham and McWilliam, 2004; Tao and Gunstone, 1999; Vosniadou, 1994). Some of them are listed below.

- A fired object initially moves in the direction of firing. Only after some impetus has to be used up, gravity act and the object fall towards the ground.

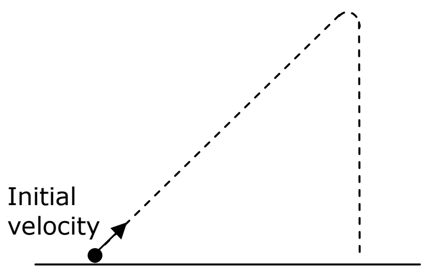


Figure 2.5 The path of fired object.

- Any body suspended in space will remain in space until made aware of its situation. This misconception is caused by the cartoon physics (Figure 2.6).

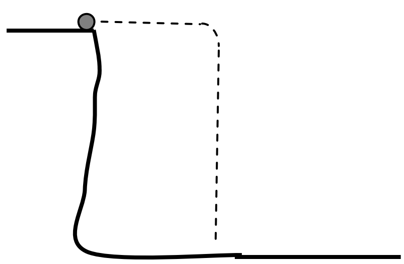


Figure 2.6 The path of fired object in cartoon physics

- Falling objects that are also moving horizontally fall straight down or in right-angle or circular arcs (Figure 2.7). A student might be able to calculate the horizontal distance that an object travels but misunderstand that objects that move both horizontally at a constant speed and vertically under the force of gravity always move in a parabola.

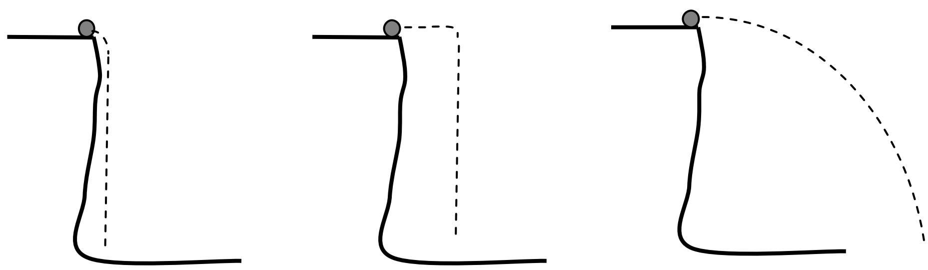


Figure 2.7 The paths of falling object which also moves horizontally.

- An object that is dropped from a moving carrier is not affected by the carrier, and therefore tends to drop straight down. Consequently, dropped objects move backwards or fall straight down.

- The speed of the carrier is important to decide where the object thrown vertically upward would fall. Therefore, students consider the motion of an object thrown from a person walking as different from that of an object thrown from a car.

- If an object is moving, then there must be a force in the direction of motion. Because force as a kind of fuel or energy that sustains the motion but at the same time is consumed by the motion itself.

- A constant force produces a constant velocity; an increase in force produces an increase in speed. Acceleration is due to increasing force.

- The force exerted on projectile, therefore, its acceleration is zero at the highest point of trajectory.

- Acceleration is the same as velocity. Acceleration and velocity are always in the same direction. If the acceleration is zero, then velocity must be zero too. So the velocity is zero at the highest point of trajectory.

- Falling objects possess more gravity than stationary objects, which may possess none at all. And the gravitational force is greater if the flying object is moving horizontally or down instead of moving up.

- If an object is on the ground then gravity is not acting on it, because it has already fallen to the ground.

- The time of flight of projectile is independent of gravity. The projectile having longer length of trajectory of projectile flies in air longer.

- The projectiles having shorter range hit ground earlier.

- Gravity is a property of the object itself. Objects with different masses are attracted by earth in different magnitudes. So, the objects having different masses fall with different accelerations. Heavier objects fall faster than lighter ones (the belief tested in Galileo's perhaps apocryphal experiment at the leaning tower of Pisa). Aritotle's belief also states that the speed of falling object is proportional with the weight of object.

- The object throwing upward slows since the object moves away from the earth, the gravity decreases as it climbs. Decreasing force causes object to slow down. Therefore the acceleration of projectile is not constant. It decreases while climbing and increases while falling.

- Projectiles launched from the same height hit the ground with the same velocity independent of their initial velocities.

- The projectiles launched at a smaller angle have a greater range.

- Gravity is the result of air pressure. Therefore there is no gravity in vacuum. Dependently there is no gravity out of the earth.

2.8 Students' Understanding of Nature of Science

It is possible to meet with varying definitions and explanations on science, scientific knowledge and/or nature of science in related literature. The followings are reckoned among the scientific knowledge's characteristics on which scientists reached a consensus in general. Scientific knowledge is subject to change (tentative), based on the observations of natural world (empirically based), subjective, and socially and culturally embedded. In addition, it unavoidably covers human inference, creativity and imagination. Furthermore, the most common answer to the question of what the science is 'the body of knowledge, and method and way of knowing'. And 'nature of science typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development' (Lederman 2007, p. 833). McComas, Clough and Almazroa (1998, p. 6) highlighted some of basic nature of science tenets on which there exists an agreement;

- Scientific knowledge while durable has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.
- There is no one way to do science (therefore, there is no universal step-by-step scientific method).
- Science is an attempt to explain natural phenomena.

- Laws and theories serve different roles in science; therefore students should note that theories do not become laws even with additional evidence.
- People from all cultures contribute to science.
- New knowledge must be reported clearly and openly.
- Scientists require accurate record keeping, peer review and replicability.
- Observations are theory laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.
- Science is part of social and cultural traditions.
- Science and technology impact each other.
- Scientific ideas are affected by their social & historical milieu.

'Learning science is related to students' and teachers' conceptions of science content, the nature of science conceptions, the aims of science instruction, the purpose of particular teaching events, and the nature of the learning process' (Duit and Treagust (1998, p. 5). Research of Gobert and Discenna (1997) provides the evidence that there is statistically significant correlation between each student's epistemology, which refers to student's understanding of how scientific ideas are built up (Songer & Linn, 1991) and his or her use of models in making inferences about scientific phenomena. Driver, Leach, Millar and Scott (1996, cited in Lederman, 2007) have introduced five significant arguments of why understanding nature of science is important and why science educators should value nature of science as an instructional objective. Understanding nature of science necessary (1) to make sense of science and menage the technical objects and process in everyday life, (2) to achieve informed decision-makings on socio-scientific issues, (3) to appreciate the value of science as part of contemporary culture. Those advocating teaching about nature of science in science education programs believe that a science curriculum that includes the historical and philosophical aspects of nature of science would be effective on overcoming many problems, such as lack of motivation and learning, female non-participation, cultural gaps, public antipathy towards science and inadequate understanding of place of science in history, culture and society (Matthews, 1998).

One of the open questions is what students should know about nature of science. The desirable science education should teach students not only the models, principles and their applications but also about the nature of science (Taber, 2008). There exist varying approaches to nature of science. Then, what would be the educational goal in teaching about science? If any particular view about the nature of science promoted among the teachers, they could in turn promote it among their students. Of course teachers can favor an approach, but good education requires an actual openness to different views. There are at least two sides to most serious intellectual questions. Different opinions, as much as possible should be presented to students and their interests in alternatives should be encouraged (Matthews, 1998).

Lederman (2007) offers a frame of reference for the aspects of nature of science that the students should know. Students often conflate nature of science with science process or scientific inquiry and observation with inference. They also often hold a hierarchical view of the relation between scientific laws and theories. Although these aspects of science may overlap and interact with each other, it is important to distinguish them. First, students should understand the crucial distinctions between these couples of concepts. Thus, students should know that, even though scientific knowledge is derived from observations of natural world, it is not lifeless, rational and orderly activity. It involves human imagination and creativity. In addition they should learn that scientific knowledge is subjective, that is, it is influenced by scientists' beliefs, experiences, prior knowledge, expectations, etc. Besides, scientific knowledge is never absolute; it is subject to change (tentative). Finally, students should be aware of that science influences and is influenced by various elements of the culture in which it is embedded.

Students' views of science and its processes may be shaped through not only classroom instruction but also a variety of factors such as media, technology and home (Chittleborough et al., 2005; Dhingra, 2003). As a result of effects of these sources students may have misconceptions about nature of science. Teachers should consider students' naïve prior knowledge when designing instruction relative to the nature of science.

Table 2.1 Myths of science described by McComas (1998)

	MYTHS OF SCIENCE
MYTH 1	Hypothesis becomes theories that in turn become laws
MYTH 2	Scientific knowledge and other such ideas are absolute.
MYTH 3	A hypothesis is an educated guess.
MYTH 4	A general and universal scientific method exists.
MYTH 5	Evidence accumulated carefully will result in sure knowledge.
MYTH 6	Science and its methods provide absolute proof.
MYTH 7	Science is procedural more than creative.
MYTH 8	Science and its methods can answer all questions.
MYTH 9	Scientists are particularly objective.
MYTH 10	Experiments are the principle route to scientific knowledge
MYTH 11	Scientific conclusions are reviewed for accuracy.
MYTH 12	Acceptance of new scientific knowledge is straightforward.
MYTH 13	Science models represent reality.
MYTH 14	Science and Technology are identical.
MYTH 15	Science is a solitary pursuit.

McComas (1998) calls misconceptions in nature of science as "myths of science" (summarized in table 2.1) and claims that some educational sources of these problem are the lack of philosophy of science content in teacher education programs, the failure of such programs to provide real science research experiences for preservice teachers and generally shallow treatment of the nature of science in the textbooks to which teachers might turn for guidance.

There are almost thirty instruments developed by scientists to assess students and teachers conceptions of nature of science. The assessment instrument used in this study was a Turkish version of VOSTS (Views on Science-Technology-Society), which was originally developed by Aikenhead, Flemming and Ryan (1989) to asses students' understanding of science, technology and their interaction with society. VOSTS has 114 multiple choice questions in its item pool. These items address these basic issues related to science, technology and society; Science and Technology, Influence of Society on Science/Technology, Future Category, Influence of Science and Technology on Society, Influence of School Science, Characteristics of Scientists, Social Construction of Scientific Knowledge, Social Construction of Technology and Nature of Scientific Knowledge (Aikenhead and Ryan, 1992). The Turkish version of Views on Science-Technology-Society (T-VOSTS), that was administered to subjects of this study, contains twenty-five items which were selected, translated and adapted in to Turkish by Doğan Bora, Aslan and Çakıroğlu, (2006). Unlike most instruments, students are not provided with numerical scores after completing this instrument. Instead, the statements reflecting their views are placed in different categories. Songer and Linn (1991) sorted students' view of science into three groups: static, mixed and dynamic. The results of this study are analyzed according to categorization used by Bradford, Rubba and Harkness (1995). They categorized the views into three groups, Realistic, Has merit and Naïve.

Aikenhead and Ryan (1992) administered a test including selected VOSTS items to investigate the students' preconceptions about the epistemology of science. They were selected item related to the meaning of science, scientific assumption, values in science, conceptual inventions in science, scientific method, consensus making in science and characteristics of the knowledge produced in science. At the end of their study, they concluded that most of the students confused science with technology. In addition they were only aware of the private and public side of science and the effect that values have on scientific knowledge. The percentage of students believed the inventive character of scientific knowledge was just 17%. 64% of students thought that there was a hierarchical relationship among hypothesis, theories and laws.

Sutherland and Dennick (2002) conducted a research to investigate the conceptions of nature of science in students with different worldviews. Their study explored the views some First Nations (Cree) and Euro-Canadian students had about the nature of science. In addition to different views of two cultural groups on various tenets of nature of science, Sutherland and Dennick ascertained some less adequate views that both of the groups held, such as tentativeness, creativity and unified nature of scientific knowledge and importance of empirical testing.

There are many researches that investigate the ways of improving students' views on nature of science. Moss (2001) conduct a research to examine the students' understandings of the nature of science and to observe the change in their beliefs over the course of an academic year. The results of his study revealed that students' conceptions did not significantly change over the year in spite of their participation in the project-based course. He concluded that nature of science should be made explicit for students. A similar conclusion was derived by Khishfe and Abd-El-Khalick (2002). In their study, two intact groups were exposed to inquiry oriented instruction by the same teacher. Determined aspects of nature of science were addressed explicitly in one of the groups and other group's instruction involved implicit attention to nature of science. Two groups had similar naïve views on various aspects of nature of science prior to the treatment. After treatment, the results showed that the views of implicit group did not change and students' understanding of one or more aspects of nature of science in explicit group improved.

Tao (2003) carried out a study to elicit students' understandings of the nature of science through a peer collaboration instruction based on science stories which presents several aspects of NOS. The study also investigated how students reacted to the stories and whether they were able to extract the aspects of NOS presented in the stories. The results show that science stories and the peer collaboration setting caused many students to change from one set of inadequate views of NOS to another rather than to adequate views. Tao concluded that students looked for aspects of nature of science that confirmed their views in the stories and ignored other that ran counter to their views. In this study, tenth grade students' understanding of science, technology and their interaction with society and the difference between the views of students who taught with modeling instruction and those who instructed with traditional methods were investigated.

2.9 The Effect of Attitude on Achievement

Attitudes are the evaluative judgments that integrate and summarize the cognitive and affective reactions of a person towards an object that person is in relation to (Crano and Prislin, 2006). They include the three components of cognition, affect, and behaviour. Students' attitudes towards science are one of the possible factors that have an effect on their achievement and also on their choices for further education. Therefore attitudes towards science and the relationship among instruction, achievement and attitude are issues with longstanding attention and interest in science education research (Barmby et al., 2008).

Barmby et al. (2008) carried out a study to examine the variation of attitudes towards science over the first three years of secondary schooling and with gender. They administered a questionnaire including separate measures for attitudes towards the following areas: learning science in school, practical work in science, science outside of school, importance of science, self-concept in science, and future participation in science. The results of their study provide evidence that pupils' attitudes towards science declined as they progressed through secondary school and this decline was more pronounced for female pupils. It was observed that whilst in the first year of secondary schooling there was very little difference between boys and girls, the differences between boys and girls increased as moved up through the year groups. In addition, the sharpest decline occurred specifically for pupils' attitude towards learning science in school. Furthermore, they identified that as pupils progress through school, this construct becomes a greater influence on attitudes towards future participation in science.

In the extent literature of science education, there exist many researches on the gender effect on students' attitudes towards science, with the result that males have a more positive attitude than females do (Baram-Tsabari and Yarden, 2008; Dawson, 2000; Jones et al., 2000; Reid and Skryabina, 2003; Weinburgh, 1995). Jones, Howe and Rua (2000) designed a survey in order to elicit students' perceptions of science and scientists, out-of-school science experiences, science topics of interest, and characteristics of future jobs. The results of their study evidenced that there exist significant gender differences in science experiences, attitudes, and perceptions of science courses and future jobs. The results of investigation in students' perceptions of science showed that females perceived science as difficult to understand, whereas males thought that science was destructive and dangerous, as well as more suitable for boys. The results of Francis and Greer (1999) on secondary school pupils' attitudes toward science revealed that males had more positive attitude toward science than females did. In addition, the results showed that younger pupils had more positive attitude toward science than older students did. The study conducted by George (2006) supports this finding. The results of his study evinced that students' attitudes toward science decreased over the middle and high school years.

Freedman (2002) claims that one of the factors that results in the differences for females and males in attitudes towards science is the type of instruction that the students receive in the classroom. Based upon findings in his study, he claims that hands-on laboratory activities may promote students' positive attitudes towards science and are effective across gender differences. Owen et al. (2008) conducted a study to explore whether physics might be made more attractive to students with different learning activities. They scored the popularity of a range of activities, students' perceptions about how often these activities are used to teach physics, and whether students consider them educationally useful. The results of the study revealed that the most popular activities among the students were constructive activities, such as doing experiments. Students have found these activities educationally useful, but they have thought that these activities were used less often than other activities. The student interviews conducted by Gibson (1998) showed that high interest students preferred the hands-on approach of science instruction to traditional classroom methods of teaching in order to maintain their interest. The study of Jovanovic and King (1998) displayed that the effects of such activities on students' perceptions and attitudes towards science might vary depending on students' gender, that is, boys and girls experience these activities differently. In their research, they examined whether boys and girls equally shared in performing the behaviors required of hands-on activities in the performance-based science classroom. The results indicated that involvement in the performance-based science classroom was a strong predictor for students' end-of-the year science attitudes. However, they observed that boys and girls did not participate equally in these classrooms. Moreover, they confirmed a decrease for girls, but not boys, in science ability perceptions over the school year.

It is obvious that student's attitude have a significant influence on their achievement and future decisions. Findings of related literature indicates that laboratory studies which provides students with the opportunities to apply their ideas in real world situations may have a positive influence on student's attitudes (Adams and Chiappetta, 1998; Etkina, et al., 2002; Freedman, 2002). In this study, we examined the effectiveness of modeling instruction, which is laboratory based and adapted to inquiry, on students' understanding of projectile motion and their attitudes towards physics.

CHAPTER 3

PROBLEMS AND HYPOTHESES OF THE STUDY

In this chapter, the problems of the study and hypotheses developed in order to find solutions to these problems were stated. Three main problems, eight sub problems and seven hypotheses were developed for this purpose.

3.1 The Main Problem and Sub-Problems

3.1.1 The Main Problem

There were three main problems of the study:

1. What are the effects of gender difference and modeling instruction compared to traditionally designed physics instruction on overcoming tenth grade students' misconceptions on concepts related to projectile motion?

2. What are the effects of gender difference and modeling instruction compared to traditionally designed physics instruction on tenth grade students' attitudes towards physics as a school subject?

3. What kind of views do the students possess on the nature of science concepts?

3.1.2 The Sub-Problems

The following sub-problems were attempted to answer in this study:

1.1 Is there a significant mean difference between the post concept test scores of students taught with modeling instruction versus traditionally designed physics instruction on concepts related to projectile motion when the effects of students' Science Process Skill Test scores are controlled as a covariate?

1.2 Is there a significant mean difference between the post concept test scores of females and males when the effects of students' Science Process Skill Test scores are controlled as a covariate?

1.3 Is there a significant interaction between the treatment and the gender of students on their understanding of concepts related to projectile motion when the effects of students' Science Process Skill Test scores are controlled as a covariate?

1.4 What is the contribution of students' science process skills on their understanding of concepts related to projectile motion?

2.1 Is there a significant mean difference between the attitude post-test scores of students taught with modeling instruction versus traditionally designed physics instruction?

2.2 Is there a significant mean difference between the attitude post test scores of females and males?

2.3 Is there a significant interaction between the treatment and the gender of students on their attitudes towards physics as a school subject?

3.1 What are the views of students participated in this study on the nature of science conception?

3.2 Null Hypotheses

In this study, the following hypotheses are developed in order to find solutions to main and sub-problems stated above. All hypotheses are stated in null form.

1.1 There is no significant mean difference between the post concept test scores of students taught with Modeling Instruction versus traditionally designed physics instruction on concepts related to projectile motion when the effects of students' Science Process Skill Test scores are controlled as a covariate.

1.2 There is no significant mean difference between the post concept test scores of females and males when the effects of students' Science Process Skill Test scores are controlled as a covariate.

1.3 There is no significant interaction between the treatment and the gender of students on their understanding of concepts related to projectile motion when the effects of students' Science Process Skill Test scores are controlled as a covariate.

1.4 There is no significant contribution of students' attitudes towards physics on their understanding of concepts related to projectile motion.

2.1 There is no significant mean difference between the attitude post test scores of students taught with modeling instruction versus traditionally designed physics instruction.

2.2 There is no significant mean difference between the attitude post test scores of females and males.

2.3 There is no significant interaction between the treatment and the gender of students on their attitudes towards physics as a school subject.

CHAPTER 4

DESIGN OF THE STUDY

In the previous chapters, purpose and significance of study were expressed, problems and hypotheses of the study were presented and related literature was reviewed accordingly. This chapter comprises the detailed explanations about experimental design of the study, population and sampling, description of variables, measuring tools used to collect data, treatment, method of data analysis and assumptions and limitations of study.

4.1 Experimental Design

This study was designed to determine and compare the effects of the two different instructional methods, traditional instruction and modeling instruction, on students understanding of physics. The non-equivalent control group design (quasi-experimental design) was preferred for the reason that although treatments were randomly assigned to groups, it was not possible to randomly assign the subjects to treatment groups (Hinkle, Wiersma and Jurs, 1998; Gravetter and Wallnau, 2000).

While the students in the control group were taught by the traditionally designed instruction (TI) that includes lecturing and a laboratory study, the students in experimental group were taught by Modeling Instruction (MI). Before the experiment, Projectile Motion Concept Test (PMCT), Attitude Scale towards Physics (ASTP) and Science Process Skill Test (SPST) were administered to all students as pre-test. After four weeks of treatment period, the PMCT, ASTP and Views on Science-Technology-Society (T-VOSTS) test were administered as a post-test to all groups. The research design of the study is presented in Table 4.1.

Table 4.1 Research design of the study

Group	Before Treatment	Treatment	After Treatment
EG	PMCT, ASTP, SPST	TI	PMCT, ASTP, T-VOSTS
CG	PMCT, ASTP, SPST	MI	PMCT, ASTP, T-VOSTS

Four kinds of measuring tools (SPST, T-VOSTS, ASTP and PMCT) were used in the study. SPST was originally developed by Burns, Okey and Wise (1985) and adopted into Turkish by Geban, Aşkar, and Özkan (1992). VOSTS was developed by Aikenhead, Fleming and Ryan (1989) and the some of the items from VOSTS item pool were selected, translated and adapted by Doğan Bora, Aslan and Çakıroğlu (2006) to form T-VOSTS which was the version used in this study. ASTP and SPST were developed by the researchers.

Detailed lesson plans to teach projectile motion to the students by using modeling instruction and a teacher guide for this instruction (see appendix I) were prepared. Students' views, experienced physics teachers' views, and physics teacher educators' views were taken into account and the required revisions were carried out. Preparation of the measuring tools and lesson plans took 6 months.

Two teaching methods were randomly assigned to the four classes. The students in two of classes were instructed by traditional method and students in other two classes were taught by modeling instruction. Each group's instruction was three 45-minute sessions per week and the topic was addressed over a 4-week period. The administration of tests and interviews with students took one week before and one week after treatment.

Before the treatment, the teachers of experimental group were informed what the modeling instruction was and how it could be used. The teacher guide for modeling instruction and detailed lesson plans were given to teachers. The researcher and teachers scrutinized the guide and plans together and teachers were asked by the researcher to follow them step by step. The process took about 2 hours. Besides, teachers and the researcher were in contact during whole treatment. The researcher was allowed by the teachers to observe both experimental and control groups during the instructions.

4.2 Population and Sample

The accessible population of this research included all tenth grade school students in science classes at a private high school in Ankara, Turkey. The subjects of study included 88 tenth grade students from four randomly selected science classes. The study was carried out during the Spring Semester of 2006-2007.

Two teaching methods (modeling instruction and traditionally designed physics instruction) were randomly assigned to the classes. Both the experimental group and the group taught by the traditional instruction consisted of 44 students.

58% (25 in experimental group and 26 in control group) of the sample were female and 42 % (19 in experimental group and 18 in control group) were male. Students' ages ranged from 15 to 17.

4.3 Variables

There are six variables in this study, which were categorized as dependent variable and independent variable. Three of them were determined as independent variables and other three were determined as dependent variables. These are listed and described below.

4.3.1 Independent Variables

The independent variables of this study were instructional method (modeling instruction and traditionally designed classroom instruction), gender of students, and students' science process skill levels measured by SPST. Instructional method and gender of students were considered as categorical variables and measured on nominal scale. SPST scores were considered as continuous variable and it is measured on interval scale.

Instructional method (modeling instruction) was coded as 1 for experimental group and it (traditionally designed physics instruction) was coded as 2 for control group. Students' gender was coded as 1 for female and as 2 for male.

4.3.2 Dependent Variables

Dependent variables of the study were students' conceptual understanding of projectile motion measured by post-PMCT, students' attitudes towards physics measured by post-ASTP and students' views on nature of science and science-technology-society-relation obtained by T-VOSTS.

Table 4.2 Identification of variables

Name of the Variable	Type of the Variable	Nature of the Variable	Type of the Data
PMCT	Dependent	Continuous	Interval
ASTP	Dependent	Continuous	Interval
SPST	Independent	Continuous	Interval
T-VOSTS	Independent	Categorical	Nominal
Gender	Independent	Categorical	Nominal
Instructional Method	Independent	Categorical	Nominal

PMCT: Projectile Motion Concept Test
ASTP: Attitude Scale towards Physics
SPST: Science Process Skill Test
T-VOSTS: Turkish Version of Views on Science-Technology-Society Test

4.4 Instruments

Four measuring tools were used to collect data in this study. These were the Projectile Motion Concept Test (PMCT), Attitude Scale toward Physics (ASTP), Science Process Skills Test (SPST), and adapted version of Views on Science-Technology-Society test (T-VOSTS). Additionally, interviews were conducted with the students from both groups and nonsystematic classroom observations were carried out during the instructions in the groups by the researcher.

In addition to measuring tools, the teaching/learning materials "How to Write a Good Lab Report" handout used in the experimental group, lab manual for the projectile motion experiment performed in the control group and problem set assigned to the students of both groups were prepared by the researcher.

4.4.1 Projectile Motion Concept Test

In order to assess students' understanding of projectile motion concepts (e.g. horizontal and vertical components of projectile motion, the horizontal range, maximum height, time in flight, graphs and equations of motion, and the factors that may affect the path of motion) a 20 item multiple choice concept test was developed by researchers. The items in the test included one correct response and four distracters that reflected students' probable misconceptions identified in related literature (Caramazza, McCloskey and Green, 1981; Clement, 1981 and 1982; Cromley and Mislevy, 2005; Gilbert, Watts and Osborne, 1982; Halloun and Hestenes, 1985; Hestenes, Wells and Swackhamer, 1992; Hope, 1994; Leboutet-Barrell, 1976; McCloskey, 1983 (a and b); Millar and Kragh, 1994; Kinematics, n. d.; Peters, 1981; Planinic et al., 2006; Prescott, 2004; Prescott and Mitchelmore, 2005; Reif and Allen, 1992; Rowlands, Graham and McWilliam, 2004; Tao and Gunstone, 1999; Vosniadou, 1994) and during interview with expert teachers. Those questions required students to make qualitative conceptual prediction about a situation in which there is a possibility to give a wrong response as a result of their misconceptions but also about the fundamental concepts to be learned and the points in which the students had difficulty in comprehending.

At the beginning of the developmental stage of the test, the instructional objectives of the projectile motion concept were stated, based on the national curriculum (See Appendix E). Second, a classification of students' misconceptions in projectile motion concept was constructed by a careful examination of related literature and by interviewing with experienced physics teachers. Lastly, the test items were constructed in a manner that each item brings out students' misconceptions related to projectile motion concepts. The distracters reflected the students' misconceptions are summarized in Table 4.3.

Table 4.3 Misconceptions investigated by the items in PMCT and their corresponding items numbers

Misconception	**Corresponding Item Number**
The initial velocity of an object released or fired from a moving carrier is independent of the velocity of this carrier.	1b, 3c, 13cd, 16d
The speed of carrier from which the object was fired is important to decide the motion of object with respect to carrier	1a, 2a, 3a, 13e
An impetus given by carrier (or person) continues to exert on projectile even after being fired because objects need a force to move	2d, 3d, 4b, 17ace
Any body suspended in space will remain in space until made aware of its situation	8d, 12e, 16b
A fired object is initially affected by weak gravity, after a while gravity begins to exert a strong impetus	8b, 12cd, 16ce
Objects that are also moving horizontally fall straight down or in circular arcs	7c, 8ab, 11a
The projectiles launched at a smaller angle have a greater range.	20a

Table 4.3 (continued)

Misconception	Corresponding Item Number
The time of flight of a projectile is independent of gravity	7b
The time of flight depends on the length of trajectory of projectile	6de, 10d
The projectiles having shorter range hit ground earlier	5a, 6a
Projectiles have zero velocity at the top of trajectory	18a
Projectiles move with constant speed during whole motion	4e, 18c, 19a
Projectiles slow down during whole motion	4c
Projectiles launched from the same height hit the ground with the same velocity independent of their initial velocities	15d
An object released falls faster than an object thrown horizontally or the one thrown vertically up. Because the gravity is greater if the object moves vertically down.	9bd
The acceleration of projectile is not constant	19cde
The acceleration of projectile is different from free fall	9bcd, 10bcd, 14abd
The net force on a projectile is zero at the highest point of trajectory	17c
Gravity is due to air pressure, therefore there is no gravity out of the earth.	17e

Prior to the treatment, all questions were piloted and required modifications were completed. The pilot test was administered to 140 eleventh grade students in a private high school in Ankara. The scores of the test range from 0 to 20. The internal reliability coefficient of the PMCT was calculated as 0.80 by using cronbach alpha coefficient. Content validity and appropriateness of the test items were determined by a group of experts in physics education and physics teachers.

Test was given to all groups both as a pre-test to control students' misconceptions in concepts related to the projectile motion at the beginning of the instruction and as a post-test to determine the effect of treatments on students' understanding of projectile motion concepts.

4.4.2 Attitude Scale towards Physics

The scale was previously developed by the researchers to measure students' attitudes toward physics as a school subject (See Appendix C). The internal consistency (Cronbach's alpha) of the instrument was found to be .94.

The Attitude Scale towards Physics consisted of 15 items designed to be rated on 5-point likert type response format (fully agree, agree, undecided, disagree, and fully disagree) in Turkish. It covered both positive and negative statements. Total possible scores in this scale vary from 15 to 75. While lower scores refer negative attitudes toward physics, higher scores refer positive attitudes toward physics. This test was given to students in both groups.

4.4.3 Science Process Skill Test

The test was originally developed by Burns, Okey and Wise (1985) and adopted into Turkish by Geban, Aşkar, and Özkan (1992). It contained 36 four-alternative multiple-choice questions (See Appendix B) about the intellectual abilities of students related to identifying variables, identifying and stating hypotheses, operationally defining, designing investigations, and graphing and interpreting data. The reliability of the test was found to be 0.85. Total possible score of the test was 36.

The test was given to all students at the beginning of study to determine and control the effect of science process skills throughout the study.

4.4.4 Views on Science-Technology-Society Test

The VOSTS is originally developed by Aikenhead, Fleming and Ryan (1989). It included 114 multiple-choice items assessing views on 9 categories; Science and Technology, Influence of Society on Science/Technology, Future Category, Influence of Science and Technology on Society, Influence of School Science, Characteristics of Scientists, Social Construction of Scientific Knowledge, Social Construction of Technology and Nature of Scientific Knowledge (Aikenhead and Ryan, 1992). The instrument of the study was Turkish version of Views on Science-Technology-Society (T-VOSTS), which contained twenty-five selected items from six categories of VOSTS item pool;

- Science and Technology (item 1)
- Influence of Society on Science/Technology (items 2 and 3)
- Influence of Science and Technology on Society (items 4, 5 and 6)
- Characteristics of Scientists (items 7, 8 and 9)
- Social Construction of Scientific Knowledge (items 10 and 11)
- Nature of Scientific Knowledge (rest of the items)

These selected items were translated and adapted by Doğan Bora, Aslan and Çakıroğlu, (2006) and the reliability of this version was found to be .72.

Each original VOSTS item is coded with a five-digit number, each of which was defined in Table M.1 (see Appendix M). The first digit refers to the number of section and the next two digits correspond to the topic number within that major section. The fourth digit indicates the item number within that topic and the fifth one differentiates items that have slight but meaningful variations in their wording (Aikenhead and Ryan, 1992). An example can be seen in Figure 4.1. (All sections, topics and subtitles were listed in Table M.1).

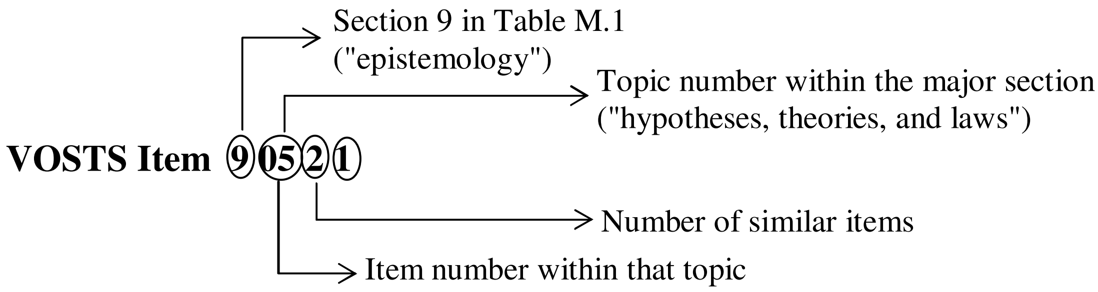


Figure 4.1 How to code a VOSTS item

Each of the items has a stem and different number of alternatives. Since the alternatives reflect different views on the statement given in steam, it would not be appropriate to call them correct or incorrect alternatives. Therefore these views were categorized into three groups as in the study of Bradford, Rubba and Harkness (1995). The first category is “Realistic” (R) and the alternatives of this category express the most appropriate and contemporary view on nature of science relative to the item stem. Second category is “Has merit” (HM) whose alternatives expresses a number of legitimate but not realistic points about nature. Last category is “Naïve” (N) and the choices express an inappropriate or not legitimate view about nature of science relative to the item stem.

Doğan Bora, Aslan and Çakıroğlu (2006) benefited from the views of experts of science and education to categorize the alternatives of each item according to types of views expressed by them. In this study, students’ responses to T-VOSTS items were evaluated regarding their categorization. The topics related to each item, its code in VOSTS item pool and the category of views introduced by the alternatives were summarized in Table 4.4.

Table 4.4 Items and scores of their alternatives

Number of Item in T-VOSTS	Code in VOSTS Item Pool	Topic	Scores of Alternatives		
			R	HM	N
1	10111	Defining Science	C	A, B, D, F, G	E, H
2	20411	Ethics	B, D	A, C, E	F, G
3	20711	Public Influence on Scientists	D, F	A, B, E	C, G
4	40111	Social Responsibility of Scientists	D, E	C, G	A, B, F
5	40213	Contribution of Social Decisions	D	A, C	B, F, E, G
6	40431	Resolution of social & practical problems	A	C, D	B, E
7	60211	Standards/values that guide scientists at work & home	B, C	D	A, E, F
8	60411	Abilities needed to do science	B, C	D, E	A
9	60511	Gender effect on the process & product of science	E, F	G	A, B, C, D
10	70412	Professional interaction in the face of competition	E	A, D	B, C
11	70511	Social interactions	A	B, C, D	E
12	90111	Nature of observations	A, B	C, D	E
13	90211	Nature of scientific models	F	E, G	A, B, C, D
14	90311	Nature of classification schemes	C, D	E	A, B, F
15	90411	Tentativeness of scientific knowledge	A, B	D	C, E
16	90511	Hypotheses, theories and laws	D		A, B, C
17	90521	Hypotheses, theories and laws	E	A, C, D	B, F
18	90541	Hypotheses, theories and laws	A, C	B, D	E, F
19	90621	Scientific approach to investigations	C	A, B	D, E

R: Realistic, HM: Has Merit, N: Naïve

Table 4.4 (continued)

Number of Item in T-VOSTS	Code in VOSTS Item Pool	Topic	Scores of Alternatives		
			R	HM	N
20	90651	Scientific approach to investigations	C	B, D	A, E
21	90711	Precision and uncertainty in scientific/technological knowledge	A, D	B, C	E
22	91011	Epistemological status of scientific knowledge	E,	A, C	B, D
23	91012	Epistemological status of scientific knowledge	F	C, E	A, B, C
24	91013	Epistemological status of scientific knowledge	E	B, C	A, D, F
25	91111	Paradigms versus coherence of concepts across disciplines	A	C, D, E	B

R: Realistic, HM: Has Merit, N: Naive

4.4.5 The Classroom Observations

The researcher attended the lessons of the both control and experimental groups as an observer. These observations helped researcher to ensure the non-biased presentation of the topic. Additionally, the researcher observed for the students' involvement in the class and their interactions with teacher and also she took notes describing the learning climate in the classes.

4.4.6 Interview Instruments

After completing treatment and administrating post-tests to all of the students, some students of both experimental and control groups were interviewed to get an idea about the nature and reasons of students' misconceptions on concepts related to projectile motion and students' opinion on the instructional methods performed in their classes. The interview session with each student took approximately 45 minutes and a tape recorder was used to record the conversation. Interview questions specifically focused on 1) the evaluation of projectile motion horizontally and vertically, 2) the path of the projectile including horizontal range, maximum height, and time in flight, 3) the factors that may affect the path and 4) the equations of horizontal and vertical components of motion.

The interviews used a semi-structured approach involving asking of structured questions followed by open ended questions (see appendix N). For interviews students were categorized by the grades they received on Projectile Motion Concept Test as high achievers, middle achievers and low achievers. The teacher was asked to select four volunteers from high achievers (two in the experimental group and two in the control group), four volunteers from middle achievers (two in the experimental group and two in the control group) and four volunteers from low achievers (two in the experimental group and two in the control group).

4.4.7 Teaching/ Learning Materials?

The students of experimental group were expected to develop a model that explains the phenomena presented to them. Students were employed in identifying the variables, designing and performing an experiment, collecting and analyzing the data, producing several representations of the model they developed and presenting their study in a lab report through the modeling instruction. "How to Write a Good Lab Report" (see appendix F) was prepared by the researcher and handed out by teachers in order to obtain a common format in students' lab reports.

The students in control group performed an experiment by following the clear and definite instructions. These instructions were given students on a lab manual prepared by the researcher (see appendix G).

A problem set including six quantitative questions was also used during the instructions (see appendix H). Five of the items were selected from the questions of International Baccalaureate Diploma Programme Physics exams administered between 2000 and 2005 and other item was developed by the researcher. This set was used in both experimental and control groups. It was given to students in control group as homework questions. And it was used as a class activity in the model deployment stage of modeling instruction.

4.5 Treatment

This study was conducted over a four week period in a private high school during the spring semester of 2006-2007 academic years. A total of 88 tenth grade students, in four physics classes of two teachers, participated in the study. Each teacher had two classes. Each of the teaching methods was randomly assigned to one class of each teacher. Two classes taught by modeling instruction formed the experimental group and other two instructed by traditional method formed control group. Each teacher gave the classroom instruction for both groups to minimize the teacher effect. The teacher bias was not recorded for each instruction. Two weeks before the treatment, teachers were trained about modeling instruction by the means of teacher guide for this instruction (see appendix I) and detailed lesson plans. Instructional materials prepared by the researcher were explained to them. However the teachers were familiar with the traditional instruction.

Instructions in both groups were observed by the researcher in order to control for the teacher bias and also verify the treatment. Observation times were randomly selected. It was observed that the teachers fulfilled the requirements of the treatment in both the control and the experimental groups. During the treatment, the projectile motion topics (horizontal and vertical components of projectile motion, range and maximum height, time in flight, position and velocity at a certain time, graphs and equations of motion) were covered as a part of the regular classroom instruction in the physics course. The classroom instruction was three 45 minute periods per week for both groups.

Before the instructions, Projectile Motion Concept Test (PMCT), Attitude Scale towards Physics (ASTP), Science Process Skill Test (SPST) and adapted version of Views on Science-Technology-Society (T-VOSTS) test were administered to all students as pre-test. PMCT was given to determine whether there was any difference between the students of experimental and control groups with respect to having misconceptions in concepts related to the projectile motion prior to the instruction. ASTP was given as a pre-test to students in order to measure students' attitudes toward physics as a school subject. SPST was given to assess the level of students' science process skills. And T-VOSTS was administered to obtain information about the students' views on the nature and content of science.

The topic of "Projectile Motion" is covered by the unit of "Motion at the Earth Surface" in 10^{th} grade Physics course. Projectile motion takes place in two dimensions and can be examined by analyzing horizontal and vertical components separately. This two-dimensional motion comprises the motion of object in free fall, motion of object thrown vertically upward or downward and motion of object moving with constant acceleration. Evaluating projectile motion separately in both horizontal and vertical dimensions, examining the path of projectile (including horizontal range, maximum height, and time in flight) and the factors that may affect its path and applying equations of (horizontal and vertical components of) motion were the main instructional objectives of the concept .

The traditionally designed physics instruction was including lecturing and discussion in class and also a laboratory activity, which the students performed following the directions given by their teacher to them. Indeed, teaching strategy in class was based on the teacher exploration and the textbooks regardless of students' misconceptions. The teacher made the definitions, explained the main ideas and gave the formulas of concept verbally and by using chalkboard. Students were passive listeners and they were taking notes. Sometimes some of the students asked questions. The teacher answered the questions and directed new ones to class in order to realize whether the concept was understood by them or not. Teacher also wrote some problems which are usually quantitative ones, on the board to reinforce important concepts from lecture and gave some time to students to solve them. While the students were studying on the problem, teacher walked in between them in the room and gave clues when it was requisite. At the end of this process, either the teacher or one of the students, who has solved the problem correctly, wrote the correct solution on the board and the other students compared their solutions with the correct one. At the end of the lesson the teacher assigned homework questions (see appendix H), which were same with the questions solved in experimental group. During the lab study, teacher distributed a paper including the instructions for the experiment and students perform the experiment by following these instructions. Firstly, they set up the apparatus shown in Figure 4.2. Then they released the ball bearing from a certain height so that it accelerates down the ramp and makes a mark on carbon paper attached to the wooden board which was initially adjoining to table. After, they repeated this step for four different distances of board to the ramp. They measured the distance of mark obtained in each trial to the first mark. Thereby, they got four height values for four distances of board. At the end, they made calculations with these data in accordance with the directions of lab manual.

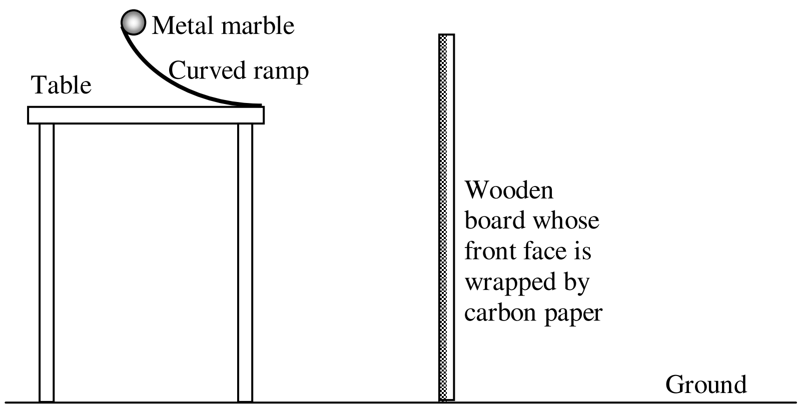


Figure 4.2 Schema of experimental set up

In the experimental group, the modeling instruction was organized into modeling cycles which involves two stages; model development (including the steps of description, formulation, ramification and validation) and model deployment. At the beginning of the instruction, students' misconceptions were activated with the provoking questions and later they were given chance to participate in the process of constructing qualitative models to explain physical phenomena and replace their misconceptions with new scientific ones through the instruction. The instruction of experimental group began with the presentation of experimental set up which includes a table, a curved ramp, a wooden board whose front face is wrapped by carbon paper, metal marbles with different masses, a meter stick and a chronometer. Then, some technical terms such as two-dimensional motion, take off velocity, range, vertical and horizontal distances, vertical and horizontal accelerations, etc. and notation that would be used by them were served to students to clarify discussions.

Students of experimental group were expected to investigate and develop models for vertical and horizontal components of projectile motion separately. In the first experiment they studied on horizontal component of motion and later they performed the second experiment for the vertical component. The set up was presented without the wooden board in the first experiment. At the beginning, teacher asked some probing questions and created a discussion in order that students could decide the quantitatively measurable parameters in the experiment that might have had cause-effect relationship. He/she listed students' all ideas such as height, length and shape of the ramp, height of the table, horizontal range of the motion, mass and size of the ball, material that the ball made from, gravity, wind, air pressure, temperature of laboratory, the person who released the ball on board, etc and teacher encouraged them to discuss which ones they could have effectively measured by using this set up (Description). Then teacher continued to ask probing questions to direct students for the identification of dependent and independent variables and parameters that should have been held constant in the experiment. In this stage, class was divided into five teams. Each team was expected to design and perform an experiment in order to obtain data (formulation). Each lab team was allowed to perform their own experimental design and collect relevant data. Then the teams carried out their own data analysis cooperatively, plotted necessary graphs, made necessary calculations (including error analysis) and constructed equations of the relationships between variables (Ramification).

Each team presented what and how they found, how they conclude these results. Teacher selected two groups and asked different members of the group to defend different parts of the experiment. The class and the teacher asked some questions during this presentation. And these questions were answered by the presenter with contribution of other members when required (Validation). Wooden board was added to apparatus for the investigation of vertical motion and all stages of model development were followed for this investigation too. At the end, teacher organized a class discussion as a post lab study. Both experiments were overviewed and evaluated together to provide a consensus about the model for the projectile motion and to achieve the expected learning. In addition some basic tenets of nature of science were discussed in this activity. Instructor played the roles of Socratic inquisitor, activity facilitator and arbiter during the whole process.

Prior to the lab study, the teacher has asked students to bring a lab notebook with them to note raw data and the procedure of their experiment. At the end of the study, students prepared the detailed lab reports of both experiments in the given format by using the notes in their notebook.

The model deployment stage was carried out in the class. Teacher handed out the problem set, which was given to control group as homework questions. Each group was assigned the first problem and one of the remaining problems. Each group developed solutions to their problems and presented these solutions to class. They also calculated the acceleration of the motion they investigated by using data obtained in the experiment. They formed necessary tables, plotted suitable graphs and made required calculations to find this acceleration.

Researchers attended the lessons of the both control and experimental groups as an observer. These observations helped her to ensure the non-biased presentation of the topic. Additionally, the researcher observed for the students' involvement in the class and their interactions with teacher and also she took notes describing the learning climate in the classes.

After four weeks of treatment period, the Projectile Motion Concept Test, Attitude Scale towards Physics and adapted version views on science-technology-society (T-VOSTS) test were administered as a post-test to all groups.

4.6 Analysis of the Data

All raw data were recorded into the computer and then analyzed statistically into two parts, including the descriptive statistics and inferential statistics, by using SPSS.

4.6.1 Descriptive Statistics

For the data obtained from the subjects in the experimental and control groups mean, standard deviation, skewness, kurtosis, range, minimum and maximum values, and charts were performed as descriptive statistics analyses.

4.6.2 Inferential Statistics

As inferential statistics, Analysis of Covariance (ANCOVA) and Analysis of Variance (ANOVA) were performed to address the research questions of the study. ANCOVA was used to compare the effectiveness of two different instructional methods on students' understanding of concepts related to projectile motion by controlling the effect of students' science process skill levels as covariate. Additionally, this analysis was used to determine the effect of students' gender on their understanding of concepts and to reveal contribution of students' science process skills to the variation in their understanding of projectile motion concepts. ANOVA was used to test the effect of treatment and gender difference on students' attitudes toward physics as a school subject.

Prior to the treatment, an independent t-test was used to determine whether there existed a statistically significant mean difference between the control and experimental groups with respect to their science process skills and prior knowledge in projectile motion concept. The results were used in the determination of covariates.

4.6.3 Power analysis

The power for this study having the total sample size of 88 students was calculated by using Cohen's power table for a medium effect size (eta square=.094) as .80.

4.7 Assumptions of the Study

1. There was no interaction between groups.
2. The teachers followed the researcher's instructions and were not biased during the treatment.
3. The PMCT, ASTP, T-VOSTS, and the SPST were administered under standard conditions.
4. The classroom observations were performed under standard conditions.
5. Interviews with the students were conducted under standard conditions.
6. The subjects answered the questions of the tests and the questions of the interview sincerely.

4.8 Limitations of the Study

1. This study was limited to the concept of projectile motion.
2. The subjects of this study were limited to 88 tenth grade students at a private high school in Ankara.
3. The nature of the T-VOSTS test was not appropriate for inferential statistics since it evolved from the qualitative research paradigm.
4. Completion time of the instruments SPST and T-VOSTS, each of which took about forty-five minutes, may have caused boredom and tiredness for some participants.

CHAPTER 5

RESULTS AND CONCLUSIONS

This chapter is devoted to the presentation of the results from testing of the hypotheses stated in Chapter III and results of the student interviews, classroom observations and analysis of T-VOSTS test. These results are presented into six sections. The first section includes the descriptive statistics associated with the data collected from the administration of Projectile Motion Pre- and Post-Concept Tests, Pre-and Post- Attitude Scales towards Physics and Science Process Skill Test. The second section of this chapter presents the inferential statistical data yielded from testing the null hypotheses outlined in Chapter 3. The hypotheses were tested at the significance level of 0.05. ANOVA and ANCOVA were used to test the hypotheses. Statistical analyses were carried out by SPSS (Statistical Package for Social Sciences) (Green, Salkind and Akey, 1997). The third section includes the descriptive analysis of adapted version of Views on Science-Technology-Society test (T-VOSTS). In this part the results of each item was elaborated in detail. The fourth section presents the results of classroom observations and the fifth section explains the results of students' interviews. Finally, the last section summarizes the findings of the study.

In addition to results, conclusions stated regarding the findings of the research were also presented in this chapter.

5.1 Descriptive Statistics

Descriptive statistics related to scores which were measured by the Projectile Motion Pre- and Post-Concept Tests, Pre-and Post- Attitude Scales towards

Physics and Science Process Skill Test in the control and experimental groups were presented in Table 5.1.

Students' scores on Projectile Motion Concepts Test could range from 0 to 20 in which higher scores mean greater achievement and more understanding of projectile motion concepts. Students' attitude scores could range from 15 to 75 in which higher scores mean greater attitude toward physics. And students' Science Process Skills Test scores range from 0 to 36. The greater scores in this test indicate higher abilities in solving science problems.

Table 5.1 Descriptive statistics related to the Projectile Motion Concept Test (PMCT), Attitude Scale towards Physics (ASTP) and Science Process Skill Test (SPST) scores according to experimental (EG) and control (CG) groups instructed by different teaching methods

Group	Test	N	Min	Max	Mean	SD	Skewness	Kurtosis
	Pre-PMCT	44	2	15	7.41	2.679	.467	1.040
	Post-PMCT	44	7	19	12.55	2.921	.215	-.644
EG	Pre-ASTP	44	37	73	53.00	8.645	-.240	.087
	Post-ASTP	44	38	73	57.34	8.480	-.402	-.022
	SPST	44	22	36	29.61	3.308	-.164	-.733
	Pre-PMCT	44	3	15	7.43	2.714	1.105	1.330
	Post-PMCT	44	4	16	11.05	3.050	-.143	-.882
CG	Pre-ASTP	44	25	75	52.39	10.191	-.417	-.138
	Post-ASTP	40	28	71	52.16	10.956	-.283	-.378
	SPST	40	14	36	29.45	3.855	-1.441	4.920

As it is seen in Table 5.1, the mean scores of students in EG ($\overline{X}_{EG}$= 7.41) and CG ($\overline{X}_{CG}$= 7.43) are almost the same in pre-PMCT. Mean achievement score of the EG students ($\overline{X}_{EG}$= 12.55) on the posttest was greater than that of the CG students ($\overline{X}_{CG}$= 11.05). Regarding the higher mean score increase in experimental group than the mean score increase in the control group, we can conclude that the students in the experimental group acquired more understanding in projectile motion and they were more successful in overcoming their misconceptions than students in the control group.

Table 5.1 also indicated the pre and post-test attitude scores of students who participated in the study in experimental and control groups. The mean of pre-ASTP is 53.00 and the mean of post-ASTP is 57.34 in the experimental group. The mean score increase of 1.34 indicates that the modelling instruction has a positive effect on students' attitudes towards physics. The mean of pre-ASTP is 52.39 and the mean of post-ASTP is 52.16 in the control group. Since two scores are almost the same, we can conclude that traditional instruction has no effect on students' attitudes towards physics.

As shown in Table 5.1, the mean of SPST is 29.61 in the experimental group and 29.45 in the control group. They are almost equal.

Some other basic descriptive statistics presented in Table 5.1 are minimum, maximum, standard deviation, skewness and kurtosis values of tests. The skewness of the pre-PMCT and post-PMCT are 0.467 and 0.215 respectively in the experimental group, while the skewness of the pre-PMCT and post-PMCT are 1.105 and -0.143 in the control group. The skewness values of the pre-and post-ASTP were 0.240 and 0.402 in the experimental group, respectively. The skewness values of the pre-and post-ASTP were –0.417 and -0.283 in the control group. The values near to 0 indicate the normal distribution of the variables; therefore these values were accepted as almost normally distributed.

When the kurtosis values taken into account, values for the EG and CG students' achievement scores were -0.644, 1.040 and -0.882, 1.330 on the posttest and pretest, respectively. Kurtosis values on the post-tests were -0.022 and 0.378 for the EG and CG students' attitude scores. Kurtosis value for pre-ASTP was 0.87 in the experimental group and -0.138 in the control group. Again these values could be accepted as normally distributed.

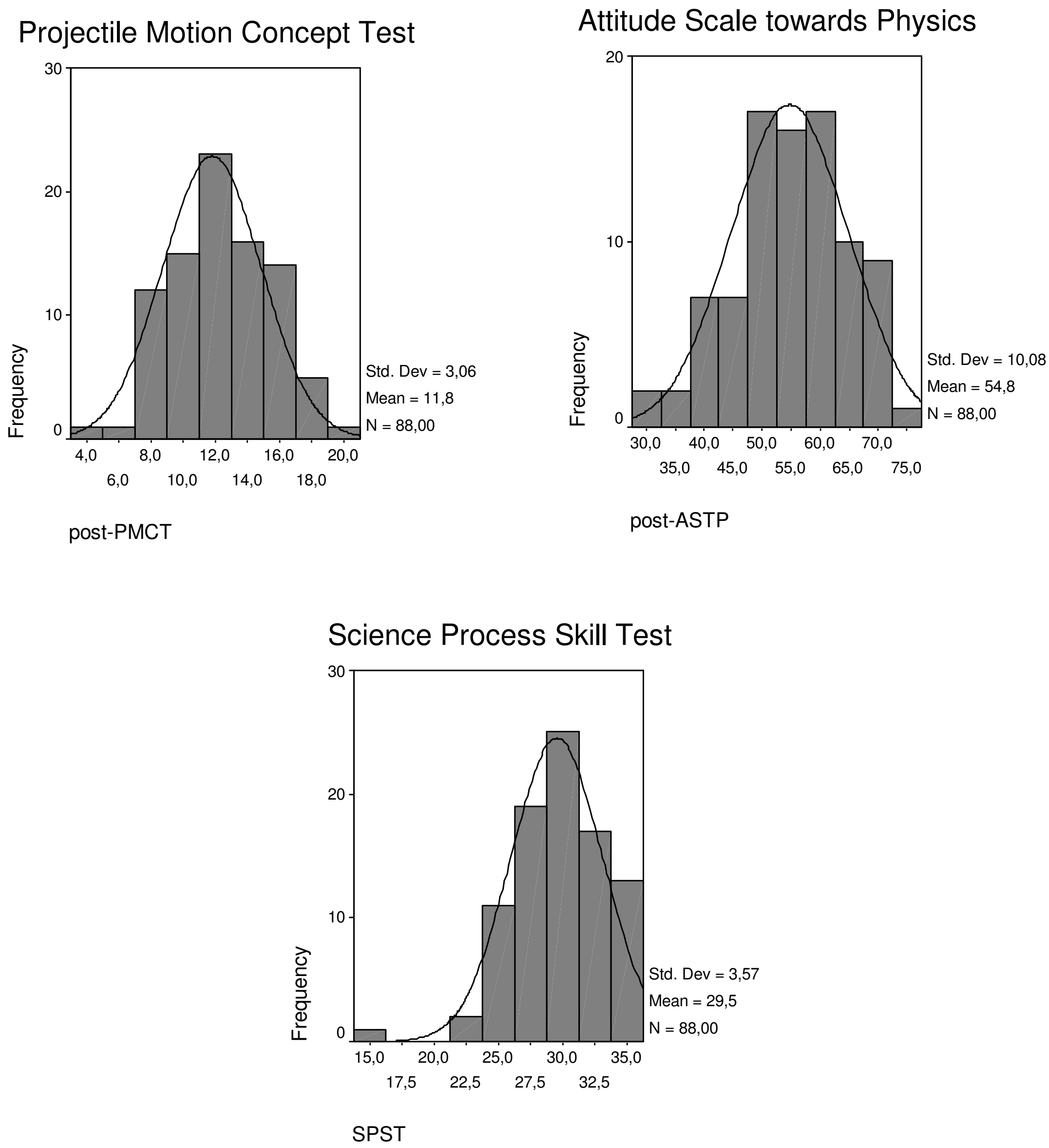


Figure 5.1 The histograms with normal curves related to the post-PMCT, post-ASTP and SPST scores of students.

The histograms (Figure 5.1) with normal curves related to the PMCT, ASTP and SPST scores of students are also an evidence for approximately normal distribution of these three variables.

5.2 Inferential Statistics

This section contains the sub-sections which deal with missing data and analyses of seven null hypotheses stated in chapter III. The hypotheses were tested at a significance level of .05. Statistical analyses were carried out by using the SPSS/PC (Statistical Package for Social Sciences for Personal Computers).

ANCOVA was used to compare the effectiveness of two different instructional methods on students' understanding of concepts related to projectile motion by controlling the effect of students' science process skill levels as a covariate. Additionally, this analysis was used to determine the effect of students' gender on their understanding of concepts and to test the contribution of students' science process skills to the variation in their understanding of projectile motion concepts. The hypotheses were tested at a significance level of .05.

ANOVA was used to compare the effectiveness of two different instructional methods on students' attitudes toward physics as a school subject. It was also used to test the effect of gender difference on students' attitudes and the effect of interaction between treatment and students' gender.

The results of independent t-test analysis revealed that there was no significant difference at the beginning of the treatment between the experimental and control groups in terms of students' understanding of projectile motion concepts ($t=.04$, $p>.05$) and their attitudes towards physics as a school subject ($t=.61$, $p>.05$). Similarly, no significant difference between two groups was found in terms of students' science process skill levels ($t=.208$, $p>.05$).

5.2.1 Missing Data Analysis

Before starting the inferential data, missing data analysis was performed. Although the total of the students included in the treatment was 103, the final sample included in the data analysis consisted of 88 students. Five students (4.85%) were excluded from the study because they were not present on the date of the post-PMCT. Four (4.5%) of the 88 students who performed post-PMCT didn't complete both the ASTP and SPST. Missing data in these scores constituted a range smaller than 5% of the whole data, therefore the series mean of the entire subjects (SMEAN) was used to replace the missing data (Cohen, Eylon and Ganiel, 1983).

Table 5.2 Missing data

Variable	Missing Data	Valid Data	Percentage of Missing Data
ASTP	4	84	4.5
SPST	4	84	4.5

5.2.2 Null Hypothesis 1.1

The first hypothesis stated that there was no significant mean difference between the post concept test scores of students taught with Modeling Instruction versus traditionally designed physics instruction on concepts related to projectile motion when the effects of students' Science Process Skill Test scores are controlled as a covariate.

Table 5.3 Summary of ANCOVA

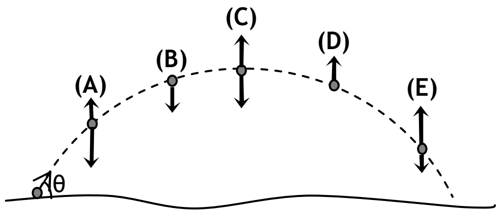
Source	SS	MS	df	F	p
Science Process Skill (Covariate)	140.568	140.568	1	20.328	.000
Treatment	49.379	49.379	1	7.141	.009
Gender	15.802	15.802	1	2.285	.134
Treatment*Gender	7.806	7.806	1	1.129	.291
Error	573.936	6.915	83		

(Dependent Variable: Post-projectile motion concept test scores)

The results of ANCOVA provided an evidence to conclude that there was a significant mean difference between students taught with modeling instruction and those instructed with traditionally designed instruction with respect to their understanding of projectile motion concepts, $F(1,83)=7.14$, $p<.05$. The students exposed to modeling instruction had higher mean score ($\overline{x}=12.55$) on the post projectile motion concept test than those taught with traditional instruction ($\overline{x}=11.05$).

The average percentage of correct responses of experimental group students was 62.7 and that of the control group students was 53.2 after treatment. When the students' misconceptions were analyzed, it was realized that there were noticeable differences between two groups in the favor of experimental group on several items. For instance, students were asked to determine the forces acting on a projectile in 17^{th} item. Before the instruction, almost 82% of all students believed that there are two forces acting on the object. As interviews with students evidenced, they thought that an impetus given to projectile by the person who threw it continues to exert on it belong its motion. Because they believed that an object requires a force to move. Even after instructions, 58% of them were still thinking in this way. In pre-test, many of the students (75% of experimental group and 55% of control group students) selected the distracter that reflects the misconception that resultant force acting on projectile at highest point is zero. The post test scores revealed that 70% of students having this misconception in experimental group refined their misconceptions, while just 21% of them in control group could have refined it after treatment.

Table 5.4 Percentages of selected alternatives of 17th item



A ball is thrown as seen in figure. In which alternative are the forces applied on ball shown correctly?

	Percentages of students' responses	
	EG	CG
Alternative A	18.2	27.3
Alternative B	*59.1*	*22.7*
Alternative C	22.7	43.2
Alternative D	0.0	2.3
Alternative E	0.0	4.5

Similarly, question 19 tested the students' idea about the acceleration of a projectile. More than half of the students thought that the acceleration of a projectile is irregular even when the air resistance is ignored. In the experimental group 77% of students answered this question correctly in post concept test, while in the control group 57 % chose the correct answer. Modeling instruction was better than traditional instruction on remedying misconceptions related to the force exerted on a projectile.

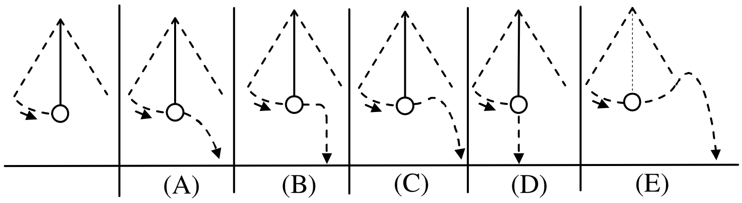
Item 8 and item 12 were about the path of projectile motion. More than half of the students in both groups gave correct answers to the questions. The common misconception in both groups was that a fired object is not affected by gravity initially, after awhile gravity begins to exert a strong impetus. There exists a noticeable difference between post test scores of two groups in those items. Whilst the percentage of correct answers increased to 82 in control group, it rose to 96 in experimental group for the 8^{th} item. A similar result was observed for the 12^{th} item; the experimental group students reached a higher achievement (91%) than control group students (82%), even though the percentage of control group students (73%) was higher than experimental group students (52%) in pretest.

In item 5, students were wanted to compare the time of flight of three punts which were reaching the same height but covering different horizontal ranges. 59% of the students in experimental group and 48% of students in control group had a misconception that the time of flight depends on the length or horizontal range of trajectory. In item 6, they were asked to compare the time of flight of three projectiles having different ranges and heights but almost the same length of paths. 24% of all students thought that the projectile having shorter range should hit the ground earlier. 30% of them thought that the projectile having shorter path should hit the ground earlier. When the post test scores of 5^{th} question were examined, it was indicated that this misconception was remedied 85% in experimental group and 70% in control group after treatment. When the post test scores of 6^{th} question were examined, it is observed that almost all students having the misconception that time in flight depends on range of projectile chose the correct answer. But both instructional methods failed to remedy other misconception. Moreover, the percentage of experimental group students who thought that time in flight depends on the path of trajectory surprisingly increased after instruction.

One of the students' major misconceptions on projectile motion was related to path of objects fired from a moving carrier. In the first item they asked to determine where a ball fired straight up from a carrier moving with constant speed would fall. In thirteenth item they were asked to determine the path of a metal ball dropped from a plane flying with constant speed at a constant altitude. Pre-test results showed that more than half of the students thought that the initial velocity of an object released or thrown from a moving carrier is not affected by the carrier and tends to move in the direction of throwing or drop straight down if it was released. While just 11% of students in experimental group could have answered the first question correctly, the percentage of correct answers was 36% in control group in pre-tests. This percentage rose up to 66% in experimental group and to 52% in control group. Similarly, the percentage of correct answers to item 13 in experimental group (32%) was lower than those in control group (46%). However, experimental group students (84%) had a higher achievement than the control group students (77%) in the same question of post test.

In 15th item, students were asked to compare the velocities of two objects one of which was released and the other was horizontally fired from the carrier shown in item 13. The common misconception in both groups was that the objects thrown from the same height hit the ground with the same velocity independent of their throwing velocity. In the post test, while the percentage of correct answers was 66 in control group, it was 82 in experimental group.

Table 5.5 Percentages of selected alternatives of 16th item



The diagram represents a side view of a metal ball swinging back and forth at the end of a string. When the ball is in the position shown in first figure and moving from left to right, the string is cut. Which of the above figures does show the correct path the ball will follow as it falls to the ground?

	Percentages of students' responses	
	EG	CG
Alternative A	*22.7*	*22.7*
Alternative B	0.0	0.0
Alternative C	56.8	54.5
Alternative D	20.5	0.0
Alternative E	0.0	22.7

Although modeling instruction resulted in a significantly better acquisition of scientific conceptions and elimination of misconceptions than traditional instruction, the students in both groups have continued to hold some misconceptions related to the projectile motion even after treatments. For example, item 16 (Table 5.5) was related to the motion of a ball swinging back and forth at the end of string. When it was its lowest point, string was cut and students were asked to determine how ball moves. In the post-test, just 23% of all students answered this question correctly. 56% of all students thought that even the string is cut; the ball continues to rise for a while (alternative C). Interviews with students revealed that the reason in their opinion was inertia. Moreover, some of control group students (23%) believed that the ball continues to rise until it reaches its original height. And this time they hold the law of conservation of energy responsible for this rise. There was no student in experimental group selected this alternative. But 20.5% of them selected the distracter that indicates the misconception that the velocity of carrier has no influence on the initial velocity of an object released from it and tends to drop straight down.

One of the other misconceptions which both instructions failed to remedy was that an object released falls faster than an object thrown horizontally. Most of the students believed that both objects can not have the same accelerations. In 9^{th} question, they were asked the compare the motion of two objects who started to move at the same time. One of those was thrown horizontally and other was just released. Even after treatment only 24% of all students thought that both objects would have equal accelerations.

Question 11 is about a two dimensional motion. A constant force is exerted in one dimension and no force is exerted in other dimension. Students were expected to combine these together and determine the path of the object. 30% of students thought that object follows a linear path regarding the force effect in one dimension. 40% of them could notice that the path should be a curve. But they chose the curve which was not correct. Only 26% could have answered the question correctly. When we look at the post-test results, we see that the percentage of correct responses does not differ significantly (28%). Students still have difficulty to bring two motions together.

5.2.3 Null Hypothesis 1.2

The second null hypothesis stated that there is no significant mean difference between the post concept test scores of females and males when the effects of students' Science Process Skill Test scores were controlled as a covariate.

When the summary of ANCOVA results presented in Table 5.3 is examined, it is realized that there is no significant difference between the performance of males that of the females, $F(1,83)=2.29$, $p>.05$. Tough the mean score of males ($\bar{X}_M =$

12.62) is higher than that of females ($\overline{X}_F$ = 11.20), this difference is not found statistically significant.

5.2.4 Null Hypothesis 1.3

The third hypothesis, stating that there is no significant effect of interaction between treatment and gender on students' understanding of concepts related to projectile motion when the effects of students' Science Process Skill Test scores are controlled as a covariate, was analyzed by running ANCOVA also.

The hypothesis was accepted accompanied by the results exhibited in Table 5.5, that is, no significant interaction between treatment and gender difference on students' understanding of projectile motion concepts was found, $F(1,83)=1.13$, $p>.05$.

5.2.5 Null Hypothesis 1.4

The fourth null hypothesis states that there is no significant contribution of students' science process skills on their understanding of concepts related to projectile motion.

ANCOVA results (Table 5.3) indicates that there is a statistically significant contribution of students' science process skills to their understanding of projectile motion, $F(1,83)=20.33$, $p<.05$.

5.2.6 Null Hypothesis 2.1

In the seventh null hypothesis, it was stated that there is no significant mean difference between the attitudes scores of students taught with Modeling Instruction versus traditionally designed physics instruction. Analysis of Variance

(ANOVA) was used to determine the difference between the post-scale mean scores of students taught by modeling instruction and those taught by traditional instruction with respect to their attitudes towards physics as a school subject.

Table 5.6 Summary of ANOVA

Source	SS	MS	df	F	p
Treatment	714,397	714,397	1	7,549	,007
Gender	38,974	38,974	1	,412	,523
Treatment*Gender	266,668	266,668	1	2,818	,097
Error	7949,627	94,638	84		

(Dependent Variable: Post-attitude scale scores)

ANOVA results evidenced that there is a significant mean difference between students taught with modeling instruction and those instructed with traditionally designed method with respect to their attitudes towards physics, $F(1,84)=7.55$, $p<.05$. Moreover, this difference is in the favor of experimental group, $\overline{X}_{EG} = 57.34$ and $\overline{X}_{CG} = 52.16$.

5.2.7 Null Hypothesis 2.2

In order to test eighth hypothesis, stating that there is no significant mean difference between the attitude scores of females and males, ANOVA was used.

The results revealed that there was no significant mean difference between male and female students with respect to their attitudes towards physics, $F(1,84)=0.41$, $p>.05$ ($\overline{X}_{F} = 54.71$ and $\overline{X}_{M} = 53.89$).

5.2.8 Null Hypothesis 2.3

Ninth hypothesis stated that there was no significant effect of interaction between treatment and gender on students' attitudes towards physics. The results clinched this hypothesis, that is, they presented that there was no significant interaction effect between gender difference and treatment on attitudes towards physics as a school subject, $F(1,84)=2.82$, $p>.05$.

5.3 Analysis of T-VOSTS Test

Item 1 (Defining Science)

The first item was asked to investigate how students define science. When we look over the literature, the most common answer to the question of what the science is 'the body of knowledge, and method and way of knowing' (Lederman 2007, p. 833).

When the responses of students were examined, it was seen that both experimental and control group students have similar views on the definition of science. These responses to this item were varied among three alternatives (B, C and F) mainly (Table 5.10). 25% of all students, who selected alternative B, perceive science just as a body of knowledge. The students selecting alternative E and F, which were constituted 29.5% of the whole sample, confused the science and technology with each other. This is the fourteenth myths of science described by McComas (1998). These participants viewed science as an instrument of social purpose, that is, they had an instrumentalist perspective.

As an interesting result, there was no student selecting alternatives A and D. Alternative A was presenting science as a body of knowledge in a restricted sense. The students holding this view must have preferred to sign alternative B.

Alternative D was taking a social look at the science. In this regard, it was parallel to the alternatives E and F which were favored by students.

The most realistic view about science, alternative C, was selected 38.6% of experimental group students and 31.9% of control group students. More than half of the students have rational but not realistic ideas about the definition of science.

Table 5.7 Percentage of students' responses to item 1.

Defining science is difficult because science is complex and does many things. But MAINLY science is:			
EG%	**CG%**		**Alternative**
0.0	0.0	*A*	*a study of fields such as biology, chemistry and physics.*
25.0	25.0	*B*	*body of knowledge, such as principles, laws and theories, which explain the world around us (matter, energy and life).*
38.6	31.9	C	exploring the unknown and discovering new things about our world and universe and how they work.
0.0	0.0	*D*	*carrying out experiments to solve problems of interest about the world around us.*
4.5	4.5	E	inventing or designing things (for example, artificial hearts, computer, space vehicles).
25.0	25.0	*F*	*finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution and improving agriculture).*
4.5	2.3	*G*	*an organization of people (called scientists) who have ideas and techniques for discovering new knowledge.*
0	2.3	H	No one can define science.

Experimental group students:

<u>Realistic: 38.6</u> *Has Merit: 54.5* Naive: 4.5

Control group students:

<u>Realistic: 31.9</u> *Has Merit: 52.3* Naive: 6.8

Item 2 (Influence of Society on Science/Technology)

Item 2 investigated the participants' opinions about the influences of religious and ethical views of the culture on the scientific researches. Science is part of social and cultural traditions and it is inevitable for science to be affected by their social and historical milieu (McComas, Clough, and Almazroa, 1998). Lederman (2007) offers a frame of reference for the aspects of nature of science that the students should know. One of these aspects is that scientific knowledge is subjective, that is, it is influenced by scientists' beliefs, experiences, prior knowledge, expectations, etc.

In this second item of the test, alternatives A, B, C, D and E introduced the collectivist and sociological nature of scientific researches. As evidenced by Table 5.11, 65.9% of experimental group students and 47.7% of control group students held this view. The percentage of students who had a realistic explanation for this view was more in experimental group (31.8%) than in control group (15.9%).

On the other hand, 29.5% of experimental group students and half of the control group students believed that science researches continue regardless cultural and ethical views. This naïve believe was frequent especially among control group students.

Table 5.8 Percentage of students' responses to item 2.

Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done.			
EG%	**CG%**		**Alternative**
			Religious or ethical views DO influence scientific research:
0	0	*A*	*because some cultures want specific research done for the benefit of that culture.*
13.6	6.8	B	because scientists may unconsciously choose research that would support their culture's views.
0	2.3	*C*	*because most scientists will not do research which goes against their upbringing or their beliefs.*
18.2	9.1	D	because everyone is different in the way they react to their culture. It is these individual differences in scientists that influence the type of research done.
34.1	29.5	*E*	*because powerful groups representing certain religious, political or cultural beliefs will support certain research projects, or will give money to prevent certain research from occurring.*
			Religious or ethical views do NOT influence scientific research:
25.0	25.0	F	because research continues in spite of clashes between scientists and certain religious or cultural groups (for example, clashes over evolution and creation).
4.5	25.0	G	because scientists will research topics which are of importance to science and scientists, regardless of cultural or ethical views.

Experimental group students:

Realistic: 31.8 *Has Merit: 34.1* Naive: 29.5

Control group students:

Realistic: 15.9 *Has Merit: 31.8* Naive: 50.0

Item 3 (Influence of Society on Science/Technology)

In item 3, the students were asked to compare the effects of upbringing received from family, school and community to effects of intelligence, ability and a natural interest on the amount of producing scientist. The answer of question why some communities produce more scientists than other communities is hidden in the close relation of science with the social and cultural traditions.

The first five alternatives of the item defend the major role of the social and cultural traditions on producing scientist. 73.8% of experimental group and 79.5% of control group students (who selected these alternatives) made upbringing accountable for producing more scientists. According to 22.7% of experimental group and 15.9% of control group students however, intelligence, ability and a natural interest were mostly responsible. But almost 75% of those students believed that upbringing had an effect too.

In both groups, 45.5% of students, who selected alternatives D and F held collectivist and sociological perspectives about the science which were coherent with the contemporary views. Alternatives B, C, E and G reflected the positivist point of view which was common among the both groups' students (40.9% of experimental group and 45.4 % of control group). Only a few students (4.5%) in both groups had naïve views on the influence of society on science.

Table 5.9 Percentage of students' responses to item 3.

Some communities produce more scientists than other communities. This happens as a result of the upbringing which children receive from their family, schools and community.			
EG%	**CG%**		**Alternative**
			Upbringing is mostly responsible:
9.1	4.5	*A*	*because some communities (for example, industrial towns such as Sudbury) place greater emphasis on science than other communities.*
11.4	22.7	*B*	*because some families encourage children to question and wonder. Families teach values that stick with you for the rest of your life.*
2.3	2.3	C	because some teachers or schools offer better science courses or encourage students to learn more than other teachers or schools.
27.3	34.1	D	because the family, schools and community all give children with an ability in science the encouragement and opportunity to become scientists.
22.7	15.9	*E*	*It's difficult to tell. Upbringing has a definite effect, but so does the individual (for example, intelligence, ability and a natural interest in science). It's about half and half.*
			Intelligence, ability and a natural interest in science are mostly responsible:
18.2	11.4	F	in determining who becomes a scientist. However, upbringing has an effect.
4.5	4.5	G	because people are born with these traits.

Experimental group students:

Realistic: 45.5 *Has Merit: 43.2* Naive: 6.8

Control group students:

Realistic: 45.5 *Has Merit: 43.1* Naive: 6.8

Item 4 (Influence of Science/Technology on Society)

Item 4 was about the social responsibility of scientists. Only a few students thought that scientists are mostly concerned with the harmful effects of their discoveries and works to prevent them from occurring. Most of the students (almost three-fourth of them) in both groups believed that scientists are concerned with both the helpful and harmful effects of their discoveries. However, 34.1% of experimental group and 36.4% of control group students realized that they can not easily know and control the long-term effects of their discoveries.

Table 5.10 Percentage of students' responses to item 4.

Most Turkish scientists are concerned with the potential effects (both helpful and harmful) that might result from their discoveries.			
EG%	**CG%**		**Alternative**
0	0	A	Scientists only look for beneficial effects when they discover things or when they apply their discoveries.
6.8	4.5	B	Scientists are most concerned with the possible harmful effects of their discoveries. Therefore, scientists test their discoveries in order to prevent harmful effects from occurring.
45.5	45.5	*C*	*Scientists are concerned with all the effects of their experiments.*
13.6	20.5	<u>D</u>	<u>Scientists are concerned but they can't possibly know all the long-term effects of their discoveries.</u>
20.5	15.9	<u>E</u>	<u>Scientists are concerned but they have little control over how their discoveries are used for harm.</u>
11.4	2.3	F	It depends upon the field of science. For instance, in medicine Canadian scientists are highly concerned. However, in nuclear power or in military research, Canadian scientists are least concerned.
0	9.1	*G*	*Scientists may be concerned, but that doesn't stop them from making discoveries for their own fame, fortune, or pure joy of discovery.*

Experimental group students:

<u>Realistic: 34.1</u> *Has Merit: 45.5* Naive: 18.2

Control group students:

<u>Realistic: 36.4</u> *Has Merit: 54.6* Naive: 6.8

Item 5 (Influence of Science/Technology on Society)

This item investigates the views of students about who should be the decision makers for the future of biotechnology. According to alternatives A, B and C, the primary decision makers should be scientists and engineers. According to alternatives F and G society should decide. Alternative E defends that government should have the responsibility in such a political issue. According to alternative C, all of these people should decide together.

The percentages of students selected each of these were similar in both groups. While 62.5% of all students believed that scientists and engineers should decide, 12.5% of all students thought that public should make such decisions. Surprisingly there was no student who thought that government should be the only decision maker. 20.5% of experimental group students and 27.3% of control group students selected alternative D that reflected the most realistic view. They regarded the collectivist and sociological aspects of science and believed that scientists-engineers, other specialists, and the informed public should decide together.

Table 5.11 Percentage of students' responses to item 5.

Scientists and engineers should be the ones to decide on future biotechnology in Turkey (for example, recombinant DNA, gene splicing, developing ore-digging bacteria or snow-making bacteria, etc.) because scientists and engineers are the people who know the facts best.			
EG%	**CG%**		**Alternative**
			Scientists and engineers should decide:
27.3	31.8	*A*	*because they have the training and facts which give them a better understanding of the issue.*
13.6	6.8	B	because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests.
27.3	18.2	*C*	*because they have the training and facts which give them a better understanding; BUT the public should be involved — either informed or consulted.*
20.5	27.3	<u>D</u>	<u>The decision should be made equally; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society.</u>
0	0	E	The government should decide because the issue is basically a political one; BUT scientists and engineers should give advice.
0	6.8	F	The public should decide because the decision affects everyone; BUT scientists and engineers should give advice.
11.4	6.8	G	The public should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences.

Experimental group students:

<u>Realistic: 20.5</u> *Has Merit: 54.6* Naive: 25.0

Control group students:

<u>Realistic: 27.3</u> *Has Merit: 50.0* Naive: 20.4

Item 6 (Influence of Science/Technology on Society)

Item 6 was asked students to reveal what they think about the scientists' abilities to solve everyday type of problems. More specifically item investigated whether students believed that scientists' problem solving skills, specialized knowledge and creativity make them better than others or they found scientists no better than others.

The students who selected alternative A (almost half of the both groups) believed that scientists are better at this because of their logical problem-solving minds or specialized knowledge. This was the most realistic view in the alternatives. And the percentages of students holding this realistic view in experimental and control groups were similar. Almost 40% of both groups' students, however, perceived scientists no better than other people. The explanations of almost 70% of those students had merit and the rest were naive.

More over, the students who selected alternative E (6.8% of experimental group and 9.1% of control group) thought that scientists are probably worse at solving any practical problem because of their complex abstract working area far removed from everyday life. About 32% of experimental group students and 30% of control group students were between two viewpoints. They saw scientists just like everyone at solving practical everyday problems.

The item gave a general idea of that there was no a significant difference between the views of students in experimental group and views of those in control group on scientists' abilities to solve everyday type of problems.

Table 5.12 Percentage of students' responses to item 6.

Scientists can solve any practical everyday problem best (for example, getting a car out of a ditch, cooking, or caring for a pet) because scientists know more science.			
EG%	**CG%**		**Alternative**
52.3	56.8	<u>A</u>	<u>Scientists are better at solving any practical problem. Their logical problem-solving minds or specialized knowledge give them an advantage.</u>
			Scientists are no better than others:
2.3	4.5	B	because science classes help everybody learn enough problem-solving skills and knowledge to solve practical problems.
9.1	4.5	*C*	*because a scientist's education doesn't necessarily help with practical things.*
20.5	20.5	*D*	*because in everyday life scientists are like everyone else. Experience and common sense will solve everyday practical problems.*
6.8	9.1	E	Scientists are probably worse at solving any practical problem because they work in a complex abstract world far removed from everyday life.

Experimental group students:

<u>Realistic: 52.3</u> *Has Merit: 29.6* Naive: 9.1

Control group students:

<u>Realistic: 56.8</u> *Has Merit: 25.0* Naive: 13.6

Item 7 (Characteristics of Scientists)

The seventh item was asked in order to detect according to students what kinds of standards or values a scientist should have in order to do best science. Some basic characteristics such as open-mindedness, logicality, honesty, objectivity, imagination, intelligence; as well as the opposite values: closed-mindedness and subjectivity were presented in the item.

81.8% of experimental group and 70.5% of control group students thought that scientists should display these characteristics, but these are not enough for being a good scientist. The best scientists also need other personal traits. Even, the more of such characteristics they have, the better they would do at science.

Most of the students, who were cited above, had a realistic view to the necessity of some personal beliefs to become a good scientist. However, the ninth one in the McComas' (1998) myths of science list which include the probable misconceptions of students is that scientists are particularly objective. This point should not leave out of account. For instance, 11.4% of participants who were included in the control group believed that scientists had to be very open-minded, logical, unbiased and objective in their work, otherwise science would suffer.

Almost 17% of whole participants thought that the best scientists do NOT necessarily display these personal characteristics; they may be even closed-minded, biased, subjective and not always logical in their work. Science are influenced by their social and historical milieu (McComas, Clough and Almazroa, 1998) and scientific knowledge is influenced by both various elements of the culture in which it is embedded and various properties of scientists such as beliefs, experiences, prior knowledge, expectations, etc. (Lederman, 2007).

Table 5.13 Percentage of students' responses to item 7.

The best scientists are always very open-minded, logical, unbiased and objective in their work. These personal characteristics are needed for doing the best science.			
EG%	**CG%**		**Alternative**
0	11.4	A	The best scientists display these characteristics otherwise science will suffer.
27.3	20.5	B	The best scientists display these characteristics because the more of these characteristics you have, the better you'll do at science.
54.5	50.0	C	These characteristics are not enough. The best scientists also need other personal traits such as imagination, intelligence and honesty.
			The best scientists do NOT necessarily display these personal characteristics:
6.8	2.3	*D*	*because the best scientists sometimes become so deeply involved, interested or trained in their field, that they can be closed-minded, biased, subjective and not always logical in their work.*
9.1	11.4	*E*	*because it depends on the individual scientist. Some are always open-minded, objective, etc. in their work; while others can be come closed-minded, subjective, etc. in their work.*
0	4.5	F	The best scientists do NOT display these personal characteristics any more than the average scientist. These characteristics are NOT necessary for doing good science.

Experimental group students:

Realistic: 81.8 *Has Merit: 15.9* Naive: 0

Control group students:

Realistic: 70.5 *Has Merit: 13.7* Naive: 15.9

Item 8 (Characteristics of Scientists)

Item 8 is concerning the family/social life of scientists. It involves mainly three points of view; scientists are away from family/social life (cited in alternative A), they have normal family/social life (cited in alternatives D and E) and it depends on the person (cited in alternatives B and C).

The percentage of students that held the first naïve belief was 18.2 in experimental group and 14.5 in control group. The percentage of students that had the second rational but not realistic point of view was 20.4 in experimental group and 34.1 in control group. 59.1% of experimental group and 45.4% of control group students had third realistic view.

Table 5.14 Percentage of students' responses to item 8.

Scientists have practically no family life or social life because they need to be so deeply involved in their work.			
EG%	**CG%**		**Alternative**
18.2	14.5	A	Scientists need to be very deeply involved in their work in order to succeed. This deep involvement takes away from one's family and social life.
25.0	15.9	<u>B</u>	<u>It depends on the person. Some scientists are so involved in their work that their families and social lives suffer. But many scientists take time for family and social things.</u>
34.1	29.5	<u>C</u>	<u>At work scientists look at things differently than other people, but this doesn't mean they have practically no family or social lives.</u>
			Scientists' family and social lives are normal:
6.8	27.3	*D*	*otherwise their work would suffer. A social life is valuable to a scientist.*
13.6	6.8	*E*	*because very few scientists get so wrapped up in their work that they ignore everything else.*

Experimental group students:

Realistic: 59.1 *Has Merit: 20.4* Naive: 18.2

Control group students:

Realistic: 45.4 *Has Merit: 34.1* Naive: 14.5

Item 9 (Characteristics of Scientists)

Students' opinion about the gender effect on the process and product of science were asked in ninth item. Particularly, they were asked whether the increasing number of women scientists made a difference to the scientific discoveries or not.

The percentage of experimental group students who believed that scientific discoveries made by women will tend to be different than those made by men was 38.6. More than half of the control group students held this naïve view. The most popular explanation among students (31.8% of experimental group and 25.6% of control group) for why gender affects the scientific discoveries was the difference between the needs of men and women. Students though that scientists discover regarding their needs.

61.4% of experimental group and 48.9% of control group students thought that female and male were not different in the discoveries they made. The results, which were summarized in Table 5.18, revealed an interesting situation related to those students. Although the most common view (alternative G) between the experimental group students was that any differences in discoveries were due to differences between individuals, not their genders; there was no student preferred this alternative in the control group.

Surprisingly, the percentage of students that held a realistic view about the gender effect on scientific discovery was lower in experimental group (25.0%) than in control group (48.9%). However, when whole logical views are investigated, the higher percentage of experimental group students is noticed.

Table 5.15 Percentage of students' responses to item 9.

There are many more women scientists today than there used to be. This will make a difference to the scientific discoveries which are made.			
EG%	**CG%**		**Alternative**
			Scientific discoveries made by women will tend to be different than those made by men.
2.3	7.0	A	because women and men have different interests.
4.5	11.6	B	because female and male scientists experience the same training.
31.8	25.6	C	Because women and men discover regarding their needs (cellulite cream, razor, etc).
0	7.0	D	Men would make better discoveries because men are better at engineering and mechanics than women.
			There is NO difference between female and male scientists in the discoveries they make:
15.9	25.6	<u>E</u>	<u>because women and men scientists are educated in the same way. However the fact that women were not given adequate opportunity from past to present have obstructed emergence of women's abilities in this area.</u>
9.1	23.3	<u>F</u>	<u>Overall women and men are equally intelligent Women and men are the same in terms of what they want to discover in science.</u>
36.4	0	*G*	*Any differences in their discoveries are due to differences between individuals. Such differences have nothing to do with being male or female.*

Experimental group students:

<u>Realistic: 25.0</u> *Has Merit: 36.4* Naive: 38.6

Control group students:

<u>Realistic: 48.9</u> *Has Merit: 0.0* Naive: 51.2

Item 10 (Social Construction of Scientific Knowledge)

Tenth item considers the professional interaction of scientists in the face of competition. Item stem introduced that sometimes this competition causes scientists to break the rules of science (rules such as sharing results, honesty, independence, etc.).

Statistical analysis displayed an amazing result. Only 4.5% of experimental group and 9.1% of control group students believed that scientists do not compete. Almost 70% of experimental group and 64% of control group students thought that scientists compete and even sometimes break the rules of science because of this competition. Just 20.5% of both groups thought that some scientists break the rules and others don't, as in other professions.

Table 5.16 Percentage of students' responses to item 10.

Scientists compete for research funds and for who will be the first to make a discovery. Sometimes fierce competition causes scientists to act in secrecy, lift ideas from other scientists, and lobby for money. In other words, sometimes scientists break the rules of science (rules such as sharing results, honesty, independence, etc.).			
EG%	**CG%**		**Alternative**
			Sometimes scientists break the rules of science:
34.1	25.0	*A*	*because this is the way they achieve success in a competitive situation. Competition pushes scientists to work harder.*
13.6	15.9	B	in order to achieve personal and financial rewards. When scientists compete for something they really want, they'll do whatever they can to get it.

Table 5.19 (Continued)

Scientists compete for research funds and for who will be the first to make a discovery. Sometimes fierce competition causes scientists to act in secrecy, lift ideas from other scientists, and lobby for money. In other words, sometimes scientists break the rules of science (rules such as sharing results, honesty, independence, etc.).			
EG%	**CG%**		**Alternative**
			Sometimes scientists break the rules of science:
18.2	22.7	C	in order to find the answer. As long as their answer works in the end, it doesn't matter how they got there.
20.5	20.5	*D*	*It depends. Science is no different from other professions. Some will break the rules of science to get ahead and others will not.*
4.5	9.1	<u>E</u>	<u>Most scientists do not compete. The way they really work, and the best way to succeed, is through cooperation and by following the rules of science.</u>

Experimental group students:

<u>Realistic: 4.5</u> *Has Merit: 54.6* Naive: 31.8

Control group students:

<u>Realistic: 9.1</u> *Has Merit: 45.5* Naive: 38.6

Item 11 (Social Construction of Scientific Knowledge)

In item 11, students were asked whether they thought that the social contacts influence the content of scientific discovery or not. Only 11.4% of control group students and 9.1% of experimental group students thought that the social contacts do not influence the content of what is discovered. The percentage of students who selected the most realistic explanation for the influence of social contacts on scientific work was higher in experimental group (50.0%) than in control group (34.1%).

Table 5.17 Percentage of students' responses to item 11.

A scientist may play tennis, go to parties, or attend conferences with other people. Because these social contacts can influence the scientist's work, these social contacts can influence the content of the scientific knowledge he or she discovers.			
EG%	**CG%**		**Alternative**
			Social contacts influence the content of what is discovered:
50.0	34.1	A	because scientists can be helped by the ideas, experiences, or enthusiasm of the people with whom they socialize.
11.4	4.5	*B*	*because social contacts can serve as a refreshing or relaxing break from work; thus revitalizing a scientist.*
13.6	29.5	*C*	*because scientists can be encouraged by people to apply or change their research to a new area relevant to the needs of society.*
9.1	22.7	*D*	*because social contacts allow scientists to observe human behavior and other scientific phenomena.*
11.4	9.1	E	Social contacts do NOT influence the content of what is discovered because a scientist's work is unrelated to socializing.

Experimental group students:

Realistic: 50.0 *Has Merit: 34.1* Naive: 11.4

Control group students:

Realistic: 34.1 *Has Merit: 56.7* Naive: 9.1

Item 12 (Nature of Scientific Knowledge)

In the twelfth item, students were asked whether they thought that the scientific observations carried out by different scientists differ from each other, or not. Scientific knowledge is based on the observations of natural world, experimental evidence, rational arguments, and skepticism. It unavoidably covers human inference (Lederman, 2007; McComas, Clough and Almazroa, 1998). Therefore it is subjective.

While 79.5% of experimental group students have a realistic thought of that scientific observations made by the scientists would usually differ if the scientists believe different theories, just 54.6% of control group students shared this thought. The rest of the students in both groups thought that observations of different scientists would be almost identical even if the scientists believed different theories. Even this was an inconsistent idea with the realistic and contemporary one; the reasons of 20.4% of experimental group students and 31.9% of control group students for this idea had merit. Only 9.1% of students, all of who took place in control group, had a naïve idea.

Table 5.18 Percentage of students' responses to item 12.

Scientific observations made by competent scientists will usually be different if the scientists believe different theories.			
EG%	**CG%**		**Alternative**
40.9	27.3	A	Yes, because scientists will experiment in different ways and will notice different things.
38.6	27.3	B	Yes, because scientists will think differently and this will alter their observations.

Table 5.18 (Continued)

Scientific observations made by competent scientists will usually be different if the scientists believe different theories.			
EG%	**CG%**		**Alternative**
15.9	20.5	*C*	*Scientific observations will not differ very much even though scientists believe different theories. If the scientists are indeed competent their observations will be similar.*
4.5	11.4	*D*	*No, because observations are as exact as possible. This is how science has been able to advance.*
0	9.1	E	No, observations are exactly what we see and nothing more; they are the facts.

Experimental group students:

Realistic: 79.5 *Has Merit: 20.4* Naive: 0

Control group students:

Realistic: 54.6 *Has Merit: 31.9* Naive: 9.1

Item 13 (Nature of Scientific Knowledge)

The thirteenth item was asked to reveal how students see the scientific models used in research laboratories; as duplicates of reality or as human inventions. The alternatives of item were placed in two main ideas; models are copies of reality (A, B, C and D) and models are not copies of reality (E, F and G).

One of the misconceptions stated by McComas (1998) related to science was that scientific models were copies of reality. 38.6% of experimental group and 36.3% control group students had this misconception. Whereas the models are just a simplified representation of structures in a physical system and they concentrate attention on specific aspects of the system (Hestenes, 1997; Ingham and Gilbert, 1991). These aspects can be illustrated with objects, events, processes and ideas (Gilbert, 1995).

Almost 60% of students in both groups believed that models are human inventions and not exactly same with the originals. Just 29.5% of students in experimental group and 38.6% in control group had a realistic explanation for this view.

Table 5.19 Percentage of students' responses to item 13.

Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.			
EG%	**CG%**		**Alternative**
			Scientific models ARE copies of reality:
4.5	4.5	A	because scientists say they are true, so they must be true.
9.1	9.1	B	because much scientific evidence has proven them true.
6.8	4.5	C	because they are true to life. Their purpose is to show us reality or teach us something about it.
15.9	20.5	D	Scientific models come close to being copies of reality, because they are based on scientific observations and research.
			Scientific models are NOT copies of reality:
22.7	15.9	*E*	*because they are simply helpful for learning and explaining, within their limitations.*
29.5	38.6	F	because they change with time and with the state of our knowledge, like theories do.
9.1	4.5	*G*	*because these models must be ideas or educated guesses, since you can't actually see the real thing.*

Experimental group students:

<u>Realistic: 29.5</u> *Has Merit: 31.8* Naive: 36.3

Control group students:

<u>Realistic: 38.6</u> *Has Merit: 20.4* Naive: 38.6

Item 14 (Nature of Scientific Knowledge)

The item was asked students to get their ideas about the nature of classification schemes. Is there only way to classify nature or are there other ways?

The results revealed that almost 30% of students in both groups had a naïve idea on the nature of classifications. 18.2% of experimental group students and 15.9% of control group members, who selected alternatives A and B believed that there is only way to classify nature and this classification matches the way nature really is. In addition, 12.5% of students thought that scientists can use more than one classification scheme, but they rest their opinion on the diversity of nature and tentativeness of science.

The rest conceded the human inventive character of scientific classification schemes. 50% of both groups' students had a realistic viewpoint. They believed that science was not duplication of reality and there was not only way to classify nature.

Table 5.20 Percentage of students' responses to item 14.

When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong.			
EG%	**CG%**		**Alternative**
9.1	4.5	A	Classifications match the way nature really is, since scientists have proven them over many years of work.
9.1	11.4	B	Classifications match the way nature really is, since scientists use observable characteristics when they classify.
13.6	20.5	C	Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.
36.4	29.5	D	There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.
15.9	18.2	*E*	*There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.*
11.4	13.6	F	Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.

Experimental group students:

Realistic: 50.0 *Has Merit: 15.9* Naive: 29.6

Control group students:

Realistic: 50.0 *Has Merit: 18.2* Naive: 29.5

Item 15 (Nature of Scientific Knowledge)

Item 15 was concerning tentativeness of scientific knowledge. Scientific knowledge has a tentative character. But some people believe that scientific knowledge and other such ideas accumulated carefully are absolute (McComas, 1998).

A major part of the students, who selected alternatives A and B, agreed on the tentativeness of scientific knowledge. The students selecting alternative A had the falsificationist point of view and the ones selecting alternative B had the constructionist point of view. Both believed that scientific knowledge is subject to change, but they had different explanations for how it changes. According to responders of alternative B (54.5% of experimental group and 45.5% of control group members) old facts become different facts. And responders choosing alternative A (38.6% of experimental group and 36.4% of control group members) thought that old facts become wrong facts. The majority of the students had contemporary views about the tentativeness of scientific knowledge.

The results revealed that, only a small part of the students (4.5% of experimental group and 9.1% of control group students) believed that the facts are unchangeably correct. According to some of those, only the interpretation and application of old facts change, and according to others, new facts are just added to old facts.

Table 5.21 Percentage of students' responses to item 15.

Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.			
EG%	**CG%**		**Alternative**
			Scientific knowledge changes:
54.5	45.5	<u>A</u>	<u>because new scientists disprove the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation.</u>
38.6	36.4	<u>B</u>	<u>because the old knowledge is reinterpreted in light of new discoveries. Scientific facts can change.</u>
4.5	6.8	C	Scientific knowledge APPEARS to change because the interpretation or the application of the old facts can change. Correctly done experiments yield unchangeable facts.
0	4.5	*D*	*Scientific knowledge APPEARS to change because new knowledge is added on to old knowledge; the old knowledge doesn't change.*
0	2.3	E	Knowledge can change in time, but scientific knowledge is absolute and does not change.

Experimental group students:

<u>Realistic: 93.1</u> *Has Merit: 0.0* Naive: 4.5

Control group students:

<u>Realistic: 81.9</u> *Has Merit: 4.5* Naive: 9.1

Item 16 (Nature of Scientific Knowledge)

Item 16 investigates the ideas about the definitions of and relations among hypothesis, theory and law. The significant part of the students (77.3% of experimental group and 65.9% of control group) held a hierarchical view of the relation between scientific laws, theories and hypothesis. According to these students (who selected alternatives A and B), hypotheses become theories and theories become laws, depending on the amount of test and proof behind the idea.

Although these aspects of science may overlap and interact with each other, it is important to distinguish them (Lederman, 2007). McComas, Clough and Almazroa (1998) highlighted some of basic nature of science tenets on which there exists an agreement among the scientists even having different points of views. One of these tenets was that laws and theories serve different roles in science; therefore students should note that theories do not become laws even with additional evidence. They should realize that many laws in science were known before any theories were developed to explain them.

The first of fifteen myths of science described by McComas (1998) was that hypotheses become theories that in turn become laws. The results of item 16 evinced that a considerable part of the students (81.8% of both groups) had this misconception.

Only 11.4% of experimental group students and 13.6% of control group students had a realistic view.

Table 5.22 Percentage of students' responses to item 16.

Scientific ideas develop from *hypotheses* to *theories,* and finally, if they are good enough, to being scientific *laws.*			
EG%	**CG%**		**Alternative**
65.9	63.6	A	Hypotheses can lead to theories which can lead to laws because a hypothesis is tested by experiments, if it proves correct, it becomes a theory. After a theory has been proven true many times by different people and has been around for a long time, it becomes a law.
11.4	2.3	B	Hypotheses can lead to theories which can lead to laws because an hypothesis is tested by experiments, if there is supporting evidence, it's a theory. After a theory has been tested many times and seems to be essentially correct, it's good enough to become a law.
4.5	15.9	C	Theories can't become laws because they both are different types of ideas. Theories are based on scientific ideas which are less than 100% certain, and so theories can't be proven true. Laws, however, are based on facts only and are 100% sure.
11.4	13.6	D	Theories can't become laws because they both are different types of ideas. Laws describe things in general. Theories explain these laws. However, with supporting evidence, hypotheses may become theories (explanations) or laws (descriptions).

Experimental group students:

Realistic: 11.4 *Has Merit: 0.0* Naive: 81.8

Control group students:

Realistic: 13.6 *Has Merit: 0.0* Naive: 81.8

Item 17 (Nature of Scientific Knowledge)

In item 7, the role of scientific assumptions in development process of theories and laws was investigated. Particularly, students were asked to interrogate the necessity of truth of these assumptions in order for science to progress properly.

Contrary to 9.1% of experimental group and 2.3% of control group students, who selected alternative F, remaining believe that scientists need to make certain assumptions about nature in order to develop new theories or laws. However, one fourth of both groups' students thought that these assumptions must be true in order for science to progress properly. Remarkably higher percent of control group students (43.2%) than experimental group members (25%) selected the realistic answer (alternative E), which stated that scientists must make some true or false assumptions in order to start an investigation.

Table 5.23 Percentage of students' responses to item 17.

When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions must be true in order for science to progress properly.

EG%	**CG%**		**Alternative**
			Assumptions MUST be true in order for science to progress:
11.4	4.5	*A*	*because correct assumptions are needed for correct theories and laws. Otherwise scientists would waste a lot of time and effort using wrong theories and laws.*
0	2.3	B	otherwise society would have serious problems, such as inadequate technology and dangerous chemicals.
13.6	18.2	*C*	*because scientists do research to prove their assumptions true before going on with their work.*

Table 5.23 (Continued)

When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions must be true in order for science to progress properly.			
EG%	**CG%**		**Alternative**
			Assumptions MUST be true in order for science to progress:
38.6	27.3	*D*	*It depends. Sometimes science needs true assumptions in order to progress. But sometimes history has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.*
25.0	43.2	E	It doesn't matter. Scientists have to make assumptions, true or not, in order to get started on a project. History has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.
9.1	2.3	F	Scientists do not make assumptions. They research an idea to find out if the idea is true. They don't assume it is true.

Experimental group students:
Realistic: 25.0 *Has Merit: 63.6* Naive: 9.1

Control group students:
Realistic: 43.2 *Has Merit: 50.0* Naive: 4.6

Item 18 (Nature of Scientific Knowledge)

One of the basic nature of science tenets highlighted by McComas, Clough, and Almazroa (1998, p. 6) is that "new knowledge must be reported clearly and openly". This item considered the views on simplicity (or complexity) of language used in science and on the nature of theories.

Alternatives A and D took part in the favor of simplicity of scientific knowledge. On the other hand, one of the most realistic answers, alternative C, stated that some good theories are simple; some are complex, depending on what the theory is. Alternatives E and F (selected by 13.6% of experimental group and 11.3% of control group students) specified that complexity was the prerequisite for the quality of a theory.

The percentages of students in experimental and control groups (36.4 and 34.1, respectively) who had contemporary views about the language and nature of theories were close to each other.

Table 5.24 Percentage of students' responses to item 18.

Good scientific theories explain observations well. But good theories are also *simple* rather than *complex.*			
EG%	**CG%**		**Alternative**
11.4	9.1	<u>A</u>	<u>Good theories are simple. The best language to use in science is simple, short, direct language.</u>
40.9	40.9	*B*	*It depends on how deeply you want to get into the explanation. A good theory can explain something either in a simple way or in a complex way.*
25.0	25.0	<u>C</u>	<u>It depends on the theory. Some good theories are simple, some are complex.</u>
9.1	9.1	*D*	*Good theories can be complex, but they must be able to be translated into simple language if they are going to be used.*
6.8	4.5	E	Theories are usually complex. Some things cannot be simplified if a lot of details are involved.
6.8	6.8	F	Most good theories are complex. if the world was simpler, theories could be simpler.

Experimental group students:

<u>Realistic: 36.4</u> *Has Merit: 50.0* Naive: 13.6

Control group students:

<u>Realistic: 34.1</u> *Has Merit: 50.0* Naive: 11.3

Item 19 (Nature of Scientific Knowledge)

Item 19 asked students whether the best scientists are those who follow the steps of the scientific method during their investigations.

People generally believe the existence of a general and universal scientific method. Another scientific myth common among people is that science is procedural more than creative (McComas, 1998). Even though scientific knowledge is derived from observations of natural world, it is not lifeless, rational and orderly activity. It involves human imagination and creativity. That is, there is no one way to do science; therefore, there is no universal step-by-step scientific method (Lederman, 2007; McComas, Clough and Almazroa, 1998).

Alternatives A and B agreed that there was a definite pattern to doing science: scientific method. 22.7% of experimental group and 38.6% of control group students held this view. Almost the quarter of whole group selected alternative D and E that reject the stepwise procedure of scientific investigation. 36.4% of experimental group and 31.8% of control group students selected the most contemporary alternative (C) in which creativity, imagination and originality had important places in carrying out scientific investigations as well as scientific procedure.

Table 5.25 Percentage of students' responses to item 19.

The best scientists are those who follow the steps of the scientific method.			
EG%	**CG%**		**Alternative**
22.7	38.6	*A*	*The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists will follow the steps of the scientific method.*
9.1	4.5	*B*	*The scientific method should work well for most scientists; based on what we learned in school.*
36.4	31.8	<u>C</u>	<u>The scientific method is useful in many instances, but it does not ensure results. Thus, the best scientists will also use originality and creativity.</u>
22.7	13.6	D	The best scientists are those who use any method that might get favorable results (including the method of imagination and creativity).
4.5	6.8	E	Many scientific discoveries were made by accident, and not by sticking to the Scientific method.

Experimental group students:
<u>Realistic: 36.4</u> *Has Merit: 31.8* Naive: 27.2

Control group students:

<u>Realistic: 31.8</u> *Has Merit: 43.1* Naive: 20.4

Item 20 (Nature of Scientific Knowledge)

What is the influence of scientists' errors in their work on the advance of science? The percentage of experimental group students (20.5) that held realistic view was remarkably higher than the percentage of control group students (9.1) that held this view. They accepted the inevitable characteristics of errors and believed the reducing effect of cooperation between scientists on these errors. Surprisingly, the alternative selected at the highest percentage was E, in which frequently positive influence of errors on the advance of science was defended. The second higher percentage belonged to alternative D, which emphasized a more rational but not realistic approach.

Table 5.26 Percentage of students' responses to item 20.

Scientists should NOT make errors in their work because these errors slow the advance of science.			
EG%	**CG%**		**Alternative**
2.3	2.3	A	Errors slow the advance of science. Misleading information can lead to false conclusions. If scientists don't immediately correct the errors in their results, then science is not advancing.
6.8	2.3	*B*	*Errors slow the advance of science. New technology and equipment reduce errors by improving accuracy and so science will advance faster.*
20.5	9.1	C	Errors CANNOT be avoided so scientists reduce errors by checking each others' results until agreement is reached.
22.7	38.6	*D*	*Some errors can slow the advance of science, but other errors can lead to a new discovery or breakthrough. If scientists learn from their errors and correct them, science will advance.*
45.5	45.5	E	Errors most often help the advance of science. Science advances by detecting and correcting the errors of the past.

Experimental group students:
Realistic: 20.5 *Has Merit: 29.5* Naive: 47.8

Control group students:

Realistic: 9.1 *Has Merit: 40.9* Naive: 47.8

Item 21 (Nature of Scientific Knowledge)

Item 21 investigated the views of students about the precision and uncertainty in scientific/technological knowledge. Students were asked why scientists could not tell what will happen for certain.

Most of the students (almost 86% of both groups) held a contemporary view about the uncertainty of predictions made by scientists and engineers. 65.9% of experimental group students and 56.8% of control group students had a more realistic reason for the uncertainty of predictions. Only 11.4% of students believed that if there is accurate knowledge and enough information then predictions has to be certain.

Table 5.27 Percentage of students' responses to item 21.

Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what *probably* might happen. They cannot tell what will happen for certain.			
EG%	**CG%**		**Alternative**
			Predictions are NEVER certain:
59.1	50.0	<u>A</u>	<u>because there is always room for error and unforeseen events which will affect a result. No one can predict the future for certain.</u>
18.2	11.4	*B*	*because accurate knowledge changes as new discoveries are made, and therefore predictions will always change.*
2.3	15.9	*C*	*because a prediction is not a statement of fact. It is an educated guess.*
6.8	6.8	<u>D</u>	<u>because scientists never have all the facts. Some data are always missing.</u>
11.4	11.4	E	It depends. Predictions are certain, only as long as there is accurate knowledge and enough information.

Experimental group students:

Realistic: 65.9 *Has Merit: 20.5* Naive: 11.4

Control group students:

Realistic: 56.8 *Has Merit: 27.3* Naive: 11.4

Item 22 (Nature of Scientific Knowledge)

Twenty second item aimed to interrogate whether students saw laws as discoveries or inventions. A, B and C shared an ontological view supported by the logical positivists; scientists discover laws. Alternative D was an erroneous view and alternative E was an epistemological viewpoint coherent with the contemporary literature.

While, 43.1% of experimental group students viewed laws as discoveries, 56.8% of them viewed science as inventions. Contrarily, in the control group the percentage of students who see science as discoveries (70.5%) was notably higher than the percentage of students who see science as inventions (27.3%).

While 47.7% of experimental group students gave realistic answer to that question by selecting alternative E, only 25% of control group students selected this alternative. There is not a significant difference between the percentages of students having naïve beliefs in experimental group and percentages of those in control group.

Table 5.28 Percentage of students' responses to item 22.

For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific LAWS. Others think that scientists *invent* them. What do you think?			
EG%	**CG%**		**Alternative**
			Scientists discover scientific laws:
31.8	52.3	*A*	*because the laws are out there in nature and scientists just have to find them.*
6.8	15.9	B	because laws are based on experimental facts.
4.5	2.3	*C*	*but scientists invent the methods to find those laws.*
9.1	2.3	D	Some scientists may stumble onto a law by chance, thus discovering it. But other scientists may invent the law from facts they already know.
47.7	25.0	E	Scientists invent laws, because scientists interpret the experimental facts which they discover. Scientists don't invent what nature does, but they do invent the laws which describe what nature does.

Experimental group students:
Realistic: 47.7 *Has Merit: 36.3* Naive: 15.9

Control group students:
Realistic: 25.0 *Has Merit: 54.6* Naive: 18.2

Item 23 (Nature of Scientific Knowledge)

Item 23 investigated whether the participants viewed hypotheses as discoveries or inventions. 36.3% of experimental group students viewed laws as discoveries and 59.1% of them viewed science as inventions. The percentage of control group students who see science as discoveries was 40.9 and the percentage of students who see science as inventions was 56.9. 27.2% of the respondents in experimental group and 36.4% of the control group had ontological views which were cited in alternatives A, B and D and inconsistent with contemporary views. On the other hand, 31.8% of the respondents in experimental group and 36.4% of the control group had contemporary views about the nature of hypotheses.

Table 5.29 Percentage of students' responses to item 23.

For this statement, assume that a gold miner "discovers gold" while an artist "invents" a sculpture. Some people think that scientists *discover* scientific HYPOTHESES. Others think that scientists *invent* them. What do you think?			
EG%	**CG%**		**Alternative**
			Scientists discover an hypothesis:
13.6	20.5	A	because the idea was there all the time to be uncovered.
9.1	4.5	B	because it is based on experimental facts.
13.6	4.5	*C*	*but scientists invent the methods to find the hypothesis.*
4.5	11.4	D	Some scientists may stumble onto an hypothesis by chance, thus discovering it. But other scientists may invent the hypothesis from facts they already know.
			Scientists invent an hypothesis:
27.3	20.5	*E*	*because an hypothesis is an interpretation of experimental facts which scientists have discovered.*
31.8	36.4	F	because inventions (hypotheses) come from the mind — we create them.

Experimental group students:
Realistic: 31.8 *Has Merit: 40.9* Naive: 27.2

Control group students:
Realistic: 36.4 *Has Merit: 25.0* Naive: 36.4

Item 24 (Nature of Scientific Knowledge)

Item 24 was about the nature of theories. Participators were asked whether theories are discoveries or inventions. Half of the experimental group students and slightly more than half (54.5%) of control group students viewed laws as discoveries and the rest viewed science as inventions. While 45.5% of experimental group students gave realistic answer to that question by selecting alternative E, only 36.4% of control group students selected this alternative. One fourth of students in both groups had ontological views inconsistent with contemporary views.

Table 5.30 Percentage of students' responses to item 24.

For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists *invent* them. What do you think?			
EG%	**CG%**		**Alternative**
			Scientists discover a theory:
9.1	13.6	A	because the idea was there all the time to be uncovered.
13.6	34.1	*B*	*because it is based on experimental facts.*
15.9	4.5	*C*	*but scientists invent the methods to find the theories.*
11.4	2.3	D	Some scientists may stumble onto a theory by chance, thus discovering it. But other scientists may invent the theory from facts they already know.
			Scientists invent a theory:
45.5	36.4	<u>E</u>	<u>because a theory is an interpretation of experimental facts which scientists have discovered.</u>
4.5	9.1	F	because inventions (theories) come from the mind — we create them.

Experimental group students:

<u>Realistic: 45.5</u> *Has Merit: 29.5* Naive: 25.0

Control group students:

<u>Realistic: 36.4</u> *Has Merit: 38.6* Naive: 25.0

Item 25 (Nature of Scientific Knowledge)

Item 25 was related to the coherence of concepts across disciplines. Since scientists working in different disciplines look at the same thing very different points of view, they may have difficulty to understand each other.

34.1% of experimental group and 31.9% of control group students believed that it was difficult for scientists in different fields to understand each other. Although almost two-third of these students had a realistic reason for this view, the rest held a naïve approach. According to them, the reason for this difficulty was the different languages of different fields.

On the other hand, 63.6% of experimental group and 65.9% of control group students thought that it was fairly easy for scientists in different fields to understand each other. More than half of the responders in both groups selected alternative E. They believed in that scientists could understand each other easily because of the common nature of scientific ideas among fields.

Table 5.31 Percentage of students' responses to item 25.

Scientists in different fields look at the same thing from very different points of view (for example, H+ causes chemists to think of acidity and physicists to think oI protons). This makes it difficult for scientists in different fields to understand each others' work.			
EG%	**CG%**		**Alternative**
			It is difficult for scientists in different fields to understand each other:
22.7	20.5	A	because scientific ideas depend on the scientist's viewpoint or on what the scientist is used to.
11.4	11.4	B	because scientists must make an effort to understand the language of other fields which overlap with their own field.
			It is fairly easy for scientists in different fields to understand each other:
4.5	4.5	*C*	*because scientists are intelligent and so they can find ways to learn the different languages and points of view of another field.*
2.3	0	*D*	*because they have likely studied the various fields at one time.*
56.8	61.4	*E*	*because scientific ideas overlap from field to field. Facts are facts no matter what the scientific field.*

Experimental group students:

Realistic: 22.7 *Has Merit: 63.6* Naive: 11.4

Control group students:

Realistic: 20.5 *Has Merit: 65.9* Naive: 11.4

5.4 The Classroom Observations

The researcher of this study attended the lessons of both control and experimental groups for the purpose of treatment verification. She observed five lessons of each class. During each observation, she sat silently and inactively on one of the back desks in the classroom and took notes describing the learning climate in the classes. She invigilated unbiased presentation of the topic and watched over the students' involvement, responses to the treatment and interactions with teacher in the class.

In the experimental group, topic was taught with modeling instruction. This instruction involved both laboratory and classroom activities. Before the laboratory studies teachers announced students that each student should have had a lab notebook on which they would record raw data and note the procedure of their experiment as they conduct it. And the teachers also expressed that each student would prepare a detailed lab report in the given format in their notebook and submit it at the end of the cycle. Although most of the study done cooperatively in the laboratory, each student was responsible to prepare his/her own lab report and also defend their results in group presentations and class discussions. This supported the involvement of each student in the experimentation. It was observed that some of the students were reluctant to pre-lab discussions. They hesitated to express their ideas during the identification of dependent and independent variables and group discussions on experimental design. Since all students had an active part in the experiment, all were more willing to post lab discussions and classroom activities.

In the control group, students instructed with traditional methods. Similar to the modeling instruction, traditional instruction included both laboratory and classroom activities. But the way of conducting these studies was different in both instructions. The lab manual which supplied students the purpose and the procedure of the experiment, how to evaluate data, and even questions suggesting appropriate conclusions was used in traditional instruction. It does not give opportunity to students for planning their own investigation and being an active builder in the process. In addition, while observing the lab studies of control group students, it was noticed that some of the students have shared the works after their teacher divided them into groups. Each member of the group has performed different part of the experiment to complete it earlier. Another complication observed in the control group was that in some of the experiment groups the students having higher achievement in physics course shared big part of the work and others preferred to watch them.

The classroom activities of experimental group included the student presentations, class and group discussions and problem solving activities. Students presented and defended their experiments and findings. Not only teacher, but also class was entitled to ask questions to group that gave presentation. This case excited students. All groups couldn’t made presentations for want of time. As cited before, since each student was engaged actively in the experiment, they were confident to participate in discussions conducted in the classroom after experiment. In the control group, students filled and submitted their lab sheets at the end of the experiment and teachers graded them. This study was not discussed in the class in detail. Students were in the classroom except one lesson in which they performed experiment. Teaching strategy was based on the teacher exploration and problem solving. Teachers wrote some problems, which were usually quantitative ones, on the board. They gave some time to students to solve them. At the end, either the teacher or one of the students who has solved the problem correctly wrote the correct solution on the board. Since students were less active, they bored and lost their motivation ever so often. Teachers were experienced and they tried to gain their attention on the topic. But they were not successful at each time.

This can be concluded on the observations that modeling instruction was more successful than the traditional instruction in attracting and keeping students’ attention on the topic, including students in lab and class activities operatively and willingly, encouraging students to express their ideas, increasing both students' and teachers' motivation and effecting students' attitudes positively.

5.5 The Interviews

Rowlands, Graham and McWilliam (2004) developed a one-to-one Socratic tutoring method to investigate the characteristics of students' misconceptions. This questioning method involves an initial concept question and subsequent parallel question(s). The parallel questions have different scenario but same explanation as to the answers to the initial concept question. If the response of student to the concept question is contrary to the scientific explanation, the subsequent question attempts to create cognitive conflict. If the response is correct, then parallel question reveals this. A similar method was used during the student interviews of this study. The questions of concept test were accepted as the initial concept questions of tutoring and different scenarios related to the scientific facts investigated in those items were served students in parallel questions during the interviews.

The major aim of the interviews was to get an idea about the nature and reasons of students' misconceptions on concepts related to projectile motion. Therefore the concept test results were investigated in detail and the major misconceptions of students which were revealed by these tests were identified in order to develop interview questions.

The questions particularly focused on the evaluation of projectile motion horizontally and vertically, the path of the projectile including horizontal range, maximum height, and time in flight and the factors that may affect the path (see appendix O). Each student interviewed for approximately 45 minutes. Selected examples of excerpts from interviews are given below.

In the first question, Figure 5.2 was shown to the students and it was explained that one of the arms of the boy who sit in the train leaned out of the window and he had a small metal ball in his hand.

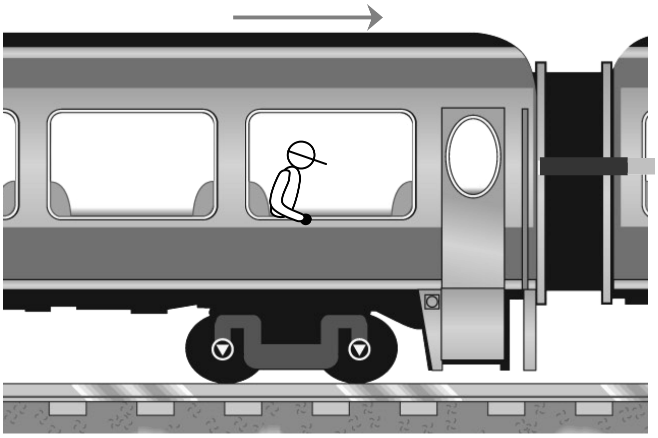


Figure 5.2 Picture shown students for the first question of interview

Teacher: The train is moving with constant speed. Boy is throwing the ball straight up. Ignoring any effects from air resistance, can he catch the ball again?
Student 1: No, he can not.
Teacher: No. Why do you think that? What happens to ball?
Student 1: Train glides below the ball. When the ball falls down, boy has moved from there and he can not catch it.
Student 2 (CG): The speed of train is important here. If the train is slow enough and the boy has long arms, then he could catch the ball.
Student 3 (EG): It falls back into his hand. It has a horizontal velocity because of the train.
Teacher: Very good. What would happen if the train was speeding up instead of moving with constant velocity? Can he catch it again?
Student 3: Yes he can. Same forces with boy's hand are acting on the ball. It would again fall back to his hand.

Teacher: Well, what happens if he just releases the ball in air? Assume that again the train is moving with constant speed. How does the ball move? Can you draw its path please?

The first student claimed that it would fall straight down.

Students 2: It does not fall vertically down. It falls toward the front because of the train's velocity.

Teacher: You mean that it has an initial horizontal velocity because of the train?

Students 2: Yes.

Teacher: Are their horizontal velocities equal?

Students 2: Initially yes, but then ball slows down. So the ball falls toward a little front but remains still behind the boy.

Teacher: At the end, train closes the station and slows down. While the train is speeding down, boy throws another ball vertically up. Can he catch the ball this time?

Student 2: I think he can catch this time, because train is slower now.

Even after instructions, students continued to hold some misconceptions related to the projectile fired from a moving carrier. The control group students were still thinking that the ball released or thrown up from a moving train was not affected by the train's velocity and it did not have forward motion after it has left the hands of boy in the train. They had difficulty to recognize that train and the ball had the same horizontal velocities. Although the experimental group student realized the effect of train, he believed that the force exerted on the carrier can affect the ball too even after it was fired.

In another question students were expected to compare the motion of three objects one of which falls down (apple), the other is shouted horizontally (stone in the sling of first boy) and the last is shouted obliquely (stone in the sling of second boy). Figure 5.3 was shown students during the interviews and the story was told. The first boy in Figure was trying to hits an apple on the tree with the stone in sling and the apple was at his level. He aimed straight at apple and shouted. Just when he shouted, apple broke away from the tree and started to fall down. Then students were asked whether his stone hit it or not.

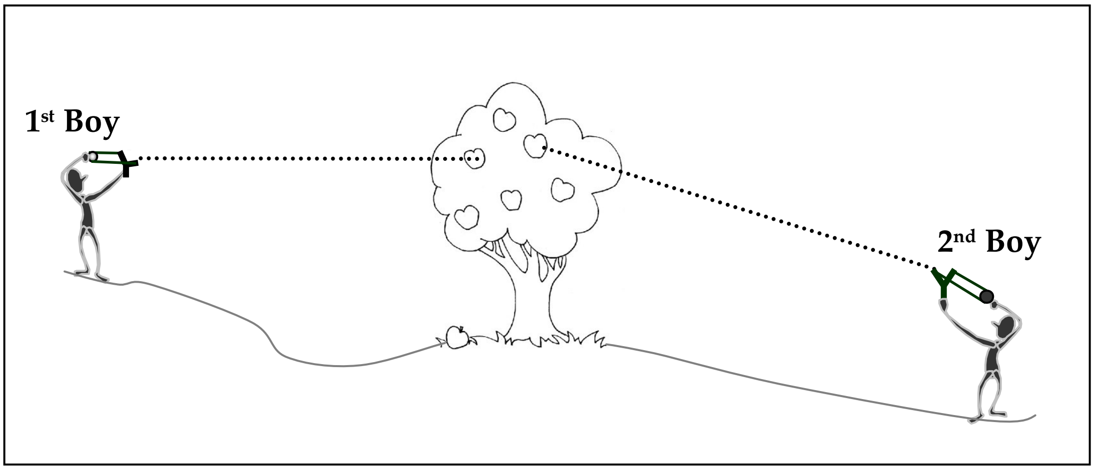


Figure 5.3 Picture shown students for the second question of interview

Students 1: It depends on the speed of stone. If it is not fast enough, it might miss the target.
Teacher: Why? Can you expand it please?
Students 1: The time of ball in air depends on its velocity. If it is slow, it reaches there later. Then he misses the apple.

Student 2: It misses the apple. The stone is going from here to tree (showing the sling and tree on the picture)*, the apple falls straight down.*
Teacher: Does not the stone fall too?
Student 2: No. Aaa..but.. There is gravity. Yes of course, it falls too.
Teacher: Well, what do you think now?
Student2: Hmmm…I am still thinking that stone misses it. Apple falls faster.
Teacher: Why do you think that apple falls faster?

Student 2: It starts to fall down immediately. But stone is flying from here to tree at the same time.

Another one of the control group students also cited that apple falls faster.

Teacher: Why do you think that apple falls faster?

Student 3: Apple is heavier. Since "F" equals "m" "a", apple falls faster.

Teacher: Yes you are right, "F" equals "m" "a" and the gravitational force on apple is bigger. But the mass of apple is bigger too. How about it?

Students 3: Hmmm… I thickened now…

This time, students were asked to conclude that what would change if the second boy, who was below the apple's position, shouted the stone. Most of the students explained that nothing would change. He could not hit the apple.

Student 3: They do not collide in air. Apple falls earlier.

Teacher: Let's talk about their accelerations again.

Student 3: This time, apple has bigger acceleration. I am sure.

Teacher: Why does it have bigger acceleration?

Students: There is a force up on the stone against the gravity. Not only gravity this time. Net force on it is smaller. This means that its acceleration is smaller.

One of the students thought in a different way expressed his idea as following;

Student 4: In the first case it was impossible, but this time they may collide in air.

Teacher: Why do you think like this? What did change this time?

Student 4: In the first case, apple was falling down and stone was moving horizontally. So, stone was moving in a higher position and it couldn't hit the apple. But this time, stone is closing the apple from a lower position, if it was thrown fast enough, they might meet each other in the air. It depends on how fast the stone was shouted.

Teacher: Could you draw their paths on this figure please.

Student drew their paths like in Figure 5.4. The first drawing (a) was showing how they would collide in air; if it was shouted fast enough and the second one (b) was showing how stone would miss the apple if it was shouted slowly.

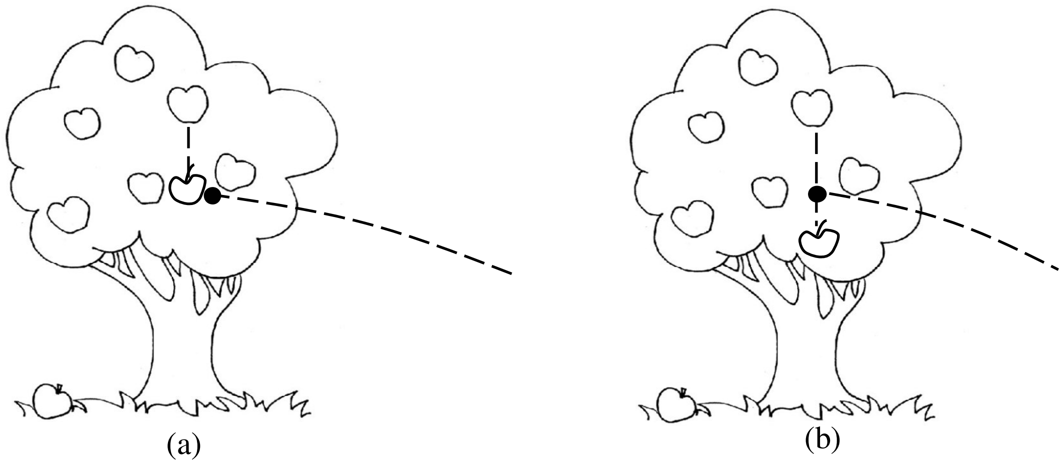


Figure 5.4 Figures drawn by the student to show paths in each case

Teacher: What would happen if the stone is faster than the first one (showing the stone in Figure 5 (a))*?*

Student 4: Well, I think apple would miss the stone. Apple would be at a higher level just stone passes through the point where they can meet.

The answers of students to this question revealed that, some of the students still held their naïve views related to the factors effecting time in flight of a projectile. They thought that the horizontal velocity of projectile had an influence on time in flight. The greater speed results in the longer time of flight. Whereupon they concluded that an object released from a certain height fell faster than an object thrown horizontally from that height. In addition, one of the interviewed control group students believed that the mass of object released in air affected the time of object to hit ground. Students' another misconception identified through this question was that the impetus given to object by the hand of person that threw it continued to exert on it belong its motion even after being fired.

The scenario of another question included a garden hose nozzle adjusted by the women for a hard stream of water. Students were explained accompanied by the Figure 5.5 that she kindly held the end of nozzle in three different positions. They wanted to assume that the water leaves the nozzle at an angle of 45^0 with the horizontal in second position.

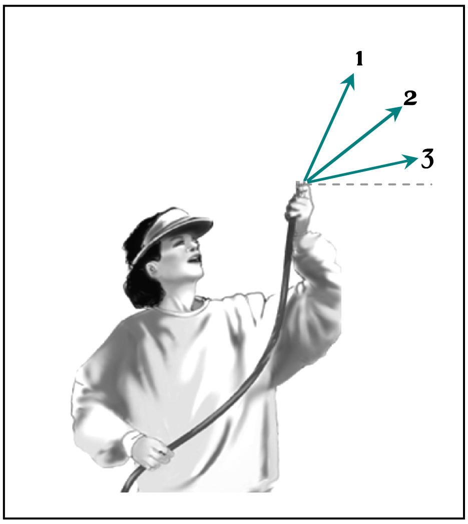


Figure 5.5 Picture shown students for the third question of interview

Teacher: In which case does the water reach the highest level?
Student 1 (CG): In the first case.
Teacher: Explain the reason please.
Student 1: It is the biggest in the first case.
Teacher: What are the factors that determine how high a projectile can reach?
Student 1: Vertical velocity.

Teacher: In which case does the water travel the greatest horizontal distance?
Student 1: In the third case because horizontal velocity is important this time. And it is biggest in third case.
Student 2 (EG): In the second case.
Teacher: Why?

Student: Both the velocity and the time are important. In the first case velocity is small; in the third case time is short. In the second case both are medium sized.

Student 3(CG): In the first case. It stays longer in air. So it can move far. It seems to be like that to me.

Teacher: Now, let's talk about the time of flight. In which case does the water hit the ground earlier?

Student 3: Is the speed of water same every time?

Teacher: Yes, its speed is the same in each case.

Student 3: Then, they hit the ground in equal time. Velocity determines the time of motion.

In the forth question, Figure 5.6 was presented to students and they were expected to draw forces acting on the projectile while it was climbing (at point A), while it was at top (at point B) and while it was falling (at point C). They also asked to decide how the length of forces that indicates the magnitude of that force changed during motion.

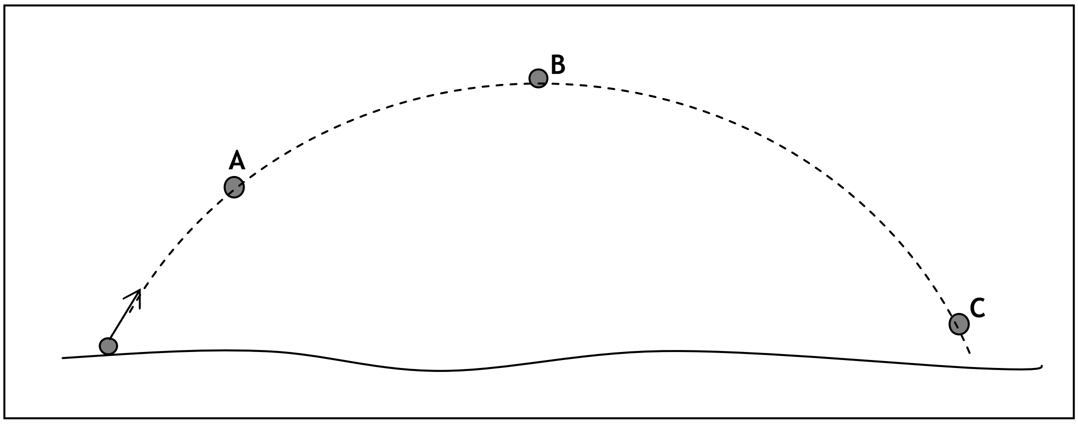


Figure 5.6 Picture shown students for the fourth question of interview

Four of the experimental group students and three of the control group students drew arrows correctly. One of those was still not clear.

Teacher: What is the name of this force?

Student 1: Gravity.

Teacher: All arrows are towards downward. You say that there is no force acting upward. Then what moves ball up?
Student 1: We gave it an initial velocity.
Teacher: Are these three arrows equal in length?
Student 1: Yes. Its weight does not change during the flight.
Teacher: What can you say about the acceleration of the motion?
Student 1: It decelerates while climbing and accelerates while falling.
Teacher: Compare the magnitudes of accelerations in both cases please.
Student 1: As I said it decreases while climbing and increases while falling.
Teacher: You think that not only its speed but also its acceleration changes during the motion.
Students: Yes. But I think this is wrong.
Teacher: Let's think together. You said that the force acting on the ball did not change. How do we calculate the acceleration of a body?
Student 1: Aa! F equals ma .Climbing acceleration and falling acceleration are equal.
Teacher: At top?
Student 1: Zero.
Teacher: Zero. Why?
Student 1: Because velocity is zero.
Teacher: But you put the same arrow on the ball at top. If there is force acting on it, it should have acceleration.
Student 1: Yes, I have had a mistake. (He erased the arrow he drew).

One of the low achiever students from the experimental group drew an arrow on the balls at point A and at point C. These arrows were towards down, equal in length and representing the gravitational force. But she did not draw any force on the ball at top for the same reason with Student 1. Two of the control group students drew two forces on each ball, one was towards up and one was towards down. In the figure drawn by one of them, upward forces were equal in all alternatives but downward forces were different. On the ball at point A, downward force was smaller that upward one. On the ball at point B, both were equal. And at point C, downward force was bigger.

Teacher: What is the name of this downward force?
Student 2: Weight.
Teacher: And what is this force (pointing her finger at upward force)*?*
Student 2: I don't know its exact name. It is the force that our hand gave the ball. It might be velocity.
Teacher: Is it the same during whole flight?
Student 2: Yes.
Teacher: But gravitational force is changing. Why?
Student 2: Yes. It is smaller than throwing velocity initially and so ball moves up. These two become equal at top. Net force is zero there and ball is in equilibrium. Gravity is bigger here (pointing at point C). *So it falls down.*

Even after instruction, most of the students continued to hold the misconception that an impetus given to projectile by the person who threw it keep exerting on it belong its motion. Teacher continued to ask questions concerning the acceleration and velocity of projectile. One of the experimental group students answered as followings;

Teacher: What is the velocity at highest point?
Student 4: There is just horizontal velocity.
Teacher: What happens to vertical velocity?
Student 4: It is zero. It decreased while climbing.
Teacher: What force is responsible for this deceleration?
Student 4: Weight of the ball.
Teacher: How does the velocity change in the second part of the motion?
Student 4: Vertical velocity increases because of weight but horizontal velocity does not change.

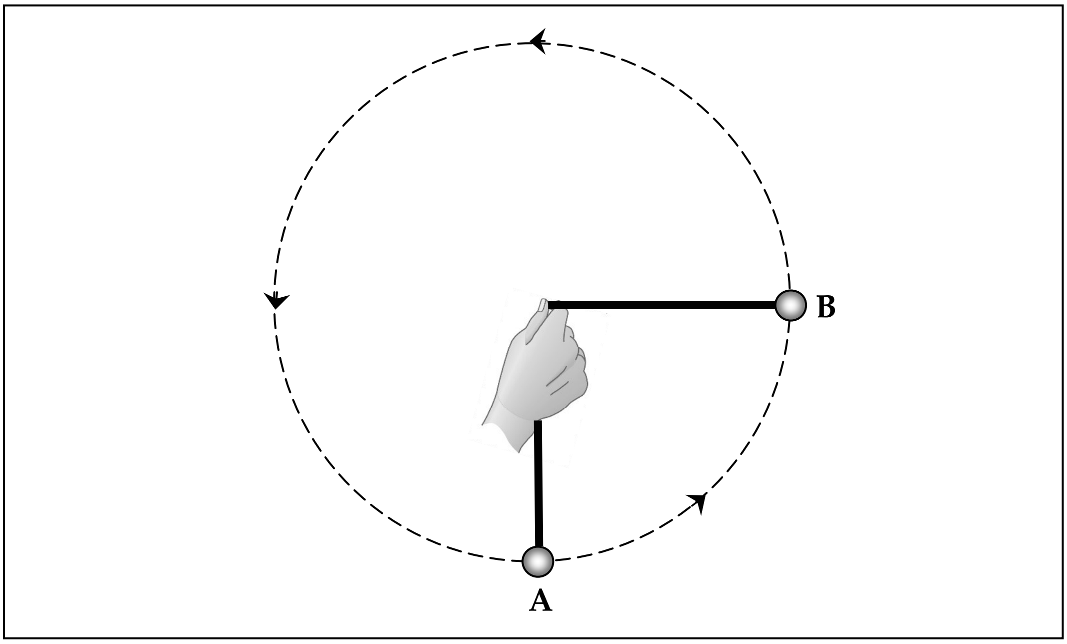


Figure 5.7 Picture shown students for the fifth question of interview

In the last question,

Teacher: Assume that you are swinging a ball vertically on the end of a string (showing figure 5.7). *Just when the string is in a vertical position and the ball passes through point A, the string breaks. Could you tell how the ball moves? It would be better if you draw it.*
Student 1: Can I try it?
Teacher: Yes, of course.
He took the pencil from the desk, kindly held one end of the pencil with his two fingers and started to swing other end back and forth. After a few oscillations he released it when it was at the midway.
Student 1: I think it moves up a bit and then falls. (Drew the path he supposed)
Teacher: What does cause it to move up?
Student 1: Its velocity.
Teacher: In your figure, its maximum height is lower then the top of the circle. Why did you draw in this way?
Student 1: It loses force because of gravity. It can not reach the top point.

One of the other students drew a similar oblique path for the stone too. After thinking for a while, she erased top of the curve and plotted the highest point on the oblique at the same level with the top of circle which ball rotates around initially. Then she made such an explanation;

Student 2: Normally, it can not reach that point. Air friction prevents it. But you said that ignore the air resistance.

Teacher: Can it reach that point in this case?

Student 2: Yes. The energy is conserved.

Teacher: Does it follow such an oblique path really? What is the direction of its velocity just before the string broke?

Student 2: Toward right.

Teacher: Then, it had only a horizontal velocity when it was free in air. As if it was thrown horizontally.

Student 2: It does not sound all right to me. What happened to inertia?

In the second part of the question, teacher asked students to predict what would happen if the string broke when the string was in horizontal position and the ball passed through point B. Student 1 drew a an oblique path from point B and to a point at the left of the circle (Figure 5.8 (a)). Student 2 drew a path (Figure 5.8 (b)) similar to the one she has drawn in the first part of the question.

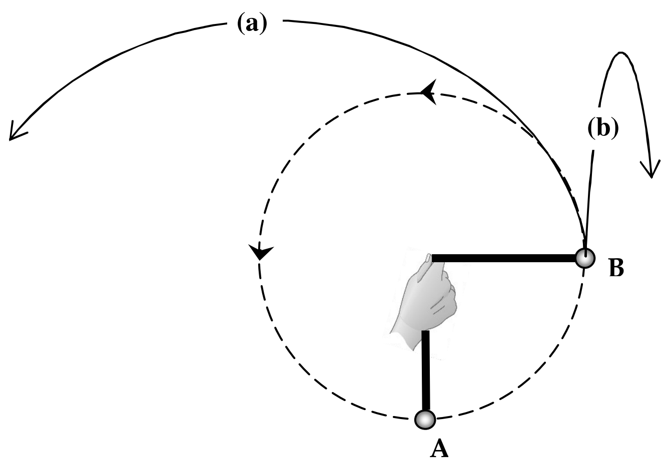


Figure 5.8 Figures drawn by students to show the path of ball after string broke.

A large proportion of the students said that they found the classroom lectures boring and physics difficult. The element that made science courses enjoyable and interesting for them was practical experiments. But they complained about that they can rarely go to the laboratory. Therefore, they could not made links between school science and everyday life.

The experimental group students commented that they enjoyed the instruction performed in their classes because of the hands on experiments and the fact that everyone could take part in these experiments. Some students told that preparing the laboratory report was time consuming. Since they have many exams to study in each course, they could not spare enough time to prepare this report.

5.6 Summary of the Quantitative Results

The quantitative findings of this study can be summarized as followings regarding the results of statistical analyses;

1. There was a significant mean difference between students taught with modeling instruction and those taught with traditionally designed instruction with respect to their understanding of projectile motion concepts. The students exposed to modeling instruction had higher mean score on the post projectile motion concept test than those taught with traditional instruction.

2. There is no significant difference between the performances of males that of females on post concept test and no significant interaction between treatment and gender difference.

3. There was a statistically significant contribution of students' science process skills to their understanding of projectile motion.

4. There was a significant difference between the experimental and control groups with respect to their attitudes in the favor of experimental group.

5. The results also revealed that there was no significant mean difference between male and female students with respect to their attitudes towards physics. In addition, there was no significant interaction effect between gender difference and treatment on attitudes towards physics as a school subject.

6. As the results of T-VOSTS test evinced, a considerable part of the students (77.3% of experimental group and 65.9% of the control group) had a misconception that hypotheses become theories and theories become laws, depending on the amount of proof behind the idea.

7. The results of T-VOSTS test revealed that one-third of students (36.3% of experimental group and 38.6% of the control group) had a misconception that scientific models are the copies of reality.

5.7 Conclusions

The following conclusions can be derived from the results of this study,

1. The modeling instruction resulted in a better acquisition of scientific conceptions related to projectile motion and remediation of misconceptions than traditionally designed physics instruction. However, students' scores on post concept test still were not high, that is, the students in both groups have continued to hold some misconceptions related to the projectile motion even after treatments. The existence of some misconceptions was also observed in student interviews conducted at the end of the treatment.

2. Students taught through modeling instruction got higher scores on attitude scale after treatment than those exposed to traditional designed physics instruction. In parallel with this result, classroom observations and students interviews revealed that modeling instruction was better in attracting and keeping students’ attention on the topic, including students in lab and class activities operatively and willingly, encouraging students to express their ideas and increasing both students’ and teachers’ motivation.

3. Gender was not a significant factor affecting the concept acquisition related to projectile motion and students’ attitudes towards physics as a school subject. Although boys had higher achievement in concept test and had more positive attitudes towards physics than girls, these differences were not significant. Contrarily, it was observed that girls were more willing to laboratory activities than boy were.

4. Science process skill levels of students were strong predictors for the students’ achievement related to projectile motion concepts.

5. A significant part of the students had a misconception that hypotheses become theories and theories become laws, depending on the amount of test and proof behind the idea. According to them there exists hierarchical relationship among these three. They ignore that theories can’t become laws because they both are different types of statements, and many laws in science were known before any theories were developed to explain them.

6. Many students had a misconception that scientific models are the copies of reality. Whereas the models are just a simplified representation of structures in a physical system and they concentrate attention on specific aspects of the system (Hestenes, 1997; Ingham and Gilbert, 1991). These aspects can be illustrated with objects, events, processes and ideas (Gilbert, 1995).

7. Regarding the results of T-VOSTS test it can be concluded that the percentage of students that had contemporary views on the nature of science conceptions including influence of society on science, characteristics of scientists, the effects of these characteristics on science and social construction, subjectivity and tentativeness of scientific knowledge was higher in experimental group than those in control group.

CHAPTER 6

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

There exist three subtitles in this chapter. Under the first title, results of the study are discussed and compared with the related literature. The implications are offered in the second section in the light of results of the study. Finally, recommendations for further studies are presented in this chapter.

6.1 Discussion of the Results

The results of the research disclosed that modeling instruction resulted in a better acquisition of scientific conceptions related to projectile motion and remediation of misconceptions than traditionally designed physics instruction. On the other hand, there was no significant difference between the male and female students in terms of their understanding of projectile motion concepts. In the same way, students taught through modeling instruction got higher scores on attitude scale after treatment than those exposed to traditional designed physics instruction. Moreover mean score of boys did not significantly differ from the mean score of girls in this scale.

Through the modeling instruction, teacher began with demonstration of experimental set up in the laboratory and introducing the research question. Other probing questions which aim to courage students for expressing their ideas and direct them to select quantitatively measurable parameter in cause-effect relationship followed them. Discussion supported students with the opportunity to become aware of their different ideas about the topic and helped them to criticize these ideas. At this point students noticed that their existing knowledge were not useful in explaining the phenomena discussed and they learned to differentiate the important aspects of phenomena from distracters. This is an important step for conceptual change. Then students were allowed to elaborate an experimental design including dependent and independent variables, measurement methods, no of trials, method of data recording, etc. and to perform their experiment in order to test and justify their predictions against the actual outcome. Next, they completed necessary data analysis. At the end of the model development stage, students were supported to resolve discrepancies between their predictions and actual outcome of the experiment in a class discussion and the class as a whole arrived a consensus on the model for the asked phenomena. The second stage of modeling instruction was model deployment. Students worked in the classroom. The purpose of the stage was to allow students for disposition of models in new situations in different ways through problem solving activities. The control group exposed to traditional instruction including lecture given by teacher, use of text books and a traditional lab study that students performed by following certain directions in lab manual. Students were passive listeners. They had no chance to be aware of their alternative conceptions. Traditional instructional methods are not effective on eliminating students' alternative conceptions.

Classroom discussion was used in the modeling instruction in order to disclose students' different ideas at the beginning and to get their ideas together for a consensus at the end. Its role on better results of modeling instruction can not be negated. Researches on conceptual change strategies showed that types of class activities combined with discussion were effective in identifying students' misconceptions prior to the instruction and improving their conceptual understanding (Nussbaum and Novick, 1982; Sprod, 1998; Van Zee et al., 2001). Nussbaum, Sinatra and Poliquin (2008, p. 1) used the scientific argument that refers to "the application of scientific standards to arguments for the purpose of understanding scientific phenomena" as a conceptual change technique in their study and they concluded that "engaging in argumentation can promote conceptual change in the minds of students asked to consider alternative points of view and evaluate alternative conceptions." Hestenes (1999) affirms that the reason why some teachers using the modeling instruction get better results than others is the way that discourse occurs in the classroom. The quality of discourse determines the instructional success. Actually, the effectiveness of discussions and prior knowledge are correlative. The level of students' prior knowledge of a subject or theory is important in students' abilities to think critically and engage in effective argumentation (Cross et al., 2008).

Another reason for the better results of modeling instruction in acquisition of scientific conceptions with respect to traditional one must be the difference between how students conduct lab studies in both instructions. The traditional lab studies are unsatisfactory to teach students scientific inquiry and to include them as an active builder in the process. The lab manual used in traditional instruction supplies students the purpose and the procedure of the experiment, how to evaluate data, and even questions suggesting appropriate conclusions. It does not give opportunity to students for planning their own investigation (Hestenes, 1999). Conversely, in the modeling instruction students identify the parameters to be measured; they design their own experiment including which materials will be used, how they measure the parameter, how they collect data, how they process data; and at the end they perform their experiment to invent and evaluate a model for the asked phenomena.

In addition, while observing the lab studies of control group students, it was noticed that some of the students have shared the works after their teacher divided them into groups. Each member of the group has performed different part of the experiment to complete it earlier. In some groups again for the same purpose, the students having higher achievement in physics course shared big part of the work and others preferred to watch them. Their disconnected works must have caused them to derive a partial benefit from the study. In the experimental group, each member of the teams should have had a lab notebook. They were asked to record raw data and note the procedure of their experiment in detail. Although most of the study done cooperatively in the laboratory, each student was responsible to prepare and submit a detailed lab report in the given format and also defend their results in group presentations and class discussions.

One of the purposes of study was to investigate whether there was a significant difference between male and female students with respect to their understanding of projectile motion concepts and attitudes towards physics. The results of many researches disclosed that gender was an important factor affecting the concept acquisition in physics. Many of these researches also indicated that boys had more positive attitudes to science than girls did (Baram-Tsabari and Yarden, 2008; Francis and Greer, 1999; Osborne, 2003; Weinburg, 1995). What is more, pupils' attitudes towards science declined as they progressed through secondary school and this decline was more pronounced for female pupils (Barmby et al., 2008). Chambers and Andre (1997) concluded that male students were better than female students in physics because of their interest in and experience with mechanical devices in their daily life. Besides, they had more positive attitudes to the everyday applications of physics rather than the theoretical physics (O'Brien and Porter, 1994). Females perceive science as difficult to understand, whereas males think that science is destructive and dangerous, as well as more suitable for boys (Jones, Howe and Rua, 2000). Similarly, Murphy and Whitelegg (2006) claimed that the contents, contexts, ways of approaching problems and investigations in physics more closely reflected what boys did, more than girls. Despite the boys had a higher mean than girls did on both post concept test and post attitude scale, these differences were not found statistically significant in this study contrary to findings of these studies. Freedman (2002) investigated the influence of laboratory investigation on students' science achievement and their attitudes towards science. Similarly, he concluded that female and male students within the treatment group did not differ significantly on the examination of achievement in science knowledge. Since the science achievement of students has a great influence on their attitudes towards science, similar scores of males and females on attitude scale may be expounded by their similar scores on concept test.

One of the factors that may affect the students' attitudes towards science is the type of instruction that students receive in the classroom. In addition to other aims, this study attempted to investigate the effect of modeling instruction on attitudes of students towards physics. The results provided an evidence that modeling instruction produced a higher increase in attitudes of students than traditional instruction did. The reason for this might be that modeling instruction includes the laboratory activities that require both intellectual and physical participation of students, and findings of related literature indicates that such laboratory studies which provides students with the opportunities to apply their ideas in real world situations has a positive influence on student's attitudes (Adams and Chiappetta, 1998; Etkina, et al. 2002; Freedman, 2002). Owen et al. (2008) conducted a study to explore whether physics might be made more attractive to students with different learning activities. The most popular activities among the students were constructive activities, such as doing experiments. Students have found these activities educationally useful, but they have thought that these activities were used less often than other activities. Similarly, during the interviews the experimental group students commented that they enjoyed the instruction performed in their classes because of the hands on experiments and the fact that everyone could take part in these experiments. The study of Barmby, Kind, and Jones (2008) has highlighted that there exist a decline in attitudes of students towards science from the start of secondary schooling and this has very important influence on whether pupils will pursue science in the future. Therefore, the main recommendation that they asserted was the need to concentrate on improving pupils' experience of science in school.

Students' perceptions about the epistemology and the nature of science are closely related to their use of models in making inference about the scientific knowledge (Gobert and Discenna, 1997). Researches revealed that students hold serious misconceptions related to epistemology and nature of science (Ryan and Aikenhead, 1992; Sutherland and Dennick, 2002). McComas (1998) calls these misconceptions as "myth of science". He formed a list including fifteen fundamental myths. The results of this study showed that the students participated in this study hold two of them. The first misconception was that hypotheses become theories and theories become laws, depending on the amount of test and proof behind the idea. According to a significant part of the students there exists hierarchical relationship among these three. And the second misconception was that scientific models were the copies of reality. Both of these misconceptions were widely held in both groups.

The nature of science should be valued as an instructional objective. Students should know important nature of science tenets such as the characteristics of scientific knowledge, the ways of doing science, the relations and differences among hypothesis-theory-law and also between science and technology, the characteristics of scientists and its effect on their science, the influence of society and various elements of culture on science and the influence of science on them, etc. (Lederman, 2007; McComas, Clough and Almazroa, 1998). The results of this study revealed that the percentage of students that had naïve views on some basic nature of science tenets was higher in control group than those in experimental group. For instance, the number of students holding naïve beliefs about the influence of society on science was higher in control group. Half of them believed that science researches continue regardless cultural and ethical views. The answers of students to T-VOSTS items related to the characteristics of scientists and its influence on science showed that experimental group students had more contemporary views on this subject. While some of control group students believed the absolute objectivity of scientists, there was no student having this idea in the experimental group. In addition, the percentage of students that accepted the inevitable characteristics of scientists' errors and that believed the reducing effect of corporation between scientists on these errors was higher in experimental group. Similarly, the number of students with a realistic view on subjectivity and tentativeness of scientific knowledge was higher in experimental group. More, the students that had naïve views on the subjectivity of scientific knowledge were all in control group.

Finally, students bring their prior knowledge to the classroom and their pre-instructional knowledge might not be in harmony with the scientific conceptions. They connect new knowledge to the existing ones in the learning process. Therefore, their existing knowledge has a crucial role in meaningful learning. Teachers should be aware of students' alternate conceptions about the topic they teach. They can use modeling instruction since it is an effective instructional method in remedying students' misconceptions and students have chance to be both physically and intellectually active in the process of constructing conceptual models through this instruction. Students' understanding of nature of science is very important in their science achievement and in their everyday life. Therefore teachers should value nature of science as an instructional objective. Science educators should also heed the attitudes of students because their attitudes have a significant influence on their achievement and future decisions. Both the curriculum and text books should be designed regarding the students' misconceptions and conceptual change conditions.

6.2 Internal and External Validity of the Study

Possible threats to the internal and external validities of this study and their control were discussed in this subsection.

6.2.1 Internal Validity

In the studies that investigate the relationships, there is always the possibility that the relationship shown in the data is due to or explained by a different factor from independent variables of the study. If these factors are not in some way or another controlled or accounted for, many alternative hypotheses may exist to explain the outcomes of the study. These alternative explanations are often referred to by researchers as threats to internal validity (Frankel and Wallen, 1996).There are various possible threats to internal validity that most of the studies suffer. The design of this study provides some control for the possible internal validity threats coincided in pretest posttest control group designs. These threats and how to cope with them are discussed in this section.

Since the intact groups were randomly assigned to the control and experimental groups in this study, one of the factors that might affect the students' scores on post concept test and post attitude scale was the subject characteristics. Therefore some possible characteristics such as students' gender, age, science process skills, prior attitudes towards physics, and prior knowledge related to the projectile motion were regarded as extraneous variables to the study. The number of females was 25 in experimental group and 26 in control group; the number of males was 19 in experimental group and 18 in control group. The groups were similar with respect to gender. In addition, the statistical analyses revealed that gender difference had no significant effect on students' conceptual understanding of projectile motion and their attitudes towards physics. Likewise, the students' ages ranged from 15 to 17 in both groups. Besides, Science Process Skill Test was administered to all students at the beginning of study in order to determine and control the effect of their science process skills as a covariate throughout the study. In addition, Projectile Motion Concept Test and Attitude Scale towards Physics were given as pre-tests to all students. The mean scores of students in both groups were almost the same in pre-concept test. Similarly, there was no significant mean difference between the pre-attitude scale scores of students in experimental and control groups (Table 5.1). Therefore the previous science knowledge related to projectile motion and the previous attitudes towards physics were assumed to be equal for the students in both groups.

Second prescribed threat for the internal validity of the study was data collector characteristics and data collector bias. In order to control them, the teachers (data collectors) were trained to ensure standard procedures under which the data were collected. Furthermore, the researcher's observation in both groups verified that these procedures were standardized in this study.

Thirdly, for eliminating the history and location threats, all of the tests used in this study were administered to all classes approximately at the same time, using the same directions and under the same conditions. Moreover, there was no remarkable difference in the locations of classes in the school that might affect students' performance.

Mortality is one of the most important threads to internal validity to control. Before the administration of the tests all of the students in both groups were informed about the importance of attendance to all of the tests. However a few students were not present in the class on the date of post tests. These students were excluded from the study and missing data analysis was carried out. The variables that have missing values were analyzed for significance and the series mean of the entire subjects (SMEAN) was used to replace the missing data.

The other possible threat to internal validity might be implementation. The researcher trained both of the teachers participated in this study to standardize the conditions under which the treatments were implemented. Each teacher had two classes. Each of the teaching methods was randomly assigned to one class of each teacher. In other words, each teacher gave the classroom instruction for both groups. In this way, it was aimed to minimize the teacher effect. Moreover, researcher observed the classrooms throughout the study. The teacher bias was not recorded for each instruction during these observations.

Confidentiality was not a problem because the names or physical characteristics of students were not used in the study. In addition, they were informed about this situation at the beginning of the treatment.

The lab study performed in the experimental group might also cause a threat for the internal validity. The better performance of experimental group could be because of the novelty of being in the laboratory rather than the specific nature of the treatment. Besides, the control group students could be discouraged because they were not received an opportunity to participate in such an activity. A traditional lab study was conducted in the control group in order to eliminate these effects.

Finally, administration of the pretest might be a threat because of the effect of taking one test may influence the scores of a subsequent test. Since students could remember the questions in pretest, this might reflect their post test performance. However, it is assumed that the pretest would affect both groups equally. In addition, testing is more likely to be a threat when the time between pre and post tests is short. In this study, the pretests were taken before treatment and the posttests were administered after treatment which continued for four weeks.

6.2.2 External Validity

When the researchers apply the findings of a particular study they generalize these findings to people or settings that go beyond the particular people or settings used in the study. The extent to which the results of a study can be generalized from a sample to a population determines the external validity of the study. In thinking about generalizability, both the nature of sample and the environmental conditions, where the study takes place, must be considered. The degree to which a sample represents the population of interest is known population generalizability and the degree to which results of a study can be extended to other settings or conditions is known ecological generalizability (Frankel and Wallen, 1996).

In this study the accessible population was the students enrolled in a private high school in Ankara. The subjects of the study were 88 high school students from four intact tenth grade science classes at one school. Most of the students participated in this study were having high socio-economic status. Moreover, students' ages were ranging from 15 to 17. 58% of the sample was female and 42% of sample was male. Subjects of the study were not randomly selected from accessible population. The use of non-random sampling limited the generalization of the research results. The generalizations of similar populations of students at private high schools might still be acceptable.

For this study, all of the treatments and the instruments were took place in regular classrooms during scheduled class time. The school participated in this study was a private high school. All of the class sizes were around 22 in this study. There were enough desks and one board in those classes. In addition the lightening was also enough in all of them. Since there were possibly no noticeable differences among the environmental conditions for all classes participated in this study, it was believed that all the threats related to the ecological validity were controlled. The results of this study can be generalized to the private schools with similar settings in their classrooms.

6.3 Implications

The implications below are offered taking into account of findings of this study.

1. Modeling instruction investigated in this study based on the laboratory activities which includes students as the active designers and performers of the experiment. Teachers might have difficulty to find such activities to teach particular topics of physics course. A guide book of laboratory activities for modeling instruction can be developed and serve for teacher use.

2. The pre-instructional knowledge of students has a crucial effect on meaningful learning. Therefore teachers should be aware of students'

alternate conceptions about the topic they attempt to teach and how these conceptions were affected by the instruction. For this purpose, they can administer misconception tests, conduct interviews with students, menage a discussion or use Socratic questioning before and after instruction. They should design and if necessary revise the instruction taking into account of these misconceptions.

3. Traditional instruction fails to notice the crucial influence of students' personal naïve beliefs on what they learn. Therefore it also fails to remedy them. Results of the study revealed that modeling instruction was an effective instructional method in remedying students' misconceptions. Students have chance to be both physically and intellectually active in the process of constructing conceptual models through this instruction. Therefore, teachers can adapt and use modeling instruction in different levels and for different topics of physics education.

4. Classroom discussion was used in the modeling instruction in order to disclose students' different ideas at the beginning and to get their ideas together for a consensus at the end. Its role on better results of modeling instruction can not be negated. Students are provided with the opportunity to express their ideas, compare them with others, be aware of their misconceptions, test their predictions and develop new ideas during the discussion. As students use their prior conceptions to understand how the world works and they are confident in them, they would not replace them with new ones willingly. They should be convinced that their views are inaccurate. Discussion is suggested to teachers as an effective and fruitful tool to create cognitive conflict.

5. There is a close relation between the students' perceptions nature of science conceptions and how they use models in making inference about the scientific knowledge in both school and in their daily life. According to

the results of the present study, it may be concluded that students participated in this study held some inconsistent views and misconceptions on nature of science. For this reason, curriculum developers and teachers should value nature of science as an instructional objective.

6. Motivational and affective factors have serious influences on students' learning of title, achievement in course and future decisions. Teachers should not see students as passive receivers of knowledge and they should be aware of crucial role of students' attitudes on their achievement. Therefore, they should prefer the instructional methods that can lead to students' positive attitudes toward physics.

7. The prospective physics teachers should be informed about the teaching strategies based on the conceptual change approach and how effectively to apply these methods. They also learn to design learning environments that give students chance to be intellectually and physically active during the instruction. Modeling instruction can be offered as a good example of these types of instructions. Besides, prospective teachers should be provided with opportunity to try modeling instruction and/or other instructional methods before serving actively. In addition, they should be informed about the history and contemporary philosophies of science. Theoretical teacher education curriculum and practical training programs in universities should be developed regarding these suggestions.

8. Not only the pre-service teachers, but also expert ones need to be aware of new conceptual change based instructional techniques developed by the experts. They could be informed about these techniques and how to apply them in class through in-service training activities prepared and organized by National Ministry of Education.

9. School administrators should encourage physics teachers to apply modeling instruction in their classes. They could arrange workshops on the modeling instruction, its advantages to traditional method, how to design and apply it, etc. They also could lay the groundwork in order that teachers can compare their notes and work collaboratively on designing instructions for different physics topics in different levels.

10. The text books are traditionally used as the main sources of knowledge in schools. They should be revised and designed to introduce the topics regarding students' misconceptions and based on the conceptual change conditions. They should include not only the laws or theories of physics but also the hands on activities about each topic. Students should engage in these activities and their performances should be assessed by the teacher. Teachers could use these performance based assessment in addition to the paper-pencil tests in order to give students semester mark.

11. Results of statistical analysis evidenced that science process skills were strong predictors for the students' understanding of projectile motion concepts. Being aware of students' science process skill levels may help teachers to plan their instruction. They can use the tests prepared for this purpose such as the one conducted in this study.

6.4 Recommendations for Further Researches

The present study has suggested some useful topics for future studies.

1. This research was conducted to investigate the effects of modeling instruction on tenth grade students' understanding of projectile motion concepts and their attitudes towards physics as a school subject. A similar research can be conducted to investigate the effectiveness of modeling

instruction on improving students' understanding of different topics in different grade levels and their attitudes towards specifically those topics.

2. The study was conducted in a private high school in Ankara. Similar research studies can be conducted in different high schools and with a larger sample size to obtain more accurate results and to provide generalization to a bigger population.

3. The effects of modeling instruction and traditional instruction were compared in this study. Future researches can compare modeling method to other types of conceptual change instructions which are laboratory based, or adapted to inquiry or combined with discussions.

4. The treatment continued for four weeks in this study. However, future research could examine the long term effects of modeling instruction on understanding a series of topics which take place in the national physics course program.

5. In addition to treatment, the gender effect on students' understanding of projectile motion concepts and their attitudes towards physics was investigated in this study. Not only gender, but also many other factors might have effect on students' performance. Further research can be conducted to evaluate some of these factors.

6. In this study the sample was secondary school students. It is also important to conduct a study to investigate the views of prospective and active science teachers on epistemology and nature of science.

REFERENCES

Abd-El-Khalick, F. (2004). Over and Over Again: College Students' Views of Nature of Science. In L. B. Flick & N. G. Lederman (Ed.). *Scientific Inquiry and Nature of Science*. (389-425). Netherlands: Kluwer Academic Publishers.

Adams, A. D. & Chiappetta, E. L. (1998). Students' beliefs, attitudes, and conceptual change in a traditional high school physics classroom. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Aikenhead, G. S., Fleming, R.W., & Ryan, A.G. (1989). CDN 5 form of VOSTS. Retrieved March 25, 2006, from http://www.usask.ca/education/people/aikenhead/vosts.pdf

Aikenhead, G. S., Ryan, A.G. (1992). The development of a new instrument: "Views on science-technology-society" (VOSTS). Science Education, 76(5): 477-491.

Baram-Tsabari, A., & Yarden, A. (2008). Girls' biology, boys' physics: Evidence from free-choice science learning settings. *Research in Science Technological Education*, *26*(1).

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining Changing Attitudes in Secondary School Science. *International Journal of Science Education, 30*(8), 1075 – 1093.

Bradford, C. S., Rubba, P. A., Harkness, W. L. (1995). Views about Science-Technology-Society interactions held by college students in general education physics and STS course. Science Education, 79(4), 355-373.

Brewe, E. (2006). Modeling Theory Applied; Modeling Instruction in University Physics. Retrieved November 9, 2007, from http://arxiv.org/abs/physics/0602086v1

Burns, J. C., Okey, J. R., & Wise, K. C. (1985). Development of an integrated process skill test: TIPS II. *Journal of Research in Science Teaching, 22*(2), 169-177.

Caramazza, A., McCloskey, M., & Green, B. (1981). Naive beliefs in "sophisticated" subjects: Misconceptions about trajectories of objects. *Cognition, 9*, 117-123.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). An Experiment is When You Try It and See If It Works: A Study of Grade 7 Students' Understanding of the Construction of Scientific Knowledge. *International Journal of Science Education*, *11*, 514-529

Chambers, S. K., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*, 107-123.

Chi, M. T. H. (2000). Self Explaining: The dual process of generating inferences and repairing mental model. In R. Glaser (Ed.). *Advances in Instructional Psychology*, *5*. (161-238). Mahwah, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H., & Roscoe, R. D. (2002). The Process and Challenges of Conceptual Change. In M. Limon and L. Mason (Ed). *Reconsidering Conceptual Change*. (29-60). Dodrecht, Netherlands: Kluwer Academic Publishers.

Chinn, C. A., & Mahlotra, B. A. (2002). Children's responses to anomalous data: How is conceptual change impeded? *Journal of Educational Psychology, 94,* 327–343.

Chittleborough, G. D., Treagust, D. F., Mamiala, T. L.,& Mocerino, M. (2005). Students' perceptions of the role of models in the process of science and in the process of learning. *Research in Science and Technological Education*, *23*(2), 195-212.

Cho, H., Kahle, J. H., & Nordland, E. H., (1985). An investigation of high school biology textbooks as sources of misconceptions and difficulties in genetics and some suggestions for teaching genetics, *Science Education*, *69*, 707-719.

Clement, J. (1981). Students' preconceptions in introductory physics. *American Journal of Physics, 50*, 66-71.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics*, *50*(1), 66-71.

Clement, J. (1993). Using Bringing Analogies and Anchoring Intuitions to Deal with Students' Misconceptions in Physics. *Journal of Research in Science Education, 30*(1), 1241-1257.

Clement, J. (2000). Model Based Learning as a Key Research Area for Science Education. *International Journal of Science Education, 22*(9), 1041-53.

Cohen, R., Eylon, B., & Ganiel, U. (1983). Potential difference and current in simple electrical circuits: A study of students' concepts. *American Journal of Physics*, *51*(5), 407-412.

Cosgrove, M., & Osborne, R. (1985). Lesson frameworks for changing children's ideas. In R. Osborne and P. Freyberg (Eds.) *Learning in Science: The implications of children's science*. (pp 101-111). Auckland, NZ: Heinemann.

Crano, W. D., & Prislin, R. (2006). Attitudes and persuasion. *Annual Review of Psychology, 57,* 345–374.

Cromley, J. G., & Mislevy, R. J. (2005). Task Templates Based on Misconception Research. PADI Technical Report 6. SRI International, Menlo Park, CA.

Cross, D., Taasoobshirazi, G., Hendricks, S., & Hickey, D. T. (2008) 'Argumentation: A strategy for improving achievement and revealing scientific identities'. *International Journal of Science Education*, 1–25.

Dawson, D. (2000). Upper primary boys' and girls' interest in science: have they changed since 1980. *International Journal of Science Education, 22,* 557 – 570.

de Kleer, J., & Brown, J. (1983). Assumptions and ambiguities in mechanistic mental models. In D. Gentner and A. Stevens (Ed.). *Mental models*. (155-190). Hillsdale, N.J.: Lawrence Erlbaum Associates.

diSessa, A. A. (2002). Why "Conceptual Ecology" is a Good Idea?. In M. limon and L. Mason Ed*). Reconsidering Conceptual Change*. (29-60). Dodrecht, Netherlands: Kluwer Academic Publishers.

Dhingra, K. (2003). Thinking about television science: How students understand the nature of science from different program genres. *Journal of Research in Science Teaching, 40*(2), 234-256.

Doğan Bora, N. Arslan, O., & Çakıroğlu, J. (2006). Lise Öğrencilerinin Bilim ve Bilim İnsani Hakkindaki Görüşleri, Hacettepe Eğitim Fakültesi Dergisi, 31, 32-44.

Dreyfus, A., Jungwirth, E. & Eliovitch, R. (1990). Applying the "Cognitive Conflict" Strategy for Conceptual Change- Some Implications, Difficulties, and Problems. *Science Education, 74*(5), 555-569.

Duit, R. & Treagust, D. F. (1998) Learning in science – from behaviorism towards social constructivism and beyond. In: B. J. Fraser and K. G. Tobin (Ed.) *International handbook of science education, 1.* (3–25). Dordrecht: Kluwer Academic Publishers.

Duit, R., & Treagust, D. F. (2003). Conceptual change: a powerful framework for improving teaching and learning. *International Journal of science education, 25*(6), 671-688.

Duschl, R. A., & Hamilton, R. (1998). Conceptual Change in Science and in the Learning of Science. In: B. J. Fraser and K. G. Tobin (Ed.). *International handbook of science education, 2. (*1047–1065). Dordrecht: Kluwer Academic Publishers.

Dykstra, D. I., & Others (1992). Studying Conceptual Change in Learning Physics. *Science Education*, *76*(6), 615-52.

Etkina, E., Van Heuvelen, A., Brookes, D. T., & Mills, D. (2002). Role of experiments in physics instruction – a process approach. *The Physics Teacher*, *40*, 351-355.

Etkina, E., Warren, A., & Gentile, M. (2006). The Role of Models in Physics Instruction. *The Physics Teacher, 44*(1), 34-39.

Freedman, M. P. (2002). The Influence of Laboratory Instruction on Science Achievement and Attitude towards Science across Gender Differences. Journal of Women and Minorities in Science and Engineering, *8*(2), 191-200.

Francis, L. J. & Greer, J.E. (1999). Measuring attitude toward science among secondary school students: The affective domain. *Research in Science and Technological Education, 17*(2), 219-226.

Frankel, J.R. and Wallen, N.E. (1996). *How to Design and Evaluate Research in Education, (3rd edition).* New York: Mc Grawhill, Inc.

Geban, Ö., Aşkar, P., & Özkan, İ. (1992). Effects of computer simulated experiments and problem solving approaches on high school students. *Journal of Educational Research, 86*, 5-10.

George, R. (2006); A Cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education, 28*(6), 571–589.

Giancoli, D. C. (2005). *Physics: Principles with Applications, (6th edition).* NJ: Pearson Prentice Hall.

Gibson, H. (1998). *Case studies of an inquiry-based science programs' impact on students' attitude towards science and interest in science careers.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. San Diego, CA: (ERIC document Reproduction Service No. ED417980)

Gilbert, J. (1995, April). *The role of models and modelling in some narratives in science learning*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Gilbert, J. K., & Boulter, C. (1998). Learning science through models and modelling. In B. J.Fraser, & K. G. Tobln (Ed.), *International handbook of science education* (53-66). Boston, Mass: Kluwer Academic.

Gilbert, J.K., Watts, D.M., & Osborne, R.J. (1982). Student's conceptions of ideas in mechanics. *Physics Education*, *17*, 62-66.

Gobert, J. D., & Buckley B. C. (2000). Introduction to model-based teaching and learning in science education. *International Journal of Science Education, 22*(9): 891- 894.

Gobert, J.D. & Discenna, J. (1997, March). *The relationship between students' epistemologies and model-based reasoning*. Paper presented at the American Educational Research Association, Chicago, IL.

Gravetter, F. J., & Wallnau, L. B. (2000). *Statistics for the Behavioral Sciences, (5th edition)*. Stamford: Wadsworth Press.

Greca, I. M., & Moreira, M. A. (2000). Mental Models, Conceptual Models and Modeling. *International journal of Science Education*, *22*(1), 1-11.

Green, S. B., Salkind, N. J., & Akey, T. M. (1997). *Using SPSS for Windows: Analyzing and Understanding Data*. New Jersey: Prentice-Hall Inc.

Gunstone, R.F. (1994). The importance of specific science content in the enhancement of metacognition. In P.J. Fensham, R.F. Gunstone and R.T. White (Ed.). *The content of science*. (131-146). London: Falmer.

Guzetti, B. J., Synder, T. E., Glass, G. V., & Gamas, W. S. (1993). Meta-analysis of instructional interventions from reading education and science education to overcome misconceptions. *Reading Research Quarterly, 28*, 116 – 159.

Halloun, I. (1996). Schematic modelling for meaningful learning of physics. *Journal of Research in Science Teaching, 33*, 1019-1041.

Halloun, I. A., & Hestenes, D. (1985). Common sense concepts about motion. *American Journal of Physics*, *53*(11), 1-18.

Hestenes, D. (1987). Toward a Modeling Theory of Physics Instruction. *American Journal of Physics, 55*(5), 440-454.

Hestenes, D. (1997). Modeling Methodology for Physics Teachers. In E. Redish and J. Rigden (Ed.). *Proceedings of the ICUPE: The changing role of the physics department in modern universities, Part 2*. (935-957). American Institute of Physics.

Hestenes, D. (1999). David Hestenes Lectures on Modeling Instruction. Retrieved June 29, 2006, from the Arizona State University, Modeling Instruction Program Web site: http://modeling.asu.edu/modeling-HS.html

Hestenes, D. (2006). Notes for a Modeling Theory of Science, Cognition and Instruction. *Proceedings of the 2006 GIREP Conference: Modeling in Physics Education*, 27, 1-28.

Hestenes, D., Jackson, J., Halloun, I., Dukerich, L., & Swackhamer, G. (2002). *Modeling instruction in high school physics 2002.* Tempe, AZ: Course material for PHS 530: Methods of Physics Teaching I, Arizona State University.

Hestenes, D., & Wells, M. (1992). Mechanics Baseline Test. *The Physics Teacher*, *30*, 159-166.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher*, *30*, 141-158.

Hewson, G. M., & Hewson, P. W. (1983). Effect of Instruction Using Students' Prior Knowledge and Conceptual Change Strategies on Science Learning. *Journal of Research in Science Teaching, 20*(8), 731-743.

Hewson, P. W., Beeth, M. E., & Thorley, R.(1998). Teaching for Conceptual Change. In B. J. Fraser and K. G. Tobin (Ed.), *International handbook of science education.* (199-218). Boston, Mass: Kluwer Academic.

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (1998). *Applied Statistics for the Behavioral Sciences (4th edition)*. New York: Houghton Mifflin Company.

Hope, P. (1994). The laws of cartoon physics. Retrieved October 9, 2005, from http://funnies.paco.to/cartoon.html.

Hynd, C., Alvermann, D., & Qian, G. (1997). Preservice Elementary School Teachers' Conceptual Change about Projectile Motion: Refutation Text, Demonstration, Affective Factors and Relevance, *Science Education*, *81*, 1-27.

Ingham, A. M., & Gilbert, J. K. (1991). The use of analogue models by students of chemistry at higher education level. *International Journal of Science Education*, *13*, 193-202.

Ivarsson, J., Schoultz, J., & Saljö, R. (2002). Map Reading Versus Mind Reading: Revising Children's Understanding of the Shape of the Earth. In M. Limon and L. Mason (Ed). *Reconsidering Conceptual Change*. (77-99). Dordrecht, Netherlands: Kluwer Academic Publishers.

Johnson-Liard, P. N. (1983). *Mental Models*. Cambridge University Press. Melbourne.

Jonassen, D., & Strobel, J. (2005). Model Building fot Conceptual Change. *Interactive Learning Environments*, *13*(1-2), 15-37.

Jones, G., Howe, A. and Rua, M. (2000). Gender differences in students' experiences, interests, and attitudes towards science and scientists. *Science Education*, *2*(84), 180–192.

Jovanovic, J., & King, S. S., (1998). Boys and Girls in the Performance-Based Science Classroom: Who's Doing the Performing? *American Educational Research Journal, 35*(3), 477-496

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry oriented instruction on six graders' views of nature of science. *Journal of Research in Science Teaching*, *39*(7), 551-578.

Kinematics, Falling Bodies and Newton's Laws. In Misconceptions and Preconceptions in Introductory Physics. Retrieved September 25, 2005, from University of Dallas, Comprehensive Conceptual Curriculum for Physics Web site: http://phys.udallas.edu/C3P/Preconceptions.pdf

Klammer, J. (1998). An Overview of Techniques for Identifying, Acknowledging and Overcoming Alternate Conceptions in Physics Education. Klingenstein Project Paper, Teacher College, Colombia University.

Lattery, M. J., & Hewson, P. W. (2006). *Teaching and Learning for Conceptual Change in Physics Education*. NSF REESE Synthesis Research Proposal, 1-15.

Leboutet-Barrell, L. (1976). Concepts of mechanics among young people. *Physics Education*, *11*(7), 462-466.

Lederman, N. G. (2007). Nature of science: past, present, and future, p. 831–880. In S. K. Abell and N. G. Lederman (Ed.), *Handbook of research on science education.* (831-880). Lawrence Erlbaum Associates Publishers, Mahwah, NJ.

Malone, K. (2007). The convergence of knowledge organization, problem-solving behavior, and metacognition research with the Modeling Method of physics instruction – Part II. *Journal of Physics Teacher Education Online, 4*(2), 3-15.

Matthews, M. (1998). The Nature of Science and Science Teaching. In: B. J. Fraser & K. G. Tobin (Ed.) *International handbook of science education, Vol. 2*. (981-1000). Dordrecht, Netherlands: Kluwer Academic Publishers.

Mayer R. E. (2002). Understanding Conceptual Change: A Commentary. In M. Limon and L. Mason (Ed*). Reconsidering Conceptual Change*. (101-111). Dordrecht, Netherlands: Kluwer Academic Publishers.

McCloskey, M. (1983a). Intuitive physics. *Scientific American*, *248*(4), 114-122.

McCloskey, M. (1983b). Naive theories of motion. In: Mental Models, D. Gentner and A. L. Stevens (Ed.). (299-324). Hillsdale, NJ: Lawrence Erlbaum Associates.

McComas, W. (1998). The Principle Elements of the Nature of Science: Dispelling the Myths. In: W. F. McComas (Ed.). *The Nature of Science in Science Education*. (53-70). Dodrecht, Netherlands: Kluwer Academic Publishers.

McComas, W., Clough, M. P., & Almazroa, H. (1998). The Role and Character of The Nature of Science in Science Education. In: W. F. McComas (Ed.). *The Nature of Science in Science Education*. (3-40). Dodrecht, Netherlands: Kluwer Academic Publishers.

McDermott, L. (1993). Guest Comment: How we teach and how students learn-- A mismatch?. *American Journal of Physics. 61*, 295-298.

McLaughlin, S. (2003). Effect of Modeling Instruction on development of Proportional Reasoning I: an empirical study of high school freshmen. Retrieved June 29, 2006, from the Arizona State University, Modeling Instruction Program Web site: http://modeling.asu.edu/modeling/McLaughlinS_PropReas-I_03.pdf

Millar, R., & Kragh, W. (1994). Alternative frameworks or context-specific reasoning? Children's ideas about the motion of projectiles. *School Science Review*, *75*(272), 27-34.

Modeling Cycle. Retrieved June 29, 2006, from the Arizona State University, Modeling Instruction Program Web site: http://modeling.asu.edu/modeling/mod_cycle.html

Modeling Instruction in High School Physics, Chemistry, Physical Science, and Biology. Retrieved June 29, 2006, from the Arizona State University, Modeling Instruction Program Web site: http://modeling.asu.edu/modeling-HS.html

Moss, D. M. (2001). Examining students' conceptions of nature of science. *International Journal of Science Education, 23*(8), 771-790.

Murphy, P. and Whitelegg, E. (2006). Girls in the Physics Classroom: A Review of Research on the Participation of Girls in Physics. London, The Institute of Physics. Retrieved February 13, 2007, from http://www.iop.org/activity/education/Making_a_Difference/Policy/page_22191.html.

Nersessian, N. J. (1995). Should physicists preach what they practice?. *Science and Education*, *4*(3), 203-226.

Norman, D. (1983). *Some observations on mental models*. In D. Gentner and A. Stevens (Ed.). *Mental Models*. (15-34). Hillsdale, NJ: Lawrence Erlbaum.

Nussbaum, E. M., Sinatra, G. M., & Poliquin, A. (2008). Role of Epistemic Beliefs and Scientific Argumentation in Science Learning. *International Journal of Science Education,* 1-23.

Nussbaum, J., & Novick, S., (1982). Alternative frameworks, conceptual conflict and accommodation: toward a principled teaching strategy, *Instructional Science, 11*, 183 – 200.

O.Brien, J. & Porter, G. (1994). Girls and physical science: The impact of a scheme of intervention projects on girls' attitudes physics. *International Journal of Science Education, 16*, 327-341.

Osborne, J. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079

Owen, S., Dickson, D., Stanisstreet, M., & Boyes, E. (2008). Teaching physics: Students' attitudes towards different learning activities. Research in Science and Technological Education, *26*(2), 113-128.

Palmer, D. (2005). A motivational view of constructivist-informed teaching. *International Journal of Science Education, 27*, 1853–1881.

Peters, P. C. (1981). Even honor students have conceptual difficulties with physics, *American Journal of Physics, 50*(6), 501-508.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63*, 167–199.

Planinic, M., Bone W. J., Krsnik, R., & Beilfuss, M. (2006). Exploring Alternative Conceptions from Newtonian Dynamics and Simple DC Circuits: Links between Item Difficulty and Item Confidence. *Journal of Research in Science Teaching*, *43*(2), 150-171.

Posner, J.G., Strike, A.K., Hewson, W.P., & Gertzog, A.W. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change*, Science Education*, *66*, 211-227.

Prescott, A. E. (2004). *Student understanding and learning about projectile motion in senior high school.* Doctoral thesis, Macquarie University, Sydney.

Prescott, A. E., & Mitchelmore, M. (2005). Teaching Projectile Motion to Eliminate Misconceptions. In H. L. Chick, and J. L. Vincent, (Ed.). *Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education*, *4.* (97-104). Melbourne: PME.

Qian, G., & Alverman, D. (1995). Role of Epistemological Beliefs and Learned Helplessness in Secondary School Students' Learning Science Concepts from Text. *Journal of Educational Psychology*, *87*, 282-292.

Read, J. R. (2004). Children's Misconceptions and Conceptual Change in Science Education. Retrieved January 25, 2006, from http://acell.chem.usyd.edu.au/Conceptual-Change.cfm

Reid, N., & Skryabina, E. A. (2003). Gender and physics. *International Journal of Science Education, 25*(4), 509–536.

Reif, F., & Allen, S. (1992). Cognition for interpreting scientific concepts: A study of acceleration. *Cognition and Instruction, 9*(1), 1-44.

Rowlands, S., Graham, T., & McWilliam, P. (2004). Misconceptions of Force: Spontaneous Reasoning or Well-formed Ideas Prior to Instruction. In Noyes, A. (Ed.) *Proceedings of the British Society for Research into Learning Mathematics, 24*(3). (51-56).

Schauble, L., Klopfer, L., & Raghavan, K. (1990). Students' Transitions From an Engineering Model to a Science Model of Experimentation. *Journal of Research in Science Education*, 28, 859-882.

Schober, J. M. (1999). Modeling Instruction in High School Physics. Retrieved July 9, 2006, from http://www.jburroughs.org/science/mschober/com/modeling.html

Schwaz, C., & Gwekwerere, Y. (2007). Using a Guided Inquiry and Modeling Instructional Framework (EIMA) to Support Preservice K-8 Science Teaching. *Science Education, 91*(1), 158-186.

Sneider, C. I., & Ohadi, M. M. (1998). Unraveling Students' Misconceptions about the Earth's Shape and Gravity. *Science Education, 82*, 265–284.

Songer, N. B., & Linn, M. C. (1991). How do students' views of science influence knowledge integration? *Journal of Research in Science Education, 28*(9), 761–784.

Sprod, T. (1998). "I Can Change Your Opinion on That": Social Constructivist Whole Class Discussions and Their Effect on Scientific Reasoning. *Research in Science Education*, *28*(4), 463-480.

Sutherland, D., & Dennick, R. (2002). Exploring culture, language and the perception of the nature of science. *International Journal of Science Education, 24*(1), 1-25.

Taber, K. S. (2008). Exploring Conceptual Integration in Student Thinking: Evidence from a case study. *International Journal of Science Education*, 1-29.

Tao, P. K., & Gunstone, R. F. (1999). The process of conceptual change in force and motion during computer-supported physics instruction. *Journal of Research in Science Teaching*, *36*, 859-882.

Tao, P. K. (2003). Eliciting and developing junior secondary students' understanding of the nature of science through a peer collaboration instruction in science stories, *International Journal of Science Education, 25* (2), 147-171.

The Modeling Method: a synopsis. Retrieved June 29, 2006, from the Arizona State University, Modeling Instruction Program Web site: http://modeling.asu.edu/modeling/synopsis.html.

Van Zee, E. H, Iwasyk, M., Kurose, A., Simpson, D., &Wild, J. (2001). Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching, 38*(2), 159-190.

Vesenka, J. (2005). Six years of modeling workshops: Three cautionary tales. *Journal of Physics Teacher Education Online, 3*(2), 16-18.

Vesenka, J., Munoz, G., Judd, F., & Key, R. (2002). A comparison between traditional and "modeling" approaches to undergraduate physics instruction at two universities. *Physics Teacher Education Online, 1*(1), 3-7.

Vosniadou, S. (1994). Capturing and Modeling the Process of Conceptual Change. *Learning and Instruction, 4*, 45-69.

Vosniadou, S. (2002). On the nature of naive physics. In M. Limon and L. Mason (Ed.), *Reconsidering conceptual change: Issues in theory and practice*. (61-76). Dordrecht, Netherlands: Kluwer.

Vosniadou, S., & Brewer, W. F. (1992). Mental Meanings of the Earth: A Study of Conceptual Change in Childhood. *Cognitive Psychology, 24*, 535-585.

Vosniadu, S., & Stathopoulou, C. (2007). Conceptual Change in Physics and Physics-Related Epistemological Beliefs: A Relationship under Scrutiny. In S. Vosniadou, A. Baltas and X. Vamvakoussi, (Ed.), *Re-Framing the Conceptual Change Approach in Learning and Instruction*. (145-165). Advances in Learning and Instruction Series, Elsevier Press.

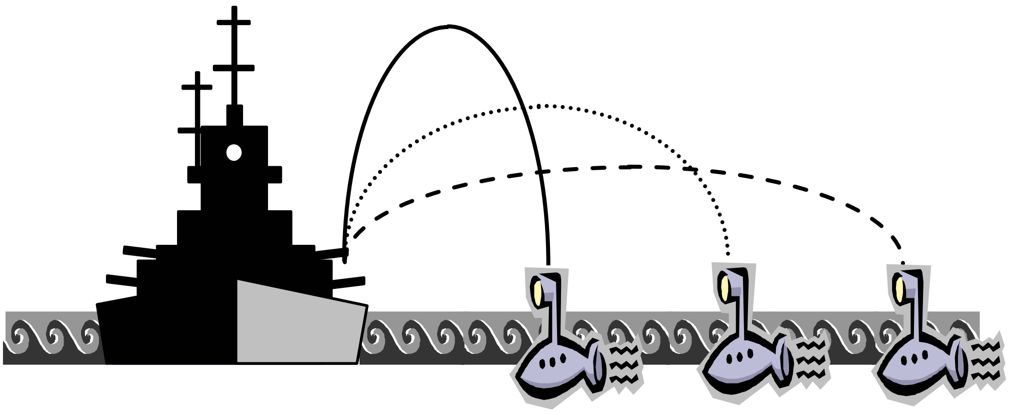
Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32,* 387–398.

Wells, M., Hestenes, D., & Swackhamer, G. (1995). A Modeling Method for High School Physics Instruction. *American Journal of Physics, 63*(7), 606-619.

Wu, C., Dale, N. B., & Bethel, L. J. (1998). Conceptual Models and Cognitive Learning Styles in Teaching Recursion. *SIGSCE Bull., 30*, 1, (292-296).

APPENDIX A:

PROJECTILE MOTION CONCEPT TEST

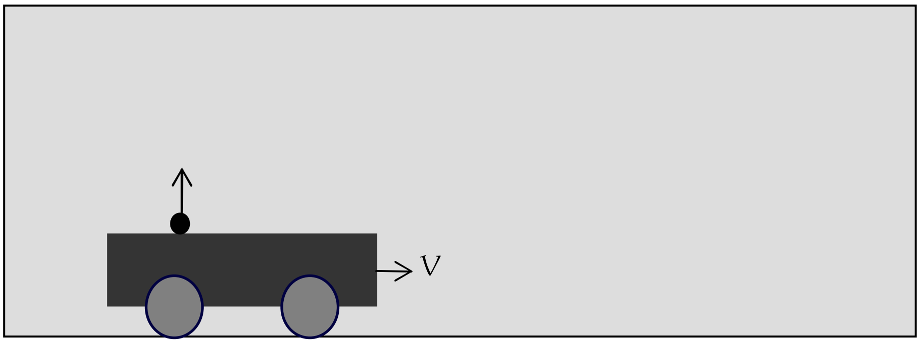


This test is prepared and applied to determine your misconceptions on the concepts of projectile motion. It contains 20 multiple choice questions about the concept. After this application, an instruction that is planned to reduce your misconceptions will be prepared and applied in your lectures.

Please read the questions carefully and sign the appropriate alternative for you. Select just one alternative in each question.

Note: Ignore the air resistance for all questions.

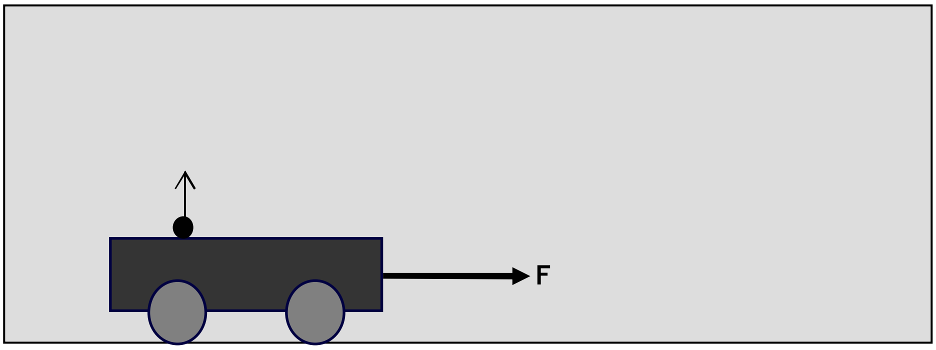
1.



A small car is moving at constant velocity on a flat surface. It fires a ball straight up into the air as it moves. After it is fired, what happens to the ball?

A) it depends on how fast the car is moving
B) it falls behind the car
C) it falls in front of the car
D) it falls right back into the car
E) it can not be estimated

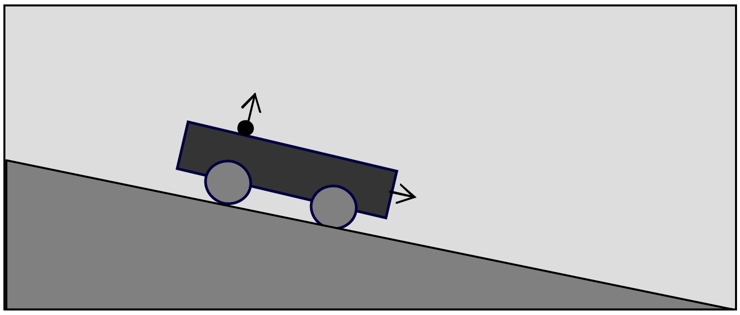
2.



Now the car is being pulled along the horizontal surface by an external force. Again a ball is fired straight out of the cannon as it moves. After it is fired, what happens to the ball?

A) it depends on how fast the car is moving
B) it falls behind the car
C) it falls in front of the car
D) it falls right back into the car
E) it can not be estimated

3.



The same small cart is now rolling down an inclined track and accelerating. It fires a ball straight out of the cannon as it moves. After it is fired, what happens to the ball?

A) it depends on how fast the car is moving

B) it falls behind the car

C) it falls in front of the car

D) it falls right back into the car

E) it can not be estimated

4. A projectile is launched from the ground at an angle of 30°. At what point in its trajectory does this projectile have the least speed?

A) just after it is launched

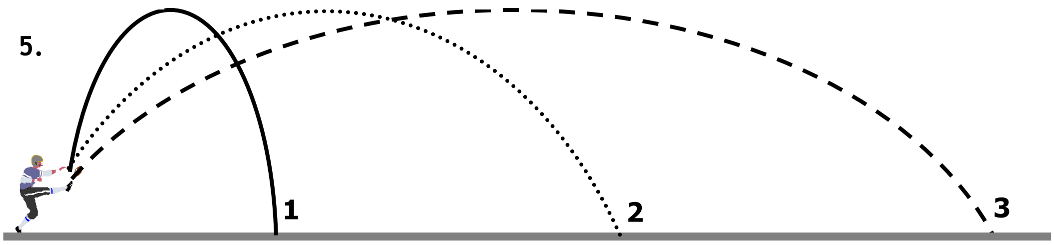
B) at the highest point in its flight

C) just before it hits the ground

D) halfway between the ground and the highest point

E) speed is always constant

5.



Three punts are reaching the same height. Which of them hits the ground firstly?

A) 1

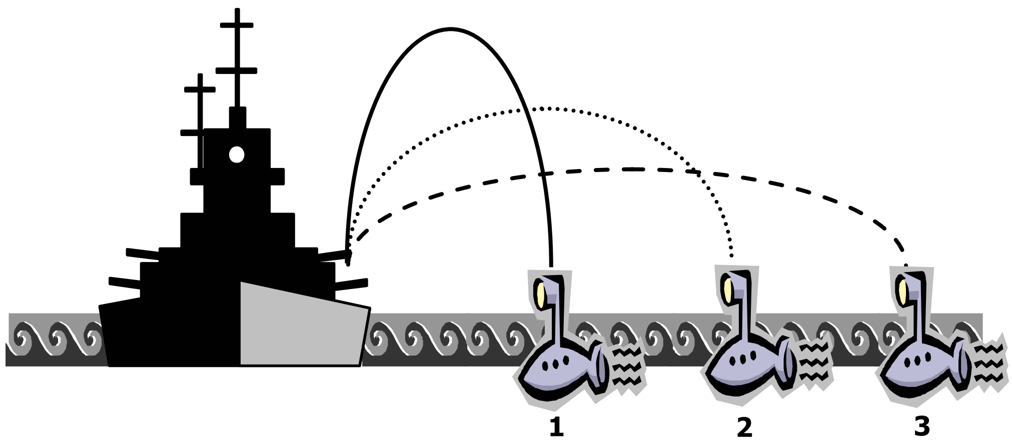
B) 2

C) 3

D) all have the same hang time

E) we can not know

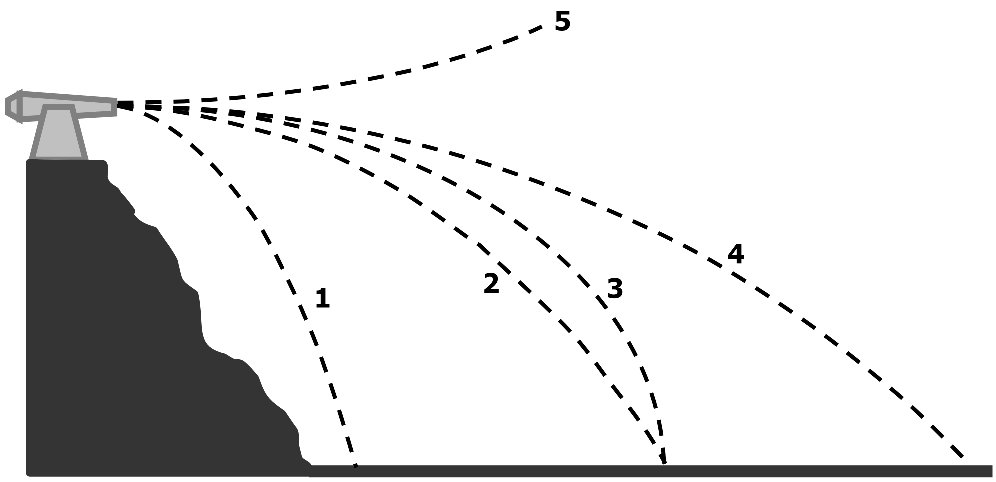
6.



A battleship simultaneously fires three shells at three enemy submarines. The shells are launched with the same initial velocity. If the shells follow the trajectories shown, which submarine gets hit first?

A) 1
B) 2
C) 3
D) all at the same time
E) it depends on how far away they are from the ship

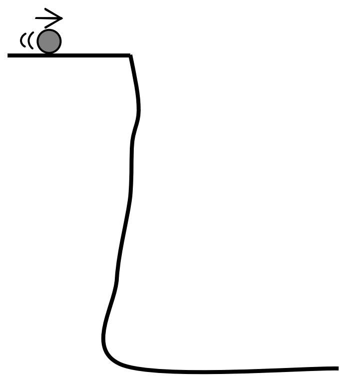
7.



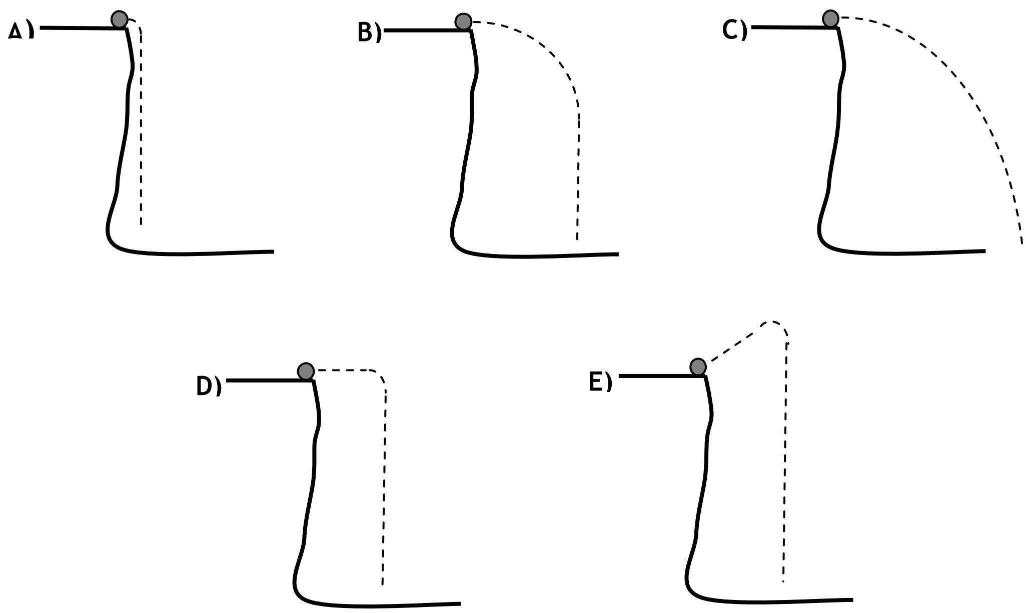
For the cannon on Earth, the cannonball would follow path 2. Instead, if the same cannon were on the Moon, where gravitational acceleration is smaller, which path would the cannonball take in the same situation?

A) 1 B) 2 C) 3 D) 4 E) 5

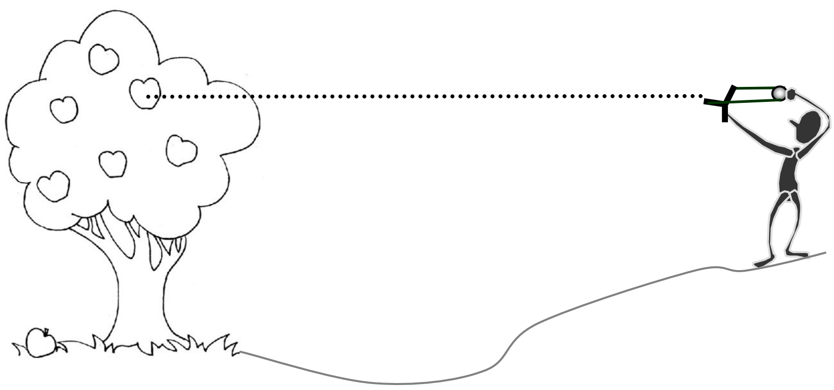
8.



The diagram shows a side view of a cliff. The top of the cliff is frictionless (in other words, perfectly smooth). A metal ball is sliding along the top of the cliff at a constant speed of 20 meter per second. Select the path the ball will follow after it goes over the edge of the cliff.



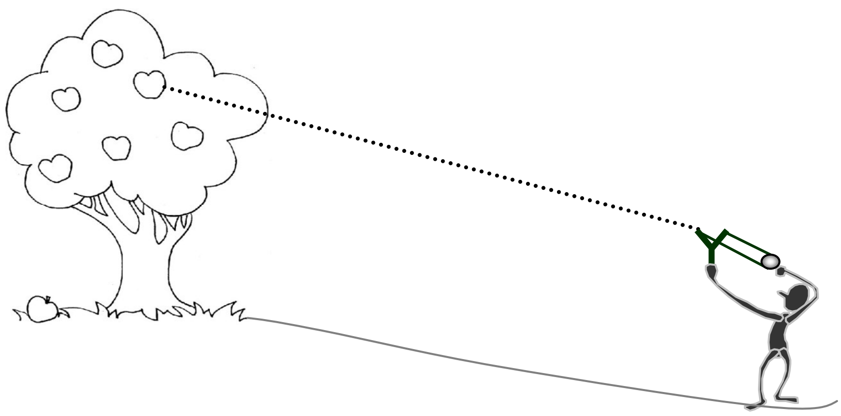
9.



You are trying to hit an apple on the tree with a stone. It is at your level. You aim straight at apple and shoot. Just when you shoot, it falls down from the tree! Does your stone hit it?

A) yes, it hits
B) maybe – it depends on the speed of the shot
C) maybe – it depends on the speed of the apple
D) no, it misses
E) not really sure

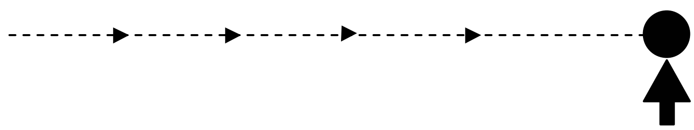
10.



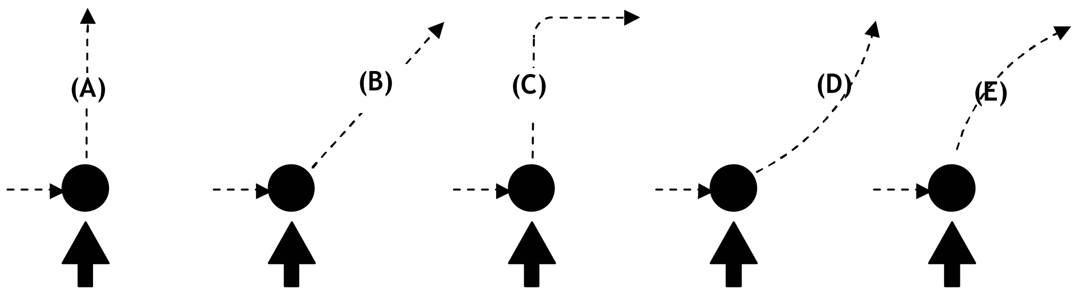
You are trying to hit an apple on the tree with a stone. It is above your position. You aim straight at apple and shoot. Just when you shoot, it falls down from the tree! Does your stone hit it?

A) yes, it hits
B) maybe – it depends on the speed of the shot
C) maybe – it depends on the speed of the apple
D) no, it misses
E) not really sure

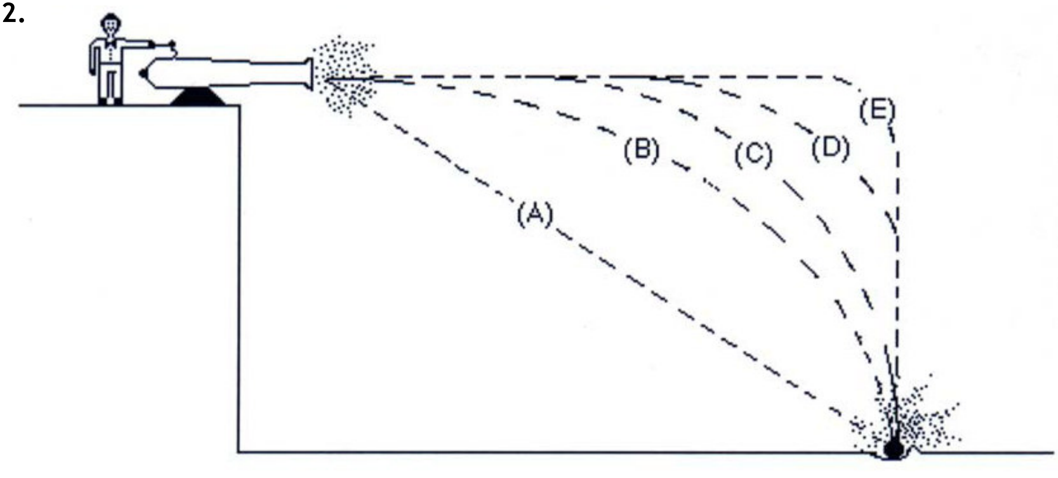
11.



The figure depicts a hockey puck sliding with constant speed in a straight line from point “a” to “b” on a frictionless horizontal surface. You are looking down on the puck. When the puck reaches point “b”, the constant force shown with heavy printed arrow begins to be exerted. (The force is applied for a few minutes). Which of the paths below would the puck most closely follow just after point “b”?

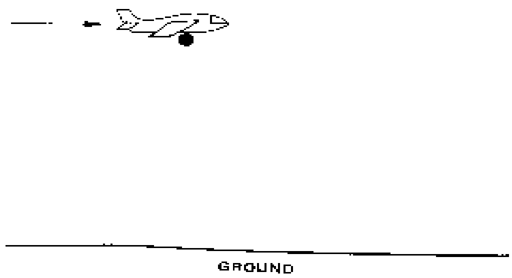


12.



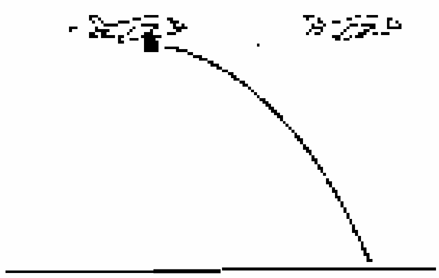
A ball is fired by cannon from the top of a cliff as shown in the figure. Which of the paths would the cannon ball closely follow?

13.

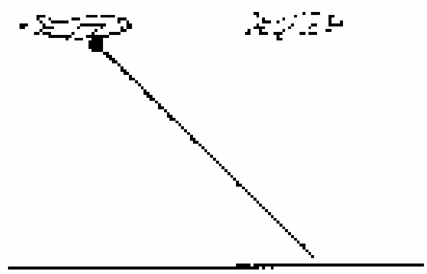


In the diagram, an airplane is flying along at a constant speed. The plane is also flying at a constant altitude, so that its flight path is parallel to the ground. When the plane is in the position shown in the diagram a large metal ball is dropped from the plane. The plane continues flying at the same speed in the same direction and at the same altitude. Select the path the ball will follow from the time it is dropped until it hits the ground. (Ignore wind)

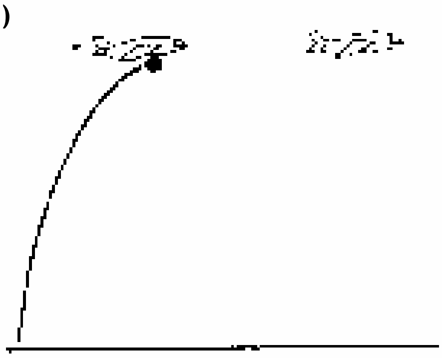
A)



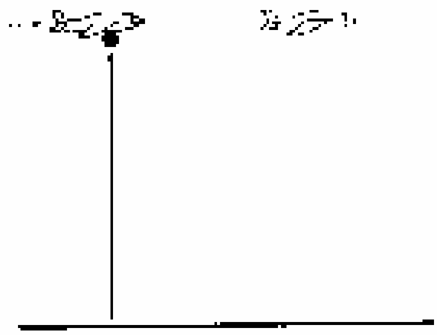
B)



C)



D)



E) It depends on the velocity of airplane.

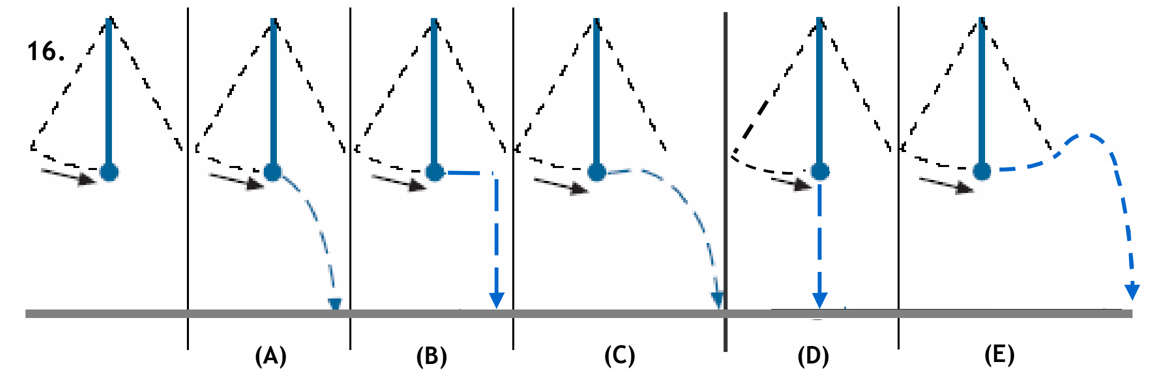
14. This time, from the *same* height (and at the *same* time), one ball is dropped and another ball is fired horizontally from the plane flying in above question. Which one will hit the ground first?

A) the "dropped" ball
B) the "fired" ball
C) they both hit at the same time
D) it depends on how hard the ball was fired
E) it depends on in which direction the ball was fired

15. In the previous problem, which ball has the greater velocity at ground level (assume that the ball is fired in the direction of flight)?

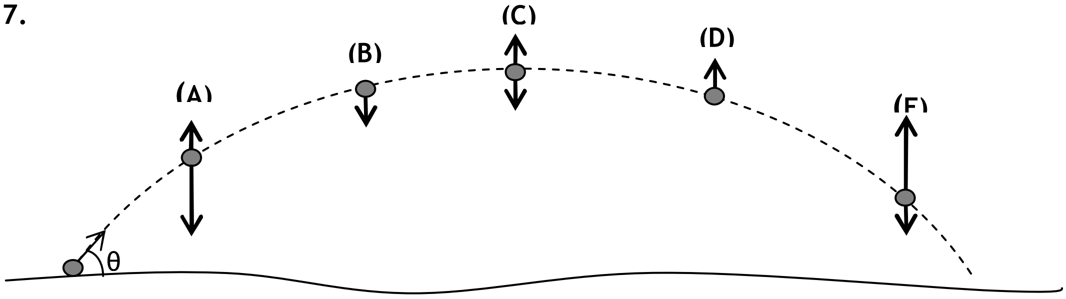
A) the "dropped" ball
B) the "fired" ball
C) neither – they both have the same velocity on impact
D) it depends on how hard the ball was fired
E) it depends on the velocity of plane

16.



The diagram represents a side view of a metal ball swinging back and forth at the end of a string. When the ball is in the position shown in first figure and moving from left to right, the string is cut. Which of the above figures does show the correct path the ball will follow as it falls to the ground?

17.



A ball is thrown as seen in figure. In which alternative are the forces applied on ball shown correctly?

18. When the ball in above question reaches its maximum height, how does its speed compare to its initial speed?

A) It is zero
B) It is less than its initial speed
C) It is equal to its initial speed
D) It is greater than its initial speed
E) It depends on how big the initial speed is

19. Ignoring air resistance, the acceleration of the ball in above question is

A) zero
B) constant but nonzero
C) continuously increasing
D) continuously decreasing
E) irregular

20. What should be the throwing angle (θ) in order ball to travel the greatest distance before landing?

A) 15^0 B) 25^0 C) 45^0 D) 60^0 E) 75^0

APPENDIX B:

BİLİMSEL İŞLEM BECERİ TESTİ

AÇIKLAMA:

Bu test, özellikle Fen ve Matematik derslerinizde ve ilerde üniversite sınavlarında karşınıza çıkabilecek karmaşık gibi görünen problemleri analiz edebilme kabiliyetinizi ortaya çıkarabilmesi açısından çok faydalıdır. Bu test içinde, problemdeki değişkenleri tanımlayabilme, hipotez kurma ve tanımlama, işlemsel açıklamalar getirebilme, problemin çözümü için gerekli incelemelerin tasarlanması, grafik çizme ve verileri yorumlayabilme kabiliyetlerini ölçebilen sorular bulunmaktadır. Her soruyu okuduktan sonra kendinizce uygun seçeneği yalnızca cevap kağıdına işaretleyiniz.

Bu testin orijinali James R. Okey, Kevin C. Wise ve Joseph C. Burns tarafından geliştirilmiştir. Türkçeye çevrisi ve uyarlaması ise Prof. Dr. İlker Özkan, Prof. Dr. Petek Aşkar ve Doç. Dr. Ömer Geban tarafından yapılmıştır.

1. Bir basketbol antrenörü, oyuncuların güçsüz olmasından dolayı maçları kaybettiklerini düşünmektedir. Güçlerini etkileyen faktörleri araştırmaya karar verir. Antrenör, oyuncuların gücünü etkileyip etkilemediğini ölçmek için aşağıdaki değişkenlerden hangisini incelemelidir?

a. Her oyuncunun almış olduğu günlük vitamin miktarını.
b. Günlük ağırlık kaldırma çalışmalarının miktarını.
c. Günlük antrenman süresini.
d. Yukarıdakilerin hepsini.

2. Arabaların verimliliğini inceleyen bir araştırma yapılmaktadır. Sınanan hipotez, benzine katılan bir katkı maddesinin arabaların verimliliğini arttığı yolundadır. Aynı tip beş arabaya aynı miktarda benzin fakat farklı miktarlarda katkı maddesi konur. Arabalar benzinleri bitinceye kadar aynı yol üzerinde giderler. Bu çalışmada arabaların verimliliği nasıl ölçülür?

a. Arabaların tipi ile.
b. Her arabanın gittiği mesafe ile.
c. Kullanılan benzin miktarı ile.
d. Kullanılan katkı maddesinin miktarı ile.

3. Bir araba üreticisi daha ekonomik arabalar yapmak istemektedir. Araştırmacılar arabanın litre başına alabileceği mesafeyi etkileyebilecek değişkenleri araştırmaktadırlar. Aşağıdaki değişkenlerden hangisi arabanın litre başına alabileceği mesafeyi etkileyebilir?

a. Arabanın ağırlığı.
b. Motorun hacmi.
c. Arabanın rengi
d. a ve b.

4. Ali Bey, evini ısıtmak için komşularından daha çok para ödenmesinin sebeplerini merak etmektedir. Isınma giderlerini etkileyen faktörleri araştırmak için bir hipotez kurar. Aşağıdakilerden hangisi bu araştırmada sınanmaya uygun bir hipotez <u>değildir</u>?

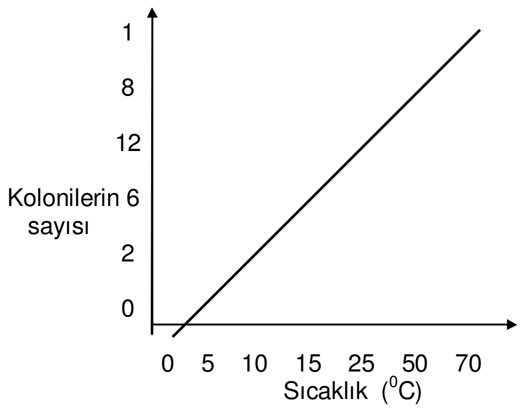
a. Evin çevresindeki ağaç sayısı ne kadar az ise ısınma gideri o kadar fazladır.
b. Evde ne kadar çok pencere ve kapı varsa, ısınma gideri de o kadar fazla olur.
c. Büyük evlerin ısınma giderleri fazladır.
d. Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

5. Fen sınıfından bir öğrenci sıcaklığın bakterilerin gelişmesi üzerindeki etkilerini araştırmaktadır. Yaptığı deney sonucunda, öğrenci aşağıdaki verileri elde etmiştir:

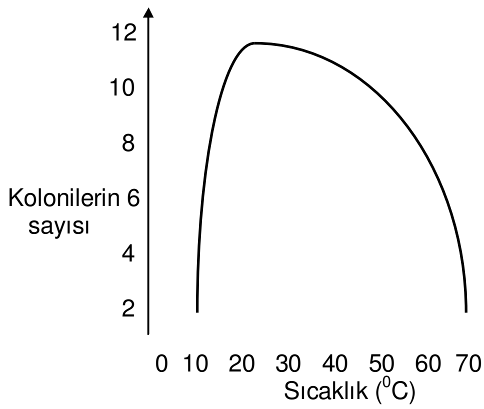
Deney odasının sıcaklığı (^0C)	Bakteri kolonilerinin sayısı
5	0
10	2
15	6
25	12
50	8
70	1

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

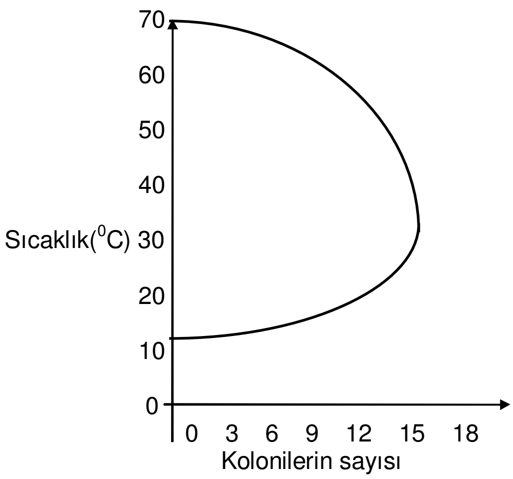
a.



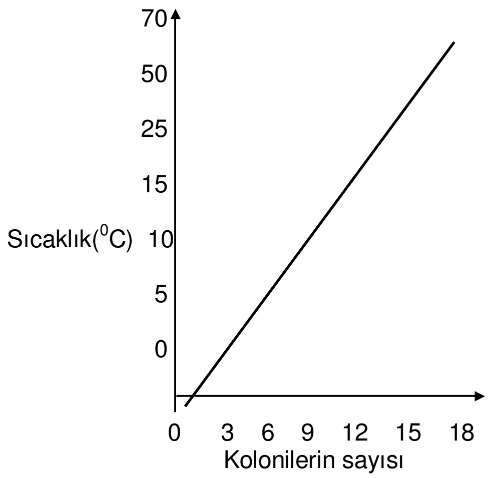
b.



c.



d.



6. Bir polis şefi, arabaların hızının azaltılması ile uğraşmaktadır. Arabaların hızını etkileyebilecek bazı faktörler olduğunu düşünmektedir. Sürücülerin ne kadar hızlı araba kullandıklarını aşağıdaki hipotezlerin hangisiyle sınayabilir?

a. Daha genç sürücülerin daha hızlı araba kullanma olasılığı yüksektir.
b. Kaza yapan arabalar ne kadar büyükse, içindeki insanların yaralanma olasılığı o kadar azdır.
c. Yollarda ne kadar çok polis ekibi olursa, kaza sayısı o kadar az olur.
d. Arabalar eskidikçe kaza yapma olasılıkları artar.

7. Bir fen sınıfında, tekerlek yüzeyi genişliğinin tekerleğin daha kolay yuvarlanması üzerine etkisi araştırılmaktadır. Bir oyuncak arabaya geniş yüzeyli tekerlekler takılır, önce bir rampadan (eğik düzlem) aşağı bırakılır ve daha sonra düz bir zemin üzerinde gitmesi sağlanır. Deney, aynı arabaya daha dar yüzeyli tekerlekler takılarak tekrarlanır. Hangi tip tekerleğin daha kolay yuvarlandığı nasıl ölçülür?

a. Her deneyde arabanın gittiği toplam mesafe ölçülür.
b. Rampanın (eğik düzlem) eğim açısı ölçülür.
c. Her iki deneyde kullanılan tekerlek tiplerinin yüzey genişlikleri ölçülür.
d. Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

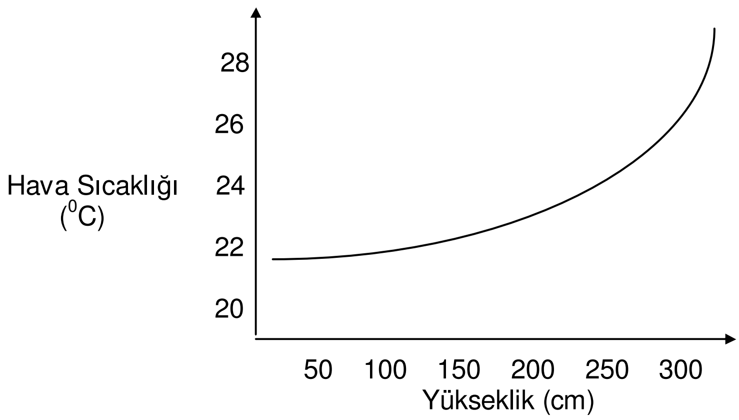
8. Bir çiftçi daha çok mısır üretebilmenin yollarını aramaktadır. Mısırların miktarını etkileyen faktörleri araştırmayı tasarlar. Bu amaçla aşağıdaki hipotezlerden hangisini sınayabilir?

a. Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.
b. Ne kadar çok mısır elde edilirse, k**a**r o kadar fazla olur.
c. Yağmur ne kadar çok yağarsa , gübrenin etkisi o kadar çok olur.
d. Mısır üretimi arttıkça, üretim maliyeti de artar.

9. Ahmet, basketbol topunun içindeki hava arttıkça, topun daha yükseğe sıçrayacağını düşünmektedir. Bu hipotezi araştırmak için, birkaç basketbol topu alır ve içlerine farklı miktarda hava pompalar. Ahmet hipotezini nasıl sınamalıdır?

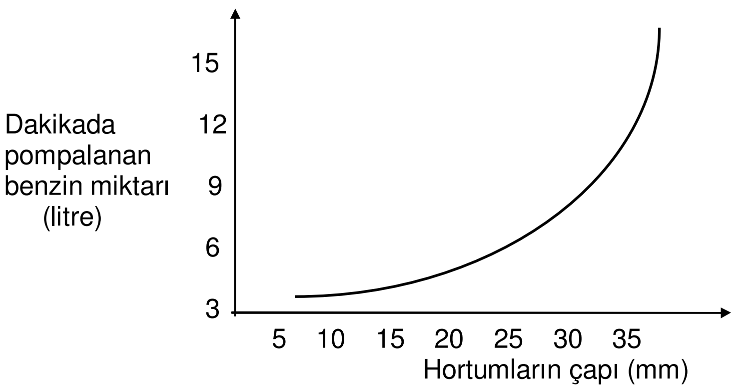
a. Topları aynı yükseklikten fakat değişik hızlarla yere vurur.
b. İçlerinde farlı miktarlarda hava olan topları, aynı yükseklikten yere bırakır.
c. İçlerinde aynı miktarlarda hava olan topları, zeminle farklı açılardan yere vurur.
d. İçlerinde aynı miktarlarda hava olan topları, farklı yüksekliklerden yere bırakır.

10. Bir odada tabandan itibaren değişik yükseklerdeki sıcaklıklarla ilgili bir çalışma yapılmış ve elde edilen veriler aşağıdaki grafikte gösterilmiştir. Değişkenler arasındaki ilişki nedir?



a. Yükseklik arttıkça sıcaklık azalır.
b. Yükseklik arttıkça sıcaklık artar.
c. Sıcaklık arttıkça yükseklik azalır.
d. Yükseklik ile sıcaklık artışı arasında bir ilişki yoktur.

11. Bir tankerden benzin almak için farklı genişlikte 5 hortum kullanılmaktadır. Her hortum için aynı pompa kullanılır. Yapılan çalışma sonunda elde edilen bulgular aşağıdaki grafikte gösterilmiştir.



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

a. Hortumun çapı genişledikçe dakikada pompalanan benzin miktarı da artar.
b. Dakikada pompalanan benzin miktarı arttıkça, daha fazla zaman gerekir.
c. Hortumun çapı küçüldükçe dakikada pompalanan benzin miktarı da artar.
d. Pompalanan benzin miktarı azaldıkça, hortumun çapı genişler.

Önce aşağıdaki açıklamayı okuyunuz ve daha sonra 12, 13, 14 ve 15 inci soruları açıklama kısmından sonra verilen paragrafı okuyarak cevaplayınız.

Açıklama: Bir araştırmada, bağımlı değişken birtakım faktörlere bağımlı olarak gelişim gösteren değişkendir. Bağımsız değişkenler ise bağımlı değişkene etki eden faktörlerdir. Örneğin, araştırmanın amacına göre kimya başarısı bağımlı bir değişken olarak alınabilir ve ona etki edebilecek faktör veya faktörler de bağımsız değişkenler olurlar.

Ayşe, güneşin karaları ve denizleri aynı derecede ısıtıp ısıtmadığını merak etmektedir. Bir araştırma yapmaya karar verir ve aynı büyüklükte iki kova alır. Bunlardan birini toprakla, diğerini de su ile doldurur ve aynı miktarda güneş ısısı alacak şekilde bir yere koyar. 8.00 - 18.00 saatleri arasında, her saat başı sıcaklıklarını ölçer.

12. Araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır?

a. Toprak ve su ne kadar çok güneş ışığı alırlarsa, o kadar ısınırlar.
b. Toprak ve su güneş altında ne kadar fazla kalırlarsa, o kadar çok ısınırlar.
c. Güneş farklı maddeleri farklı derecelerde ısıtır.
d. Günün farklı saatlerinde güneşin ısısı da farklı olur.

13. Araştırmada aşağıdaki değişkenlerden hangisi kontrol edilmiştir?

a. Kovadaki suyun cinsi.
b. Toprak ve suyun sıcaklığı.
c. Kovalara koyulan maddenin türü.
d. Her bir kovanın güneş altında kalma süresi.

14. Araştırmada bağımlı değişken hangisidir?

a. Kovadaki suyun cinsi.
b. Toprak ve suyun sıcaklığı.
c. Kovalara koyulan maddenin türü.
d. Her bir kovanın güneş altında kalma süresi.

15. Araştırmada bağımsız değişken hangisidir?

a. Kovadaki suyun cinsi.
b. Toprak ve suyun sıcaklığı.
c. Kovalara koyulan maddenin türü.
d. Her bir kovanın güneş altında kalma süresi.

16. Can, yedi ayrı bahçedeki çimenleri biçmektedir. Çim biçme makinesiyle her hafta bir bahçedeki çimenleri biçer. Çimenlerin boyu bahçelere göre farklı olup bazılarında uzun bazılarında kısadır. Çimenlerin boyları ile ilgili hipotezler kurmaya başlar. Aşağıdakilerden hangisi sınanmaya uygun bir hipotezdir?

a. Hava sıcakken çim biçmek zordur.
b. Bahçeye atılan gürenin miktarı önemlidir.
c. Daha çok sulanan bahçedeki çimenler daha uzun olur.
d. Bahçe ne kadar engebeliyse çimenleri kesmekte o kadar zor olur.

17, 18, 19 ve 20. soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın her birine 50 şer mililitre su koyar. Bardaklardan birisine 0 ^{0}C de, diğerine de sırayla 50 ^{0}C, 75 ^{0}C ve 95 ^{0}C sıcaklıkta su koyar. Daha sonra her bir bardağa çözünebileceği kadar şeker koyar ve karıştırır.

17. Bu araştırmada sınanan hipotez hangisidir?

a. Şeker ne kadar çok suda karıştırılırsa o kadar çok çözünür.
b. Ne kadar çok şeker çözünürse, su o kadar tatlı olur.
c. Sıcaklık ne kadar yüksek olursa, çözünen şekerin miktarı o kadar fazla olur.
d. Kullanılan suyun miktarı arttıkça sıcaklığı da artar.

18. Bu araştırmada kontrol edilebilen değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.
b. Her bardağa konulan su miktarı.
c. Bardakların sayısı.
d. Suyun sıcaklığı.

19. Araştırmanın bağımlı değişkeni hangisidir?

a. Her bardakta çözünen şeker miktarı.
b. Her bardağa konulan su miktarı.
c. Bardakların sayısı.
d. Suyun sıcaklığı.

20. Araştırmadaki bağımsız değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.
b. Her bardağa konulan su miktarı.
c. Bardakların sayısı.
d. Suyun sıcaklığı.

21. Bir bahçıvan domates üretimini artırmak istemektedir. Değişik birkaç alana domates tohumu eker. Hipotezi, tohumlar ne kadar çok sulanırsa, o kadar çabuk filizleneceğidir. Bu hipotezi nasıl sınar?

a. Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.
b. Her sulamadan bir gün sonra domates bitkisinin boyunu ölçer.
c. Farklı alanlardaki bitkilere verilen su miktarını ölçer.
d. Her alana ektiği tohum sayısına bakar.

22. Bir bahçıvan tarlasındaki kabaklarda yaprak bitleri görür. Bu bitleri yok etmek gereklidir. Kardeşi "Kling" adlı tozun en iyi böcek ilacı olduğunu söyler. Tarım uzmanları ise "Acar" adlı spreyin daha etkili olduğunu söylemektedir. Bahçıvan altı tane kabak bitkisi seçer. Üç tanesini tozla, üç tanesini de spreyle ilaçlar. Bu çalışmada böcek ilaçlarının etkinliği nasıl ölçülür?

a. Kullanılan toz ya da spreyin miktarı ölçülür.
b. Toz ya da spreyle ilaçlandıktan sonra bitkilerin durumları tespit edilir.
c. Her fidede oluşan kabağın ağırlığı ölçülür.
d. Bitkilerin üzerinde kalan bitler sayılır.

23. Ebru, bir alevin belli bir zaman süresi içinde meydana getireceği ısı enerjisi miktarını ölçmek ister. Bir kabın içine bir litre soğuk su koyar ve 10 dakika süreyle ısıtır. Ebru, alevin meydana getirdiği ısı enerjisini bulmak için aşağıdaki ölçümlerden hangisini yapmalıdır?

a. 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kaydetmeli.
b. 10 dakika sonra suyun hacminde meydana gelen değişmeyi ölçmeli.
c. 10 dakika sonra alevin sıcaklığını ölçmeli.
d. Bir litre suyun kaynaması için geçen zamanı ölçmeli.

24. Ahmet, buz parçacıklarının erime süresini etkileyen faktörleri merak etmektedir. Buz parçalarının büyüklüğü, odanın sıcaklığı ve buz parçalarının şekli gibi faktörlerin erime süresini etkileyebileceğini düşünür. Daha sonra şu hipotezi sınamaya karar verir: Buz parçalarının şekli erime süresini etkiler. Ahmet bu hipotezi sınamak için aşağıdaki deney tasarımlarının hangisini uygulamalıdır?

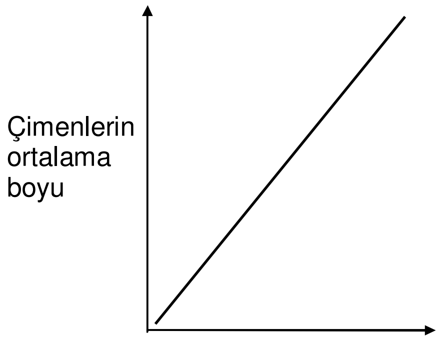
a. Her biri farklı şekil ve ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
b. Her biri aynı şekilde fakat farklı ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
c. Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
d. Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

25. Bir araştırmacı yeni bir gübreyi denemektedir. Çalışmalarını aynı büyüklükte beş tarlada yapar. Her tarlaya yeni gübresinden değişik miktarlarda karıştırır. Bir ay sonra, her tarlada yetişen çimenin ortalama boyunu ölçer. Ölçüm sonuçları aşağıdaki tabloda verilmiştir.

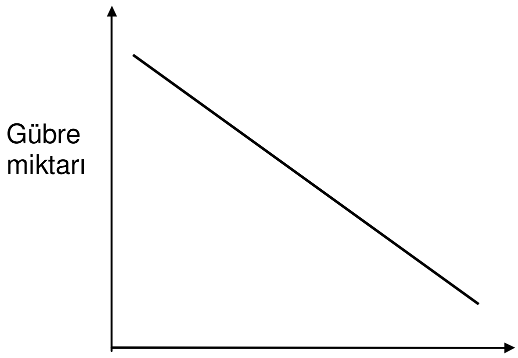
Gübre miktarı (kg)	Çimenlerin ortalama boyu (cm)
10	7
30	10
50	12
80	14
100	12

Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

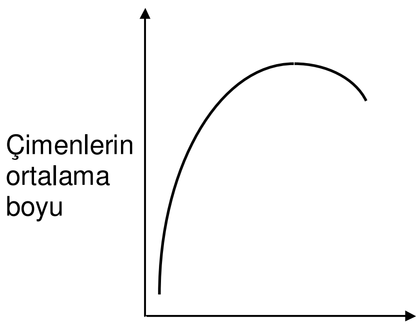
a.



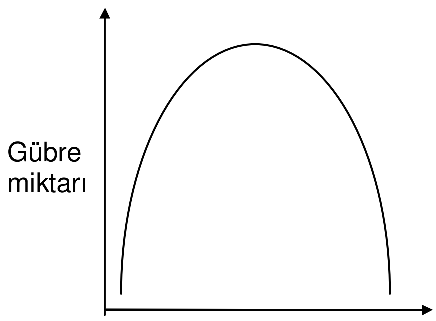
b.



c.



d.



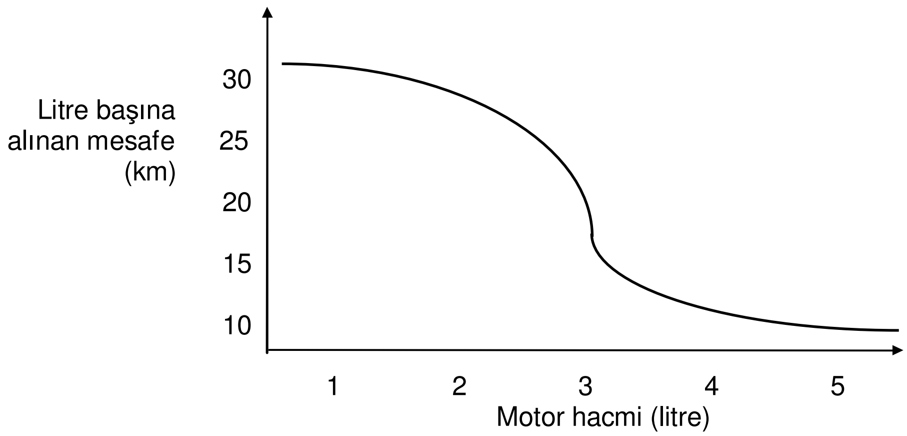
26. Bir biyolog şu hipotezi test etmek ister: Farelere ne kadar çok vitamin verilirse o kadar hızlı büyürler. Biyolog farelerin büyüme hızını nasıl ölçebilir?

a. Farelerin hızını ölçer.
b. Farelerin, günlük uyumadan durabildikleri süreyi ölçer.
c. Her gün fareleri tartar.
d. Her gün farelerin yiyeceği vitaminleri tartar.

27. Öğrenciler, şekerin suda çözünme süresini etkileyebilecek değişkenleri düşünmektedirler. Suyun sıcaklığını, şekerin ve suyun miktarlarını değişken olarak saptarlar. Öğrenciler, şekerin suda çözünme süresini aşağıdaki hipotezlerden hangisiyle sınayabilir?

a. Daha fazla şekeri çözmek için daha fazla su gereklidir.
b. Su soğudukça, şekeri çözebilmek için daha fazla karıştırmak gerekir.
c. Su ne kadar sıcaksa, o kadar çok şeker çözünecektir.
d. Su ısındıkça şeker daha uzun sürede çözünür.

28. Bir araştırma grubu, değişik hacimli motorları olan arabaların randımanlarını ölçer. Elde edilen sonuçların grafiği aşağıdaki gibidir:



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?

a. Motor hacmi ne kadar büyükse, bir litre benzinle gidilen mesafe de o kadar uzun olur.
b. Bir litre benzinle gidilen mesafe ne kadar az olursa, arabanın motoru o kadar küçük demektir.
c. Motor küçüldükçe, arabanın bir litre benzinle gittiği mesafe artar.
d. Bir litre benzinle gidilen mesafe ne kadar uzun olursa, arabanın motoru o kadar büyük demektir.

29, 30, 31 ve 32 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Toprağa karıştırılan yaprakların domates üretimine etkisi araştırılmaktadır. Bir araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki torağa 15 kg, ikinciye 10 kg, üçüncüye ise 5 kg çürümüş yaprak karıştırılmıştır. Dördüncü saksıdaki toprağa ise hiç çürümüş yaprak karıştırılmamıştır.
Daha sonra bu saksılara domates ekilmiştir. Bütün saksılar güneşe konmuş ve aynı miktarda sulanmıştır. Her saksıdan elde edilen domates tartılmış ve kaydedilmiştir.

29. Bu araştırmada sınanan hipotez hangisidir?

a. Bitkiler güneşten ne kadar çok ışık alırlarsa, o kadar fazla domates verirler.
b. Saksılar ne kadar büyük olursa, karıştırılan yaprak miktarı o kadar fazla olur.
c. Saksılar ne kadar çok sulanırsa, içlerindeki yapraklar o kadar çabuk çürür.
d. Toprağa ne kadar çok çürük yaprak karıştırılırsa, o kadar fazla domates elde edilir.

30. Bu araştırmada kontrol edilen değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki torak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

31. Araştırmadaki bağımlı değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki torak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

32. Araştırmadaki bağımsız değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki torak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

33. Bir öğrenci mıknatısların kaldırma yeteneklerini araştırmaktadır. Çeşitli boylarda ve şekillerde birkaç mıknatıs alır ve her mıknatısın çektiği demir tozlarını tartar. Bu çalışmada mıknatısın kaldırma yeteneği nasıl tanımlanır?

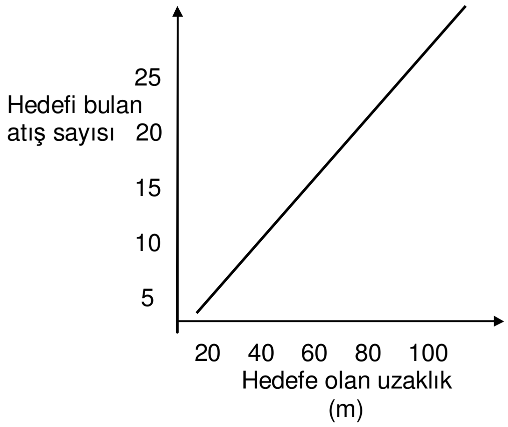
a. Kullanılan mıknatısın büyüklüğü ile.
b. Demir tozlarını çeken mıknatısın ağırlığı ile.
c. Kullanılan mıknatısın şekli ile.
d. Çekilen demir tozlarının ağırlığı ile.

34. Bir hedefe çeşitli mesafelerden 25 er atış yapılır. Her mesafeden yapılan 25 atıştan hedefe isabet edenler aşağıdaki tabloda gösterilmiştir.

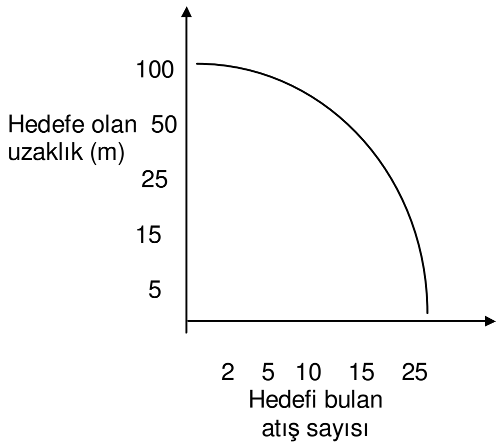
Mesafe(m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

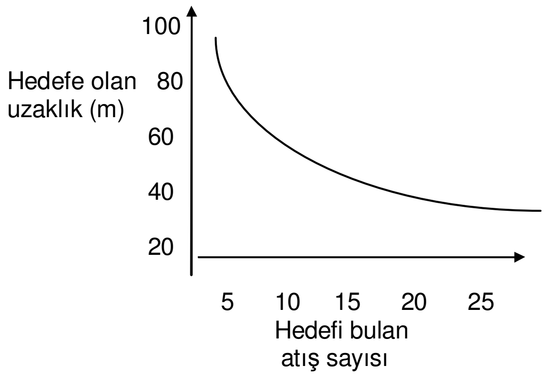
a.



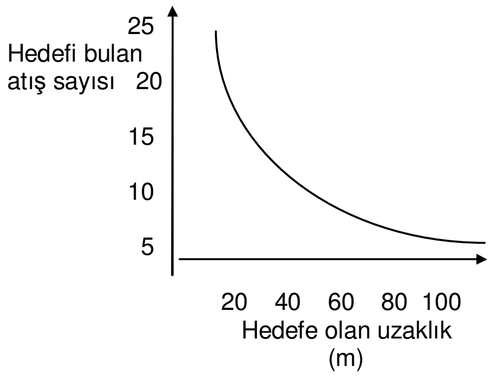
b.



c.



d.



35. Sibel, akvaryumdaki balıkların bazen çok hareketli bazen ise durgun olduklarını gözler. Balıkların hareketliliğini etkileyen faktörleri merak eder. Balıkların hareketliliğini etkileyen faktörleri hangi hipotezle sınayabilir?

a. Balıklara ne kadar çok yem verilirse, o kadar çok yeme ihtiyaçları vardır.
b. Balıklar ne kadar hareketli olursa o kadar çok yeme ihtiyaçları vardır.
c. Suda ne kadar çok oksijen varsa, balıklar o kadar iri olur.
d. Akvaryum ne kadar çok ışık alırsa, balıklar o kadar hareketli olur.

36. Murat Bey'in evinde birçok elektrikli alet vardır. Fazla gelen elektrik faturaları dikkatini çeker. Kullanılan elektrik miktarını etkileyen faktörleri araştırmaya karar verir. Aşağıdaki değişkenlerden hangisi kullanılan elektrik enerjisi miktarını etkileyebilir?

a. TV nin açık kaldığı süre.
b. Elektrik sayacının yeri.
c. Çamaşır makinesinin kullanma sıklığı.
d. a ve c.

APPENDIX C

FİZİK DERSİ TUTUM ÖLÇEĞİ

KİŞİSEL BİLGİLER

1. Adınız, Soyadınız : ___________________________
2. Sınıfınız: ____________
3. Cinsiyetiniz:

O Kız O Erkek

4. Yaşınız: _________

Aşağıda fizik dersine yönelik tutumunuzu ölçme amaçlı ifadeler yer almaktadır. Lütfen cümleleri dikkatlice okuyarak size uygun olan tek bir yanıtı (X) ile işaretleyiniz. Teşekkür ederim.

FİZİK DERSİ TUTUM ÖLÇEĞİ

	Hiç katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Tamamen Katılıyorum
1. Fizik çok sevdiğim bir alandır.					
2. Fizik ile ilgili kitapları okumaktan hoşlanırım.					
3. Fiziğin günlük yaşamda çok önemli yeri yoktur.					
4. Fizik ile ilgili ders problemlerini çözmekten hoşlanırım.					
5. Fizik konuları ile ilgili daha çok şey öğrenmek isterim.					
6. Fizik dersine girerken sıkıntı duyarım.					
7. Fizik derslerine zevkle girerim.					
8. Fizik derslerine ayrılan ders saatinin daha fazla olmasını isterim.					
9. Fizik dersini çalışırken canım sıkılır.					

	Hiç katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Tamamen Katılıyorum
10. Fizik konularını ilgilendiren günlük olaylar hakkında daha fazla bilgi edinmek isterim.					
11. Düşünce sistemimizi geliştirmede Fizik öğrenimi önemlidir.					
12. Fizik çevremizdeki doğal olayların daha iyi anlaşılmasında önemlidir.					
13. Dersler içinde Fizik dersi sevimsiz gelir.					
14. Fizik konularıyla ilgili tartışmaya katılmak bana cazip gelmez.					
15. Çalışma zamanımın önemli bir kısmını Fizik dersine ayırmak isterim.					

APPENDIX D

Bilimin Doğası Hakkındaki Görüşler Anketi T-VOSTS

Sevgili Öğrenciler,

Bu anket, sizlerin bilimin doğası konusundaki düşüncelerinizi anlamak amacı ile hazırlanmıştır. Anket, 25 soru içermektedir ve her sayfaya iki soru gelecek şekilde düzenlenmiştir. Her soru bilimin doğası konusunda bir cümle ile başlamaktadır. Bu cümle genellikle temel bir görüş bildirmektedir. Konu hakkındaki farklı görüş ve durumlar seçeneklerde sıralanmaktadır. Her soru için düşüncenize uyan BİR TEK SEÇENEĞİ işaretleyiniz.

Bu ankette doğru yanıt yoktur. Burada amaç sadece sizin bilimin doğası hakkındaki görüşlerinizi öğrenmektir. Vereceğiniz cevaplar, Orta Öğretim Fen programlarının geliştirilmesinde önemli katkılarda bulunacaktır. Sizlerin görüşleri çok değerlidir. Yardımlarınız için teşekkür ederiz.

Kişisel Bilgiler

Adı Soyadı:
Sınıfı:
Numarası:

1. Bilimi tanımlamak zordur; çünkü bilim, karmaşıktır ve değişik birçok konuyla ilgilenmektedir. ***(Lütfen A' dan H' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

Fakat bilim asıl olarak:

A. Fizik, kimya ve biyoloji gibi konularda çalışmaktadır.
B. Yaşadığımız dünyayı açıklayan prensipler, kanunlar ve teoriler gibi bilgi birikimidir.
C. Dünyamız ve evren hakkında bilinmeyen yeni şeyleri araştırmak, keşfetmektir.
D. Yaşadığımız dünya ile ilgili problemleri çözmek için deneyler yapmaktır.
E. Bir şeyler icat etmek ya da tasarlamaktır (yapay kalpler, uzay araçları gibi).
F. Bu dünyayı daha iyi bir duruma getirmede gerekli olan bilgiyi bulmak ve kullanmaktır (hastalıkları tedavi etmek, kirliliği çözümlemek gibi).
G. Bilim insanlarının yeni bilgileri keşfetmek üzere bir arada oldukları organizasyondur.

H. Hiç kimse bilimi tanımlayamaz.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
..

2. Bazı toplumların, doğa ve insan üzerine belirli görüşleri vardır. Bilim insanları ve bilimsel araştırmalar, çalışmanın yapıldığı yerdeki kültürün ***dînî ya da ahlâkî*** **görüşlerinden** ***etkilenirler. (Lütfen A 'dan G' ye kadar okuyunuz ve sîzin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

Dinî ya da ahlâkî görüşler bilimsel araştırmaları etkiler;

A. Çünkü bazı toplumlar kendi yararları için araştırmaların yapılmasını isterler.
B. Çünkü bilim insanları kendi kültürlerinin bakış açısını destekleyen araştırmaları seçebilirler.
C. Çünkü bilim insanlarının çoğu kendi kültürlerine uymayan araştırmaları yapmazlar.
D. Çünkü her toplumun kültürü yapılan araştırmaların türünü etkiler.
E. Çünkü belirli kültürel inanışı temsil eden güçlü gruplar, belirli araştırma projelerini destekleyecek ya da engelleyecektir.

<u>Dinî ya da ahlâkî görüşler bilimsel araştırmaları etkilemez:</u>

F. Çünkü araştırmalar, bilim insanları ve kültürel gruplar arasındaki tartışmalara rağmen devam eder (Örneğin; evrim).

G. Çünkü bilim insanları kültürel ve ahlaki görüşleri dikkate almaksızın araştırma yapacaklardır.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
...

3. Bazı toplumlar daha çok bilim insanı yetiştiriyor. Bu durum, ailelerin, okulun ve toplumun çocukları *yetiştirme tarzından* kaynaklanmaktadır.
(Lütfen A' dan G' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).

<u>Yetiştirme tarzı çok önemli bir faktördür;</u>

A. Çünkü bazı toplumlar diğerlerine göre bilime daha fazla önem verirler.

B. Çünkü bazı aileler çocuklarını soru sormaya ve meraka teşvik ederler.

C. Çünkü bazı okullar ve öğretmenler öğrencileri daha çok araştırmaya teşvik ederler.

D. Çünkü, aile, okullar ve toplum çocuklara bilimsel beceri kazandırır; bilim insanı olmak için cesaret ve fırsat verir.

E. **Bir şey söylemek zordur.** Yetiştirme tarzı etkilidir, ama kişinin zekâ, yetenek ve bilime olan ilgi gibi özellikleri de önemlidir.

F. **Kimin bilim insanı olacağını belirlemede zekâ, yetenek ve bilime olan doğal ilgi daha etkilidir** .Fakat yetiştirme tarzının da etkisi vardır.

G. **Kimin bilim insanı olacağını belirlemede zekâ, yetenek ve bilime olan doğal ilgi daha etkilidir**.Çünkü insanlar bu özelliklerle doğarlar.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
...

4. Birçok Türk bilim insanı, buluşlarının doğuracağı sonuçların potansiyel etkileriyle (yararlı ve zararlı) ilgilenmektedir. ***(Lütfen A' dan G' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

A. Bilim insanları buluşları gerçekleştirirken, **sadece faydalı yönleri** ile ilgilenirler.
B. Bilim insanları buluşlarının olası **zararlı etkilerini** önlemek için daha fazla çalışırlar.
C. Bilim insanları deneylerinin **bütün etkileri** ile ilgilidirler.
D. Bilim insanları buluşlarının uzun **vadeli etkilerinin tümünü tahmin edemezler.**
E. Bilim insanları buluşlarının tehlikeli amaçlar için kullanılıp kullanılmayacağını **pek fazla kontrol edemezler**.
F. **Buluşların yararlı ve zararlı etkileri bilimin dallarına bağlıdır**. Örneğin, Tıp ve askeri alanlarda çalışan Türk bilim insanları buluşlarının etkileriyle daha çok ilgilenirken, nükleer güç alanında çalışanlar daha az ilgilenirler.

G. Bilim insanları deneylerinin etkilerini dikkate alabilir, fakat bu durum onların, ünleri veya zevkleri için buluş yapmalarını engellemez.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

..
..
..

5. Türkiye'de biyoteknolojinin geleceği üzerine karar verenler, gerçekleri en iyi bildikleri için bilim insanları ve mühendisler olmalıdır (Örneğin: Genleri değiştirilmiş organizmalar, genom projesi, insan kopyalama).
(Lütfen A' dan G' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).

<u>Bilim insanları ve mühendisler karar vermelidir.</u>

A. Çünkü onların bu konuda eğitimleri ve bilgileri vardır.
B. Çünkü bilim insanları bürokratlardan veya özel şirketlerden daha iyi karar verebilirler.

C. Fakat toplum da bilgilendirilerek veya danışılarak bu sürece katılmalıdır.
D. Fakat karar toplumu etkileyeceğinden uzmanların ve bilgilendirilmiş toplumun da görüşleri eşit oranda dikkate alınmalıdır.

E. **Hükümetin** karar vermesi gerekir; çünkü bu konu temelde politiktir.

F. **Halk** karar vermelidir. Çünkü karar herkesi etkileyecektir.

G. **Toplumun** karar vermesi gerekir. Çünkü, bilim insanları ve mühendisler konu hakkında idealist bir bakış açısına sahiplerdir ve bu nedenle sonuçlarına pek fazla dikkat etmezler.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

..
..
..

6. Bilim insanları karşılaştıkları gündelik problemleri en iyi şekilde çözebilirler (örneğin bir arabayı hendekten çıkarma, yemek yapma ya da evcil bir hayvana bakma). ***(Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

<u>Çünkü bilim insanları, diğer insanlardan daha bilgilidirler.</u>

A. Çünkü problem çözme becerileri ve bilgileri bu konuda onlara avantaj sağlar.

<u>Bilim insanları gündelik problemleri çözmede diğer insanlardan daha iyi değillerdir;</u>

B. Çünkü fen bilgisi dersleri herkese yeterli problem çözme becerisi ve bilgisi kazandırır.

C. Çünkü genelde bilim insanlarının aldıkları eğitim günlük sorunları çözmede yardımcı ***<u>olmaz.</u>***

D. Çünkü gündelik yaşamda bilim insanları da herkes gibidir.

E. **Bilim insanları herhangi bir gündelik problemi çözmede büyük bir ihtimalle diğer insanlardan daha kötüdür**, çünkü onlar gündelik yaşamdan uzak olarak çalışırlar.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

..
..
..

7. Başarılı bilim insanları çalışmalarında daima çok *açık fikirli, mantıklı, önyargısız* ve *tarafsızdırlar.* Bu kişisel özellikler bilimi en iyi şekilde uygulamak için gereklidir. *(Lütfen A' dan F' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

Başarılı bilim insanları 'bu özellikleri taşırlar.

A. Aksi halde bilim kötüye gidecektir.
B. Çünkü bu özellikleri ne kadar fazla taşırsanız, bilimi o kadar iyi yaparsınız.

C. **Bu özellikler yeterli değildir.** Başarılı bilim insanlarının hayal gücü, zeka ve dürüstlük gibi diğer kişisel özelliklere de sahip olmaları gerekir.

Başarılı bilim insanlarının bu kişisel özelliklere sahip olması şart değildir;

D. Çünkü bazen en iyi bilim insanları, çalışmalarında sübjektif, önyargılı ve yeni fikirlere açık olmayabilirler.
E. Çünkü bu kişisel olarak bilim insanlarına bağlıdır. Bazıları çalışmalarında daima açık fikirli, tarafsız iken bazıları dar görüşlü ve taraflıdır.

F. **Bilimde başarılı olmak için,** bilim insanlarının bu kişisel özelliklere sahip olması **şart değildir.**

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………………………

8. Çalışmalarıyla, çok yoğun uğraşmaları gerektiğinden *bilim insanlarının ne aile ne de sosyal yaşantıları vardır.* *(Lütfen A 'dan E' ye kadar okuyunuz ve sîzin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

A. Bilim insanlarının başarılı olmak için, çalışmalarıyla çok yoğun uğraşmaları onları ailelerinden ve sosyal hayattan uzaklaştırır.
B. Bu kişiye bağlıdır. Bazı bilim insanları aile ve sosyal etkinliğe vakit ayırırlarken bazıları ayıramazlar.
C. Bilim insanlarının çalışmaları diğer insanlardan farklıdır ama; bu aile ve sosyal yaşantısı olmadığı anlamına gelmez.

<u>Bilim insanlarının aile ve sosyal hayatları normaldir.</u>

D. Bilim insanı için sosyal hayat önemlidir, aksi takdirde çalışma performansı azalır.

E. Çünkü çok az bilim insanı çalışmaları dışında ***<u>her şeyi</u>*** göz ardı edecek kadar işlerine yoğunlaşır.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………

9. Bugün, bilimle uğraşan kadın sayısı eskiye **oranla çok daha fazladır. Bu, yapılan bilimsel buluşlarda bir farka neden olur.** ***(Lütfen A' dan G' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

Kadın ve erkek bilim insanlarının yaptıkları keşifler ***<u>farklı olacaktır;</u>***

A. Çünkü kadın ve erkeklerin ilgi alanları farklıdır (Çocukluklarında farklı oyuncaklarla oynadıkları gibi).

B. Çünkü kadınlar ve erkekler buluş yaparken ihtiyaçlarını göz önünde bulunduracaklardır (Selülit kremi, tıraş makinesi vb).

C. Çünkü doğaları gereği kadınlar farklı hafızaya, içgüdüye ve farklı bakış açılarına sahiptir.

D. **Erkekler kadınlardan daha iyi buluşlar yapabilirler;** çünkü erkekler mühendislik ve mekanik alanlarında kadınlardan daha başarılıdır.

Kadın ve erkek bilim insanlarının yaptıkları keşifler arasında ***<u>fark yoktur;</u>***

E. Çünkü; kadın ve erkek bilim insanları aynı eğitimi alır. Fakat kadınlara geçmişten günümüze kadar, yeterli olanakların verilmemesi, onların bu alandaki yeteneklerinin ortaya çıkışına engel olmuştur.

F. Kadın ve erkek eşit derecede zekidir. Bilimde keşfetmek istedikleri konular açısından kadın ve erkek aynıdır.

G. Buluşları arasındaki herhangi bir fark, aralarındaki bireysel farktan dolayıdır. Bu tür farklar kadın ya da erkek olmakla ilgili değildir.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
..

10. Bilim insanları, araştırmalarına bazı kurumlardan maddi destek almak ve buluşu yapan ilk kişi olmak için yarışırlar. Bazen bu acımasız yarış, bilim insanlarının gizlilik içinde davranmasına, başka bilim insanlarının fikirlerini çalmalarına ve para için kulis yapmalarına yol açar. Diğer bir deyişle, bazen bilim insanları (paylaşma', dürüstlük, bağımsızlık gibi) bilimin kurallarını çiğnerler. ***(Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

Bazen bilim insanları, bilimin kurallarını çiğnerler;

A. Çünkü rekabet ve başarı isteği bilim insanlarını daha sıkı çalışmaya iter.
B. Çünkü kişisel ve parasal ödüllere ulaşmak için her şeyi yapabilirler.
C. Çünkü; onlar için sonuca nasıl ulaşıldığı değil, sonuç önemlidir.

D. Bilim diğer mesleklerden farklı değildir. Bazen bilim insanları da bilimin kurallarını **duruma bağlı olarak çiğnerler.**

E. Birçok bilim insanı birbiriyle iş birliği yapar, **yarışmaz.**

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
..

11. Bilim insanı tenis oynayabilir, partilere gidebilir ya da konferansa katılabilir. Bu *sosyal ilişkiler,* bilim insanının çalışmasını etkileyeceği için bu buluşların içeriğini de etkileyebilir. *(Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

Sosyal ilişkiler bulusun içeriğini etkileyebilir;

A. Çünkü bilim insanları etkileşim içinde oldukları insanların fikirlerinden, deneyimlerinden yararlanır.
B. Çünkü bu ilişkiler, dinçleştirici özelliğiyle bilim insanını canlı tutar.
C. Çünkü bu ilişkiler, bilim insanlarını toplumun ihtiyaçlarıyla ilgili araştırmalar yapmaya teşvik eder.
D. Çünkü bilim insanları bu ilişkilerle, insan davranışlarını ve bilimsel olayları gözleyebilir.

E. **Sosyal ilişkiler buluşun içeriğini etkilemez;** çünkü sosyalleşmeyle bilim insanının çalışması arasında
herhangi bir ilişki yoktur.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.
..
..
..

12. Farklı teorilere inanan başarılı bilim insanlarının yaptıkları gözlemler de farklı olacaktır. *(Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

A. **Evet**, çünkü bilim insanları farklı yöntemler kullanarak yaptıkları deneylerde farklı şeylere dikkat edeceklerdir.
B. **Evet**, çünkü bilim insanları birbirlerinden farklı düşündükleri için gözlemleri de farklı olacaktır.

C. Başarılı bilim insanları farklı teorilere inansalar da bilimsel gözlemleri çok fazla değişmez.

D. **Hayır,** çünkü bilim kesin olan gözlemlerle gelişir.
E. **Hayır,** gözlemler gördüklerimizden başka bir şey değildir ve gerçektir.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

....
....
....

13. Araştırma laboratuarlarında kullanılan birçok bilimsel model (örneğin DNA modeli ve atom modeli) gerçeğin kopyasıdır. ***(Lütfen A' dan G' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

<u>Bilimsel modeller gerçeğin kopyasıdır.</u>

A. Çünkü bilim insanları böyle söyler.
B. Çünkü birçok bilimsel kanıt onların **gerçek** olduğunu kanıtlamıştır.
C. Çünkü onlar **hayatın gerçekleridir.** Amaçlan bize gerçekleri göstermektir.
D. Çünkü onlar bilimsel gözlem ve araştırmalara dayanır.

<u>Bilimsel modeller gerçeğin kopyaları değildir.</u>

E. Çünkü sadece kendi sınırları içinde öğrenme ve açıklamaya yardım ederler.
F. Çünkü onlar da teoriler gibi, zamana ve bilgimizin durumuna göre değişir.
G. Çünkü onlar düşünce ya da tahminlerden oluşur.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

....
....
....

14. Bilim insanları sınıflandırmayı (örneğin türlerine göre bitkileri, periyodik tabloya göre bir elementi vb.) doğaya uygun olarak yaparlar. Bundan *<u>başka bir yol yanlış</u>* olurdu. *(Lütfen A' dan F' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

A. Çünkü; bilim insanları sınıflandırmaların **doğadaki gerçeklerle birebir uyumlu olduğunu** kanıtlamışlardır.
B. Bilim insanları, sınıflandırma yaparken gözlenebilir özellikleri kullandıkları için, **doğadaki gerçeklerle birebir uyar.**
C. Bilim insanları, doğayı en basit ve mantıklı bir şekilde sınıflandırırlar, ama bunun için kullandıkları yol her zaman tek yol değildir.
D. Doğayı sınıflandırmanın birçok yolu vardır, ama bir **evrensel sistem** üzerinde anlaşmak bilim insanlarının çalışmalarındaki karışıklıkları önler.
E. **Doğayı sınıflandırmanın başka doğru yolları da olabilir.** Çünkü bilim, değişikliklere uğrar.
F. **Hiç kimse doğanın gerçek şeklini bilemez.** Bilim insanları, doğayı, algılamalarına göre veya teorilere göre sınıflandırırlar.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.
...
...
..

15. Bilim insanları tarafından yapılan araştırmalar doğru olarak yapılsa bile, araştırma sonunda vardıkları bulgular gelecekte *değişebilir. (Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

A. **Bilimsel bilgi değişir;** çünkü, bilim insanları yeni teknikleri ve geliştirilmiş araçları kullanarak, kendilerinden önceki bilim insanlarının teorilerini ya da buluşlarını çürütebilirler.
B. **Bilimsel bilgi değişir;** çünkü eski bilgiler yeni buluşların ışığında yeniden yorumlanır. Bilimsel gerçekler değişebilir.

C. **Bilimsel bilgi değişir gibi görünür** ama doğru şekilde yapılan deneyler **değişmez gerçeklere yol açar.**

D. Eski bilgilere yeni bilgiler eklendiği için **bilimsel bilgi değişir gibi görünür.**

E. Bilgiler zamanla değişebilir, ama bilimsel bilgi **kesindir, değişmez.**

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
...

16. Bilimsel düşünceler, hipotezlerden teorilere doğru gelişir; ve sonuçta yeterince güçlülerse, *bilimsel kanun* olurlar. (Lütfen A' dan D' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).

A. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bir hipotez deneylerle test edilir, eğer doğruluğu **kanıtlanırsa** teori olur. Teori uzun zamanda birçok, kez farklı insanlar tarafından test edilip **kanıtlanırsa** kanun olur.

B. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bilimsel düşüncenin gelişmesi için bu mantıklı bir yoldur.

C. **Teoriler kanun olamaz;** çünkü bunlar farklı türdeki düşüncelerdir. Teoriler, kesinliğinden tam olarak emin olunamayan birimsel düşüncelere dayanır ve doğrulukları kanıtlanamaz. Ancak kanunlar sadece gerçeklere dayanır ve %100 kesindir.

D. **Teoriler kanun olamaz;** çünkü bunlar farklı türdeki düşüncelerdir. Kanunlar olguları genel olarak **tanımlar.** Teoriler ise bu kanunları **açıklar.** Ancak destekleyici kanıtlarla, hipotezler teorilere veya kanunlara dönüşebilirler.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
...

17. Bilim insanlarının, yeni teorileri ya da kanunları geliştirirken, doğa hakkında bazı tahminler yapmaları gereklidir (örneğin: maddeler atomlardan oluşur). Bilimin düzenli bir şekilde gelişmesi için bu tahminler doğru olmak zorundadır. ***(Lütfen A' dan F' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

<u>Bilimin gelişmesi için bu tahminler doğru olmalıdır;</u>

A. Çünkü doğru teori ve kanunlar için doğru tahminler gereklidir. Aksi halde çok fazla zaman ve çaba boşa harcanabilir.

B. Aksi halde toplum, yetersiz teknoloji ve tehlikeli kimyasal maddeler gibi ciddi problemlerle karşı karşıya kalır.

C. Çünkü bilim insanları çalışmalarını ilerletmeden önce, tahminlerinin doğru olduğunu kanıtlamak için araştırma yaparlar.

D. **Bilimin gelişmesi için tahminlerin doğru olması gerekir düşüncesi duruma göre değişir.** Tarihin, bir teorinin **çürütülmesi** veya onun **yanlış tahminlerinin** öğrenilmesi ile büyük buluşların oluştuğunu gösterdiği olmuştur.

E. **Bilimin gelişmesi için tahminlerin doğru olup olmaması sorun değildir.** Bilim insanları, projelerine başlamak için doğru ya da yanlış tahminler yapmak zorundadırlar.

F. Bilim insanları varsayımlarda **bulunmazlar.** Onlar, bir fikrin doğru olup olmadığını öğrenmek için araştırırlar.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

....
....
....

18. İyi bilimsel teoriler, gözlemleri iyi bir şekilde açıklar. Aynı zamanda iyi teoriler, karmaşık değil basit olurlar.
(Lütfen A' dan F' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).

A. İyi teoriler **basit** olurlar. Bilimde kullanılacak en iyi dil basit ve kısa olandır.

B. Bu ne derecede **derin** açıklamalar yapmak istediğinize bağlıdır, hem basit hem de karmaşık bir yolla açıklayabilir.

C. **Bu, teoriye** bağlıdır. Bazı iyi teoriler basit, bazıları ise karmaşık olabilir

D. İyi teoriler karmaşık olabilir, ama kullanılacaklarsa **basit ve anlaşılabilir** olmalıdır.

E. Teoriler genellikle **karmaşıktır.** Bazı şeyler, eğer birçok ayrıntı içeriyorsa basitleştirilemez.

F. İyi teorilerin çoğu **karmaşıktır.** Eğer dünya daha basit olsaydı, teoriler de daha basit olabilirdi.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

....
....

19. En iyi bilim insanları bilimsel yöntem basamaklarını izleyenlerdir. ***(Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).***

A. Çoğu bilim insanı, geçerli, açık, mantıklı ve kesin sonuçlar sağlaması nedeniyle ***bilimsel yöntemi*** izler.

B. Okulda öğrendiğimize göre, bilimsel yöntem birçok bilim insanı için uygun olandır (problemi tespit etmek, veri toplamak, hipotez kurmak, kontrollü deney yapmak vs.)

C. En iyi bilim insanları bilimsel yöntemin yanında özgünlük ve yaratıcılığı da kullanacaklardır.

D. En iyi bilim insanları hayal gücü ve yaratıcılığı içeren, ***herhangi bir yöntemle*** sonuca ulaşabilirler.

E. Birçok bilimsel keşif, bilimsel yönteme bağlı kalmadan ***tesadüfen*** keşfedilmiştir.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

....
....
....

20. Bilim insanları çalışmalarında hata yapmamalıdır, çünkü bu hatalar bilimin ilerlemesini *yavaşlatır. (Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

A. **Hatalar bilimin ilerlemesini yavaşlatır.** , Eğer bilim insanları sonuçlarındaki hataları anında düzeltmezlerse bilim ilerlemez.
B. **Hatalar bilimin ilerlemesini yavaşlatır.** Yeni teknoloji ve araçlar, doğruluğu artırarak hataları azaltır ve böylece bilim daha hızlı gelişir.
C. **Hatalardan kaçınılamaz;** bu nedenle bilim insanları birbirlerini kontrol ederek hataları azaltırlar.
D. Bazı hatalar bilimin ilerlemesini yavaşlatabilir, ama bazı hatalar yeni veya büyük bir buluşa neden olabilir.
E. Hatalar genellikle bilimin ilerlemesine **yardım** eder. Bilim, geçmişin hatalarını tespit edip düzelterek ilerler.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………

21. Bilim insanları ve mühendisler, bize, doğru bilgilere dayanarak varsayımlar yaparken bile, sadece neyin muhtemel olabileceğini söyleyebilirler. Kesin olarak ne olacağını *<u>söyleyemezle</u>r. (Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

<u>Varsayımlar asla kesin değildir; çünkü,</u>

A. Sonucu etkileyecek, önceden tahmin edilemeyen olaylar ve hata olasılığı her zaman vardır. **Hiç kimse geleceği kesin olarak tahmin edemez.**
B. Yeni buluşlar yapıldıkça, doğru bilgi ve varsayımlar daima değişir.
C. Varsayımlar iyi yapılmış tahminlerdir.
C. Bilim insanları asla tüm gerçeklere sahip değildirler. Bazı bilgiler daima eksiktir.
D. **Duruma bağlıdır.** Varsayımlar ancak doğru ve yeterli bilginin olması halinde kesindir.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………..

22. Bir sanatçı bir heykeli "icat ederken", bir altın madencisinin de altın "keşfettiğini" farz edelim. Bazı insanlar bilim insanlarının bilimsel *KANUNLARI "keyfettiğini",* bazıları ise *"icat ettiklerini"* düşünürler. Siz ne dersiniz? *(Lütfen A 'dan E' ye~ kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz),*

<u>Bilim insanları bilimsel kanunları keşfederler:</u>

A. Çünkü kanunlar her zaman doğada açığa çıkartılmayı bekler.

B. Çünkü kanunlar deneysel **gerçeklere** dayanır.

C. Aynı zamanda bu kanunları bulmak için de **yöntemler** yaratırlar.

D. Bazı bilim insanları, bir kanunu şans eseri bulur. Ancak diğer bilim insanlarda kanunları önceden bildikleri gerçeklere dayanarak icat ederler.

E. **Bilim insanları bilimsel kanunları icat ederler;** çünkü onlar doğanın yaptıklarını değil, doğanın yaptıklarını **tanımlayan** kanunları icat ederler.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

..
..
...

23. Bir sanatçı bir heykeli "icat ederken", bir altın madencisinin de altın "keşfettiğini" farz edelim. Bazı insanlar bilim insanlarının bilimsel *HİPOTEZLERİ "keşfettiğini",* bazıları ise *"icat ettiklerini"* düşünürler. Siz ne dersiniz? *(Lütfen A' dan F' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

<u>Bilim insanları bir hipotezi keşfederler;</u>

A. Çünkü fikir her zaman doğada, açığa çıkartılmayı bekler.

B. Çünkü hipotez deneysel **gerçeklere** dayanır.

C. Aynı zamanda bir hipotezi bulmak için **yöntemler** yaratırlar.

D. Bazı bilim insanları, bir **hipotezi şans eseri bulur.** Ancak diğer bilim insanları da hipotezi önceden bildikleri gerçeklere dayanarak icat ederler.

<u>Bilim insanları bir hipotezi icat ederler;</u>

E. Çünkü bir hipotez, bilim insanlarının keşfetmiş olduğu deneysel gerçeklerin yorumlanmasıdır,

F. Çünkü hipotezler zihinden gelir, onları biz oluştururuz.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
...

24. Bir sanatçı bir heykeli "icat ederken", bir altın madencisinin de altın "keşfettiğini" farz edelim. Bazı insanlar bilim insanlarının bilimsel *TEORİLERİ "keşfettiklerini",* bazıları ise *"icat ettiklerin?'* düşünürler. Siz ne dersiniz? *(Lütfen A' dan F' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).*

<u>Bilim insanları bir teoriyi keşfederler;</u>

A. Çünkü fikir her zaman doğada açığa çıkartılmayı bekler.
B. Çünkü bir teori deneysel **gerçeklere** dayanır.
C. Aynı zamanda bu teorileri bulmak için **yöntemleri** yaratırlar

D. Bazı bilim insanları, bir teoriyi şans eseri bulur. Ancak diğer bilim insanları da teoriyi önceden
bildikleri gerçeklere dayanarak icat ederler.

<u>Bilim insanları bir teoriyi icat ederler;</u>

E. Çünkü bir teori, bilim insanlarının keşfetmiş olduğu deneysel gerçeklerin yorumlanmasıdır.
F. Çünkü teoriler zihinden gelir, onları biz oluştururuz.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

...
...
...

25. **Farklı alanlardaki bilim insanları, aynı şeye çok farklı açılardan bakarlar (örneğin, H^+ kimyagerlerin asit oranını, fizikçilerin protonları düşünmelerine sebep olur). Bu, farklı alanlarda çalışan bilim insanlarının birbirlerinin çalışmalarını anlamalarını *zorlaştırır.***

(Lütfen A' dan E' ye kadar okuyunuz ve sizin görüşünüze uygun olan bir seçeneği işaretleyiniz).

Farklı alanlardaki bilim insanlarının birbirlerini anlamaları zordur;-

A. Çünkü bilimsel düşünceler, bilim insanlarının **bakış açısına** veya onların alışkanlıklarına bağlıdır.

B. Çünkü bilim insanları farklı alanlarda farklı dil kullanırlar.

Farklı alanlardaki bilim insanlarının birbirlerini anlamaları oldukça kolaydır;

C. Çünkü bilim insanları zekidir, diğer alanların dillerini öğrenmenin yollarını bulabilirler.

D. Çünkü bilim insanları aynı anda değişik alanlarda çalışmış olabilirler.

E. Çünkü farklı alanlardaki bilimsel düşünceler kesişir. Gerçekler bilimsel alan ne olursa olsun gerçektir.

Yukarıda size uygun bir seçenek yoksa, lütfen bu konudaki görüşlerinizi aşağıdaki boşluğa yazınız.

....

....

....

APPENDIX E

INSTRUCTIONAL OBJECTIVES

GOAL 1: The learner will build an understanding of projectile motion.

At the end of the cycle, students will be able to

1. evaluate the motion of a projectile both horizontally and vertically.
2. recognize that the horizontal component of velocity does not change (neglecting air resistance).
3. recognize that the vertical component of velocity changes due to gravitational acceleration.
4. describe the similarities between vertical component of projectile motion launched horizontally and free fall.
5. select appropriate measurements for an investigation of projectile motion.
6. identify factors that may affect results.
7. predict the path of the projectile
8. measure the path of the projectile including horizontal range, maximum height, and time in flight
9. recognize that vector components are independent of each other.
10. apply the equations of uniform velocity to the horizontal component.
11. To apply the equations of accelerated motion to the vertical component of velocity.
12. relate height, time in air and initial vertical velocity (such as a projectile launched horizontally or from the ground at a given angle).

13. relate horizontal distance of projectile, time in air and initial horizontal velocity (such as a projectile launched horizontally or from the ground at a given angle).
14. relate intantanous vertical velocity with time.
15. relate maximum height of a projectile, that is launched from the ground at a given angle, with initial vertical velocity.
16. relate time in flight of a projectile, that is launched from the ground at a given angle to initial vertical velocity.

GOAL 2: The learner will develop abilities necessary to do and understand scientific inquiry.

17. identify questions and problems that can be answered through scientific investigations.
18. design and conduct scientific investigations to answer questions about the physical world.
19. create testable hypotheses.
20. identify variables.
21. use a control or comparison group when appropriate.
22. select and use appropriate measurement tools.
23. collect and record data.
24. organize data into charts and graphs.
25. analyze and interpret data.
26. communicate findings.
27. formulate and revise scientific explanations and models using logic.
28. make inferences and predictions for different situations.

APPENDIX F

HOW TO WRITE A GOOD LAB REPORT

THE FORMAT OF A GOOD LAB REPORT

- ✓ Aim of the Experiment
- ✓ Research Question
- ✓ Hypothesis
- ✓ Key variables
- ✓ Materials (Apparatus)
- ✓ Method
- ✓ Data Collection
- ✓ Data Processing and Presentation
- ✓ Conclusion and Evaluation

AIM OF THE EXPERIMENT

What students are trying to prove by this experiment should be expressed clearly and concisely in a sentence.

To investigate the effect of cross-sectional area and length of a certain kind of conducting wire on its resistance.

RESEARCH QUESTION

The question whose answer is found out by this experiment should be expressed in this title.

How do the length and cross-sectional area of a certain kind of conducting wire affect its resistance?

HYPOTHESIS

This is an educated guess about the solution to the problem based on the scientific knowledge. The students must also defend the hypothesis by their own words in this section.

The resistance of a conducting wire is directly proportional with its length and inversely proportional with its surface area.

KEY VARIABLES

The dependent and independent variables of the study should be stated one by one. Other variables that might affect the outcome should be also mentioned, even if they are not to be specifically investigated.

Cross-sectional area of conducting wire (independent variable)
Length of conducting wire (independent variable)
Resistance of conducting wire (dependent variable)

MATERIALS

The list of materials used in the experiment should be expressed with their kind, size, quantities and some other physical properties. The diagram of the experimental set-up must be appropriate to this list.

- *Five aluminum wires having the same diameter of 2 mm and each of lengths with 0,5m, 1m, 2m, 3m and 4m.*
- *Four aluminum wires having the same length of 1m and each of diameters with 0,5mm, 1mm, 1,5mm, 2mm.*
- *(0-25V) Voltmeter*
- *(0-10A) Ammeter*
- Power supply (0-15V)...

METHOD

- **A realistic and appropriate method that allows for the control of variables and the collection of sufficient data must be designed**

- **Steps of method must be in point (numbered) form**

- **Note wording should be used**

  Correct: Place 100 ml of water in beaker
  Incorrect: I placed 100 ml of water

- **The experimental set up and measurement techniques must be described. If appropriate, a labeled diagram of the apparatus can be used to show how it should be set up**
  Set up the apparatus seen in the Figure

- **If the procedure of the experiment is given to students, they must not rewrite this procedure in the method part of their report**

DATA COLLECTION

All quantitative or qualitative raw data obtained by actual measurements or unaided observations should be presented in this part.

- **Data collection tables should be used to present raw data**

- **Each table should be named and numbered**

- **Accuracy and precision of data should be recorded into table**

- **The number of digits after decimal point should be the same in uncertainties and data**

Table 1: Input and output voltages and currents in different transformers

Record No	N_1	N_2	V_1(V) (±0.5)	V_2(V) (±0.5)	I_1(A) (±0.05)	I_2(A) (±0.05)
1	600	300	12.5	6.0	0.50	0.60
2	600	300	6.0	3.0	0.10	0.30
3	600	300	3.0	1.5	0.05	0.10

N_1: Number of turns in primary coil
N_2: Number of turns in secondary coil
V_1: Potential difference across primary coil
V_2: Potential difference across secondary coil
I_1: Current in primary coil
I_2: Current in secondary coil

DATA PROCESSING AND PRESENTATION

All data collected and presented in Data Collection part are transformed and presented in a form suitable for the evaluation. Processing raw data may include,

- Unit conversion
- Subjecting data to statistical calculations
- Choosing a correct presentation (converting tabulated data into graphs or converting drawings into diagrams)
- Error analysis

CONCLUSION AND EVALUATION

In the CONCLUSION part,

- a final short sentence which is a summary of whole conclusion should be written
- the results of experiment should be analyzed (analysis may include comparisons of different graphs or descriptions of trends shown in graphs)

In the EVALUATION part,

- The theory behind the experiment may be summarized and how this theory agrees with the results and conclusions of the experiment may be expressed
- The method of the experiment (the process, use of equipment and management of time) should be evaluated
- Possible sources of error (such as accuracy of the measurements, assumptions made during the experiment, the variables that can not be taken under control during measurements) should be stated
- Modifications to improve the investigation should be suggested. A better way of doing this experiment in order to get more accurate results must be explained

APPENDIX G

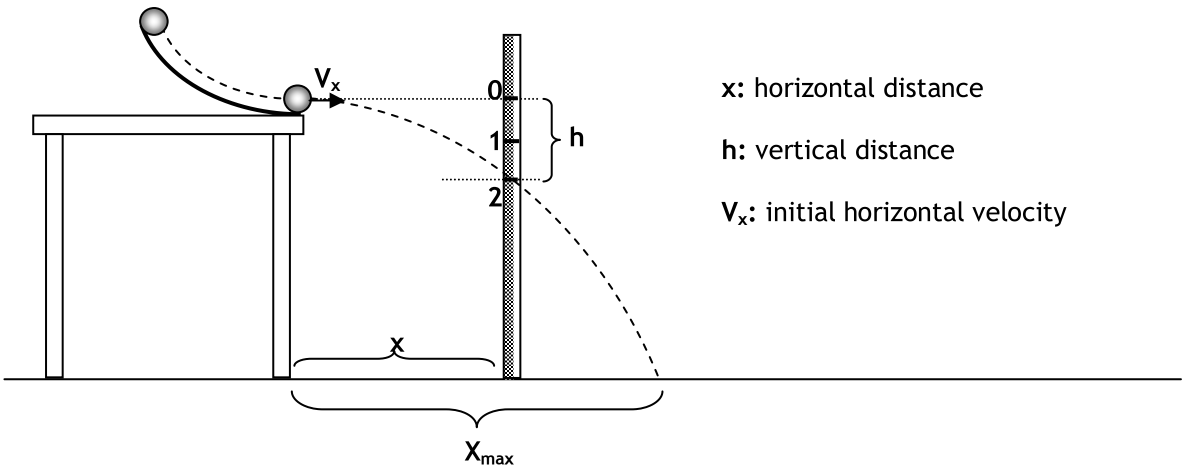
LAB MANUAL FOR TRADITIONAL INSTRUCTION

PROJECTILES

AIM:

To investigate the horizontal and vertical components of motion of an object that is allowed to fall after being released from the ramp.

DIAGRAM:



PROCEDURE:

1. Set up the apparatus as shown above.
2. Place the wooden board in the vertical position so that it is touching the bottom of the ramp. (x=0)
3. Release the ball bearing from the top of ramp so that it accelerates down and makes a mark on carbon paper attached to the wooden board. Sign this mark as "O".
4. Remove board and release the ball from the same place and measure the maximum horizontal distance of ball (X_{max}).
5. Place again the board away from the ramp by a small distance (**x**), which should be shorter than X_{max} and release the ball once again. Sign the mark on carbon paper as "1".
6. Repeat step 5 for two different distances of **x**. shorter than X_{max}.
7. Measure distances **x** and corresponding distances **h** and record these values in Data Table.

Data Table

TRIALS	X (m)	h (m)	t (s)	v_x (m/s)
1				
2				
3				
4	X_{max}=			

DATA PROCESSING:

- Calculate the time for the ball to fall each height by using $h = \frac{1}{2}gt^2$ equation and record them into table above. (Take g=9.8m/s^2)
- Calculate the initial horizontal velocity for the ball for each trial by using $V_x = \frac{x}{t}$ equation and record them into the table above.
  Compare the V_x values you have calculated for each trial. Are they the same or different from each other? Explain the reason for this.

APPENDIX H

PROJECTILE MOTION PROBLEM SET

PROBLEM 1:

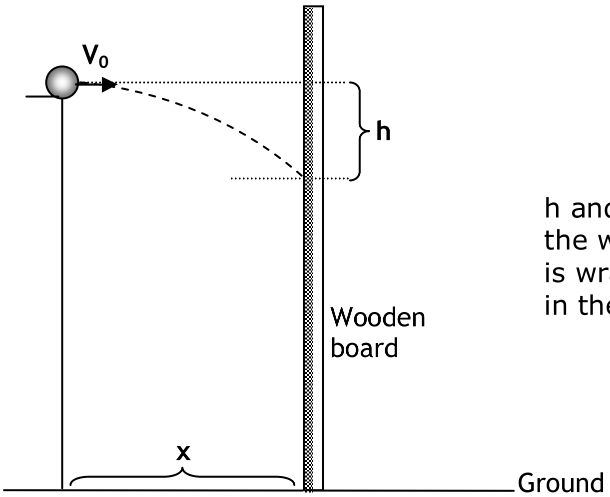


Figure: Schema of the experimental set up

h and x values obtained by moving the wooden board whose front face is wrapped by carbon paper is given in the table bellow.

x(cm) (±0.1)	10.0	20.0	25.0	30.0	40.0
h(cm) (±0.1)	7.8	31.3	48.8	70.3	125

(a) Draw the graph of data on graph paper.

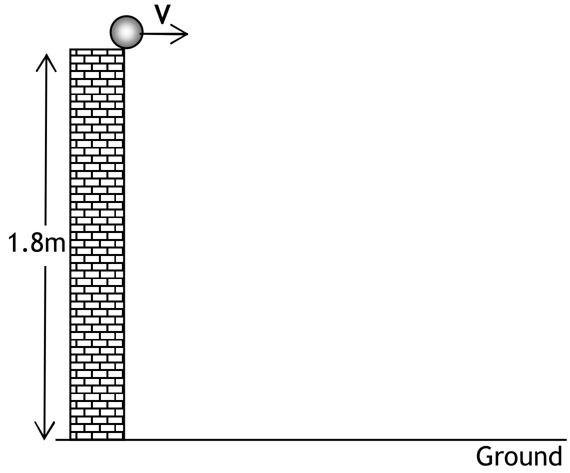
(b) State the algebraic relation between variables.

(c) Replace the variables in the suitable form to obtain straight line graph.

(d) What is the slope of straight line graph equal to?

(e) What is the initial velocity (V_0) of the ball? ($g=9.8ms^{-2}$)

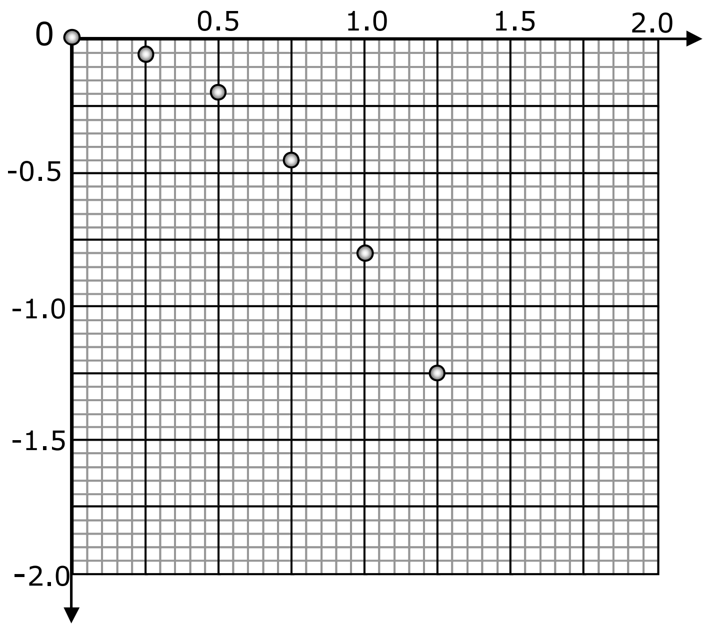
PROBLEM 2:



A marble is projected horizontally from the edge of a ball 1.8m high with an initial speed V.

A series of flash photographs are taken of the marble. The photographs are combined into a single photograph as shown below. The images of the marble are superimposed on a grid that shows the horizontal distance x and vertical distance y traveled by the marble.

The time interval between each image of the marble is 0.1s.



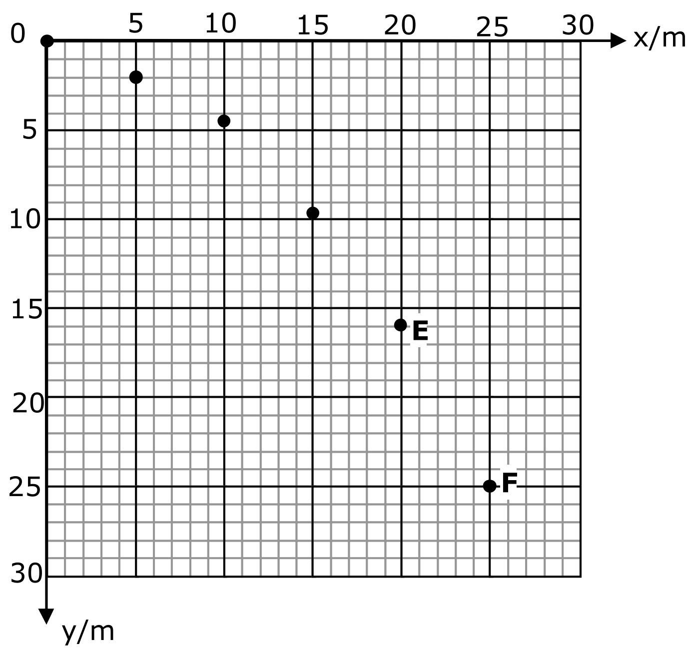
(a) On the images of the marbles at x=0.5m and x= 1.0m, draw arrows to represent the horizontal velocity V_H and vertical velocity V_V.

(b) On the photograph, draw a suitable line to determine the horizontal distance d from the base of the wall to the point where the marble hits the ground. Explain your reasoning.

(c) Use data from the photograph to calculate a value of acceleration of freefall.

IB Higher Level Physics Exam (19 May 2005) Paper 2 Question A2

PROBLEM 3:



A projectile is launched on a cliff on a planet in a distant solar system. The graph below plots the horizontal (x) and vertical (y) positions of the projectile every **0.5 seconds.**

(a) Determine the initial velocity which with the horizontal was launched.

(b) Draw a vector on the graph to represent the displacement of the projectile between points E and F of the motion. Then draw vectors to represent the horizontal and vertical components of this displacement

(c) Determine the vertical component of the average velocity of the projectile between points E and F.

(d) Another projectile is fired at **half the speed** of the first one. On the graph opposite, plot the positions of this projectile on time intervals 0.5s.

IB Higher Level Physics Exam (05 Nov 2002) Paper 2 Question A1.

PROBLEM 4:

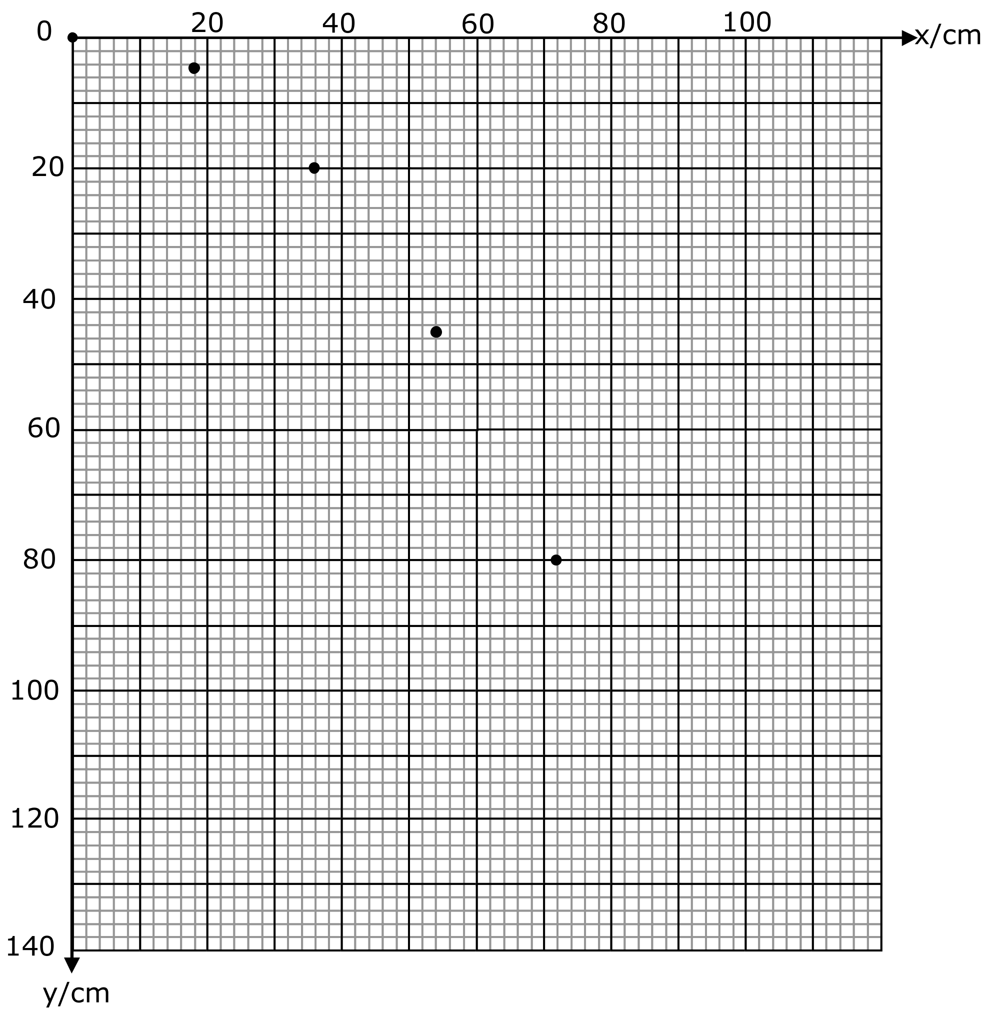
A small steel ball is projected horizontally from the edge of a bench Flash photographs of the ball are taken at 0.1s intervals. The resulting images are shown against a scale as in the diagram below.

(a) Use the diagram to determine:
  (i) The constant horizontal distance of the ball
  (ii) The acceleration of free fall.

(b) Mark the position of the ball 0.5s after projection. You should carry out any calculations so that you can accurately position the ball.

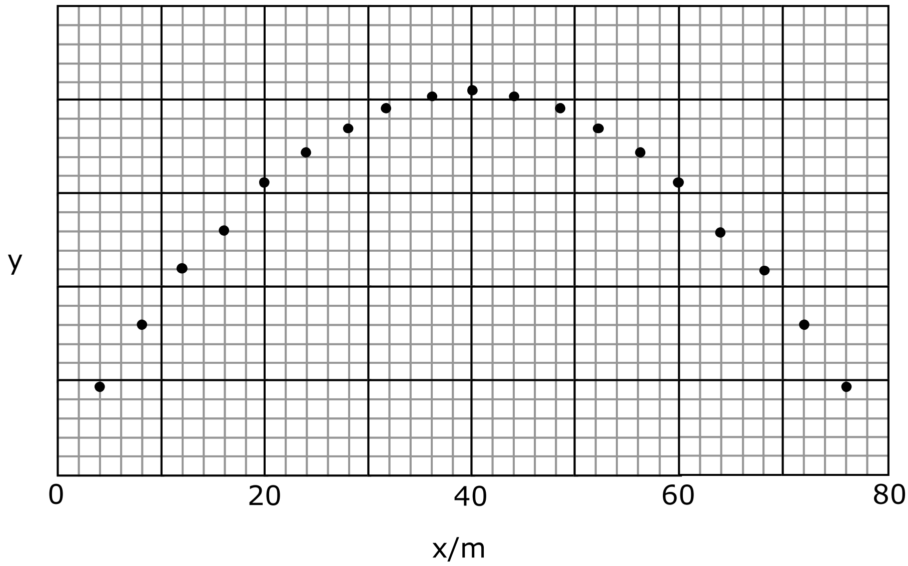
(c) A second ball is projected from the table at the same speed as the original ball. The ball has small mass so that the air resistance can not be neglected. Draw on the diagram approximate shape of the path you would expect the ball to take.

IB Standard Level Physics Exam (05 May 2004) Paper 3 Question A2.



PROBLEM 5:

A projectile is launched from the surface of a planet. The initial vertical component of velocity is $40 ms^{-1}$. The diagram below shows the positions of the projectile in 0.20s intervals. Note that no scale is given on the vertical axis.



(a) Calculate

(i) the horizontal velocity of the projectile
(ii) acceleration of free fall at the surface of the planet
(iii) the maximum height reached by the projectile

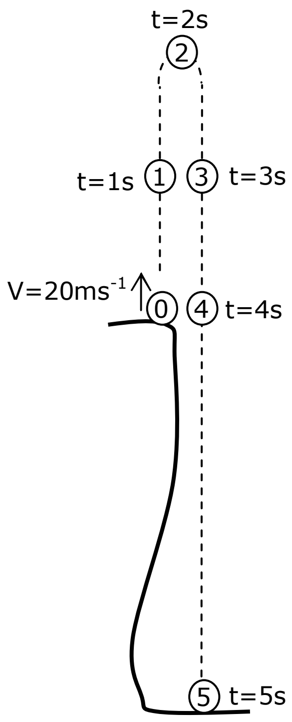
(b) Determine angle to the horizontal at which projectile is launched.

(c) The projectile is launched with the same velocity from the surface of a planet where the acceleration of free fall is twice that calculated in (a)(ii). Draw the path of this projectile on the graph.

IB Standard Level Physics Exam (20 May 2005) Paper 3 Question A1.

PROBLEM 6:

A stone is projected almost vertically upwards at 20 m/s from the edge of a cliff. The sequence diagram below shows the position of the stone at one-second intervals. Image 0 is just after projection, and Image 5 is just before landing. Gravitational acceleration is taken as $10 ms^{-2}$ and air resistance is ignored.



(a) State whether the stone's acceleration is upward, downward or zero in each of the following cases:

(i) when the stone is on its way **up**
(ii) when the stone is on its way **down**
(iii) when the stone is at the **top** of its path

(b) Next to each of the six images draw in a vector to represent the **instantaneous velocity** at that stage of the motion. The vector at image 0 has been drawn in for you. Pay attention to the direction and relative lengths of the vectors, and label them with their magnitudes in ms^{-1}.

(c) At each image of the stone, draw in vectors to represent the **force**(**s**) acting on the stone at that instant. Pay attention to both magnitude and direction. State the cause of any force.

(d) Draw a velocity–time graph to represent the motion of the stone. On the graph label the stages representing **upwards motion** and **downwards motion**, and label the **topmost point** of the motion.

(e) What does the gradient of the graph represent?

(f) Determine the height of the cliff.

IB Higher Level Physics Exam (10 Nov 2000) Paper 2 Question B3.

APPENDIX I

TEACHER GUIDE FOR MODELING INSTRUCTION

Target Model:

The horizontal and vertical components of the particle in projectile motion (Horizontal motion with constant velocity and vertical motion with constant acceleration)

Prerequisite:

Before beginning this cycle students should have previously experience with kinematics models, so they have fairly clear concepts of **distance**, **velocity**, **acceleration**, **uniformly accelerated linear motion**, **linear motion with constant velocity** and **two-dimensional motion**. They should also have experience with **Law of Conservation of Mechanical Energy** and **Newton's Second Law of Motion** which of each is a prior topic in high school physics. Therefore, they will need to go over these concepts before (and maybe during) the discussion.

In addition, students should be familiar with how to make a graph, how to determine the algebraic representation of the graph and how to write a good lab report. Prior to the lab study, "How to Write a Good Lab Report" papers should be handed out and students should be asked to bring a lab notebook with them to note raw data and the procedure of their experiment. They should be also announced that at the end of the study they will individually prepare the detailed lab reports of both by using the notes in their notebook and in the pre-given format.

The modeling instruction is organized into **"modeling cycles"** and a modeling cycle has 2 stages: **model development** and **model deployment**. In the earlier parts of the model development stage, the horizontal and vertical components of motion will be examined separately; at the end they will be combined together. Therefore students are expected to design separate experiments for each component.

STAGE 1: MODEL DEVELOPMENT

- At the beginning of this stage, aim of the experiment should be introduced to students. They should be clear about what they are expected to do: TO DEVELOP A MODEL THAT EXPLAINS THE MOTION OF AN OBJECT FIRED HORIZONTALLY FROM A CERTAIN HEIGHT.

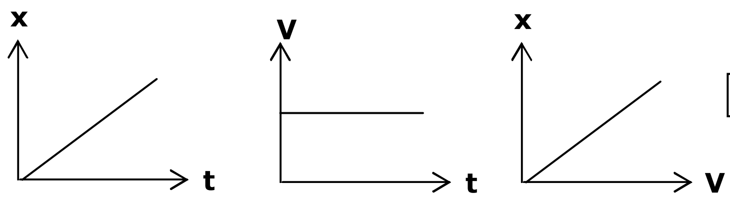
  They should be explained that the motion of such an object is two-dimensional, that is, it flies horizontal and vertical distances concurrently. Understanding the idea of motion in two dimensions is difficult for some students. It is important to emphasize that motion in each direction is independent and that therefore students can examine two components of motion separately. Exemplifying motion with the boat that tries to cross a river under the stream effect (they are familiar with this example) is a handy method to help students to make sense of independence of x and y components of the projectile's velocity.

- Students have covered the prerequisite concepts before, but they will still do need to recall these concepts in order to use them efficiently. It is recommended that you start with the "**kinematics models**", continue with "**Newton's Second Law**" and end with "**Law of Conservation of Mechanical Energy**". These revisions should include at least the following items.

REVISION

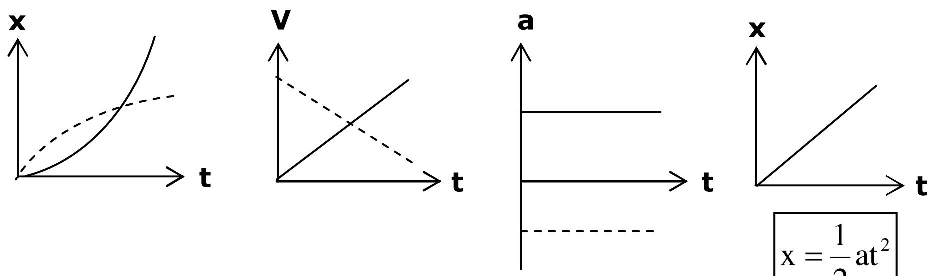
KINEMATICS MODELS:

1. Motion with uniform (constant) velocity:
   Roughly plotted position-time, velocity-time graphs (It is good idea to talk about how the distance in an exact time varies depending on velocity) and related equation.



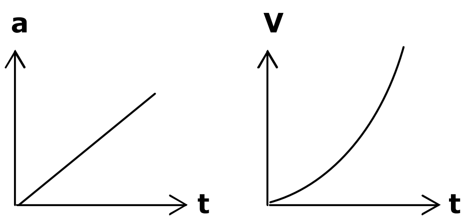
x= V.t

2. Motion with uniform acceleration:
   Roughly plotted position-time, velocity-time and acceleration-time graphs. The straight line graph of position versus time variation and related equation.



$$x = \frac{1}{2}at^2$$

3. Motion with uniformly increasing acceleration
   Roughly plotted acceleration-time and velocity-time graphs

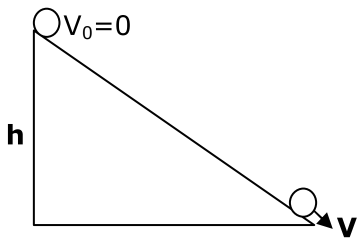


NEWTON'S SECOND LAW OF MOTION: $F = m.a$

LAW OF CONSERVATION OF MECHANICAL ENERGY:

When only the conservative forces acting, the mechanical energy (sum of kinetic and potential energies) of an object is conserved. Energy is not created or destroyed, although it does change form. The potential energy is converted to kinetic energy or vica versa.

It should be illustrated with following example:



$$KE_{Bottom} = PE_{Top}$$
$$\frac{1}{2}mV^2 = mgh$$
$$V^2 = 2gh$$
$$V = \sqrt{2gh}$$

- As students discuss the quantitatively measurable parameters in the experiment that might have cause-effect relationship, it would be better to serve them some technical terms such as take off (initial) velocity, range, vertical and horizontal distances, vertical and horizontal accelerations, time in flight, etc. and notation that will use for them to clarify the discussion.

- There are 4 main phases of model development: description, formulation, ramification and validation. These four phases will be performed for each component of motion separately. And the model deployment stage will be run together.

EXPERIMENT 1: Horizontal Component of Projectile Motion

1. **DESCRIPTION**: ***(1 teaching period)***

- Students study on the horizontal component of projectile motion firstly. The experimental set up is presented them and a class discussion is organized in order to courage students for expressing their ideas and to direct them to select quantitatively measurable parameters in cause-effect relationship. It is very important to create a climate of openness in the classroom before the discussion begins. Students should feel comfortable.

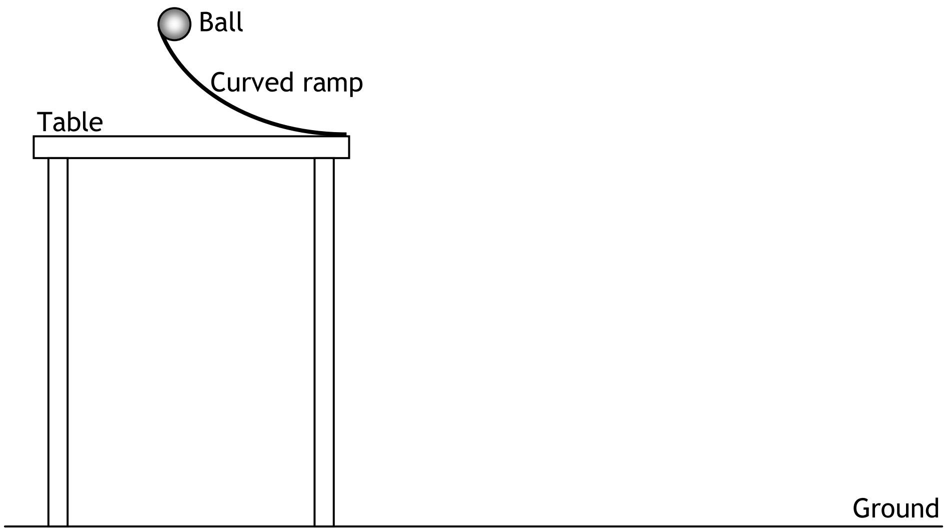


Figure 1: The apparatus of Experiment 1

- It is important at this point to provoke students' misconceptions by probing questions such as "What are the factors that might affect the horizontal distance (x) of the dropping ball", "What are the factors that might affect the time of flight" "does heavier objects fly further", "what is the shape of path of projectile", etc. Discussion supports students with the opportunity to become aware of their different ideas about the topic and helps them to criticize these ideas.

- Some ideas that might come from students are height of the ramp at which you release it, height of the table, mass of the ball, size of the ball, color of the ball, material that the ball made from, material that the ramp made from, gravity, wind, air pressure, temperature of laboratory, the person who released the ball, etc.

- All factors are listed on the board and discussed which ones they could effectively measure by using this set up. They probably decide to measure the initial horizontal velocity of the ball. They should have a discussion about how they can obtain this velocity. Also they may prefer to measure the time of flight. The time of ball in air would not be so long that they can measure accurately. However, as a result of this measurement, they can realize that the time of flight is the same for each trial performed from the same height (the height of the table). They also may think that the mass of the ball influences where the object hits the ground. They may perform experiment with the metal and glass marbles separately.

2. **FORMULATION**: ***(1/2 teaching period)***

- In this phase students should finally elaborate what they should measure to see if these factors affect the motion (i.e., what should the dependent and independent variables be), how they should design the experiment, which parameters should be hold constant, how many trials they should perform, how they should record the trials, how they should display their data.

- Then class is divided into teams to perform their own experiments. Each team should include 4-5 people. And each team is allowed to design their experiment in detail.

- It is recommended that you remind students to record raw data and note the procedure of their experiment and any changes to the procedure as they conduct the lab in their lab notebook. And also they should be announced that they will submit their notebooks including these notes and a detailed lab report in the given format at the end of the cycle.

3. **RAMIFICATION**: ***(3/2 teaching periods)***

- Each lab team is allowed to perform their own experimental design and collect relevant data.

- Then the teams carry out their own data analysis cooperatively, plotting necessary graphs, and constructing mathematical representations of the functional relationships they posited previously. They may plot the graphs of **x** (the horizontal range of motion) v**ersus**

h (height where the object released from on the ramp), **x versus V_0** (initial horizontal velocity), **x versus t** (time in flight). They must plot the graphs by hand and each person in the group should have a graph which they can compare with other group members' ones. If the time will not be enough for this study, some part of the study can be given as homework.

4. **VALIDATION**: ***(1 teaching period)***

- Each team concludes their own lab activity by preparing a general analysis that includes the graphs, algebraic representation of the graphs, relationships they have found and all other conclusions related to model.

- Two or three groups (because of lack of time) are selected and different members of the groups defend different parts of the experiment. The class and the instructor ask some questions during this presentation. And these questions are answered by the presenter. If the presenter can not answer a question, other members of the team can help him/her. But this may effect the grading of presenter.

EXPERIMENT 2: Vertical Component of Projectile Motion

1. **DESCRIPTION**: ***(1 teaching period)***

- Students perform the second experiment to develop a model to explain the vertical component of the projectile motion. Again, the experimental set up is presented them. This time the apparatus also includes a wooden board whose front face is wrapped by carbon paper. The carbon paper should be wrapped as its inked face will be placed on the board so that ball can make a mark on the board when it hits.

- A class discussion is organized to success a satisfactory characterization of the concept and to direct the students for the identification of quantitatively measurable parameters and dependent and independent variables in the experiment. The method in the first experiment should be followed.

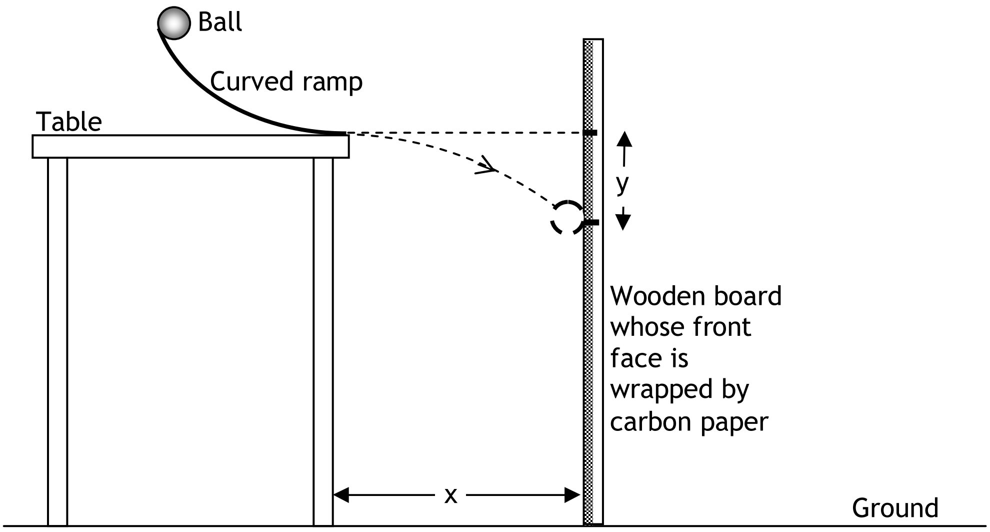


Figure 2: The apparatus of Experiment 2

- Students should notice that they can measure the vertical displacement of ball at any point on the trajectory by placing the board at an appropriate distance in vertical position. You can also have a good class discussion about how to use the wooden board.

The recommended method is initially to place the wooden board in the vertical position so that it touches the bottom of the ramp and then to release the ball bearing from a certain height so that it accelerates down the ramp and makes a mark on carbon paper attached to the wooden board. In this way, the first point that represents the level at which the ball was thrown horizontally would be marked. Then the vertical displacement of the ball can be measured at any preferred point by moving board to that point.

In the first experiment students have concluded that ball moved with a constant velocity in x direction. It means that it flies equal horizontal distances in equal time intervals. Therefore students may obtain the vertical distances covered in equal time intervals by moving board in equal amount of horizontal distance for each trial. The graph of vertical *distance (y) versus horizontal distance (x) helps them to discover the model behind the motion.*

2. **<u>FORMULATION</u>: *(1/2 teaching period)***

- Each team should design their experiment in detail. It is important at this point to allow students to find their own way. Although a method was recommended above, students should be provided with opportunity to explain and implement their own ideas. Teachers should direct questions to reinforce key ideas and challenge misconceptions.

3. **<u>RAMIFICATION</u>**: ***(3/2 teaching periods)***

- Each lab team is allowed to perform their own experimental design and collect relevant data.

- Then the teams carry out their own data analysis cooperatively, plotting necessary graphs (such as y-x and y-x^2) and constructing mathematical representations of the functional relationships they posited previously. Students must plot the graph by hand and each person in the group should have his/her own graph. If the time will not be enough for this study, some part of the study can be given as homework again.

4. **<u>VALIDATION</u>**: ***(2 teaching periods)***

- Each team concludes their own lab activity by preparing a general analysis that includes the graphs, algebraic representation of the graphs, relationships they have found and all other conclusions related to model.

- Two groups which are different from the ones presented their study in the previous experiment are selected and different members of the groups are asked to defend different parts of the experiment. The class and the instructor ask some questions during this presentation too.

- After completing presentations, a class discussion is organized as a post lab study. Class as whole revises the study from beginning to end and arrives at a consensus about the models. It is recommended to discuss particularly the experiments which had different procedures but same results and the ones which followed the same procedure but obtained different results in order to highlight some basic tenets of nature of science. This would help students to realize that there is no one way to do science. And also it must be emphasized that science is an attempt to explain natural phenomena and involves the human imagination, creativity and inference. Different scientists may draw different inferences from the same observation. Therefore scientific knowledge is subjective, that is, it is influenced by scientists' beliefs, experiences, prior knowledge, expectations, etc.

- This is one of the important segments of whole study. The most significant learning is expected to occur in the post lab discourse conducted at the end of model development stage. Followings are some other important questions and expected answers that this post-lab discussion must include.

  - Why and how does the height of ramp affect the horizontal distance of the ball?
    The height of the ramp affects the take off velocity of the ball and this velocity affects how far the ball will travel horizontally.

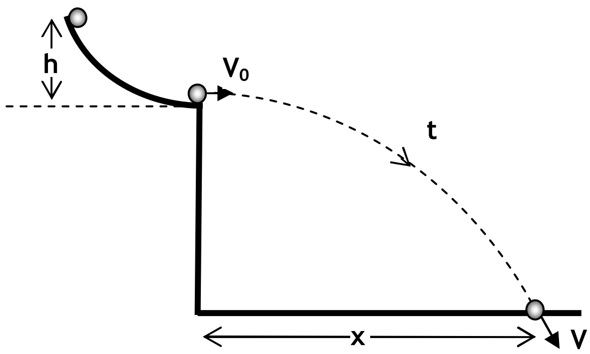
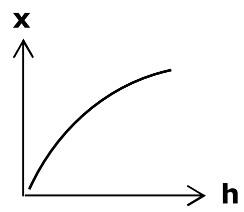
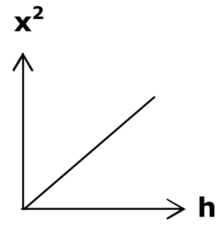


Figure 3: The motion schema of Experiment 1

- Is the graph of horizontal range versus height of the ramp, a straight line, a parabola or a hyperbola?
  It would be parabola since the horizontal distance (x) is directly proportional with the root of height (h) of ramp. What is more, the graph of x^2 versus h is a straight line.

$$KE_{Bottom} = PE_{Top}$$
$$\frac{1}{2}mV^2 = mgh$$
$$V^2 = 2gh$$
$$V = \sqrt{2gh}$$
$$x = V.t = \sqrt{2gh}.t$$





- Does the height of ramp (h), therefore the horizontal take of velocity (V_0), affect the time in flight?
  No. If the ball is fired horizontally from the same height even with different velocities, its time in air would be the same every time. In such a case, the time of flight is independent of throwing velocity.

- What kind of motion is the horizontal component of trajectory?
  As the velocity is increased, the distance covered in a certain time proportionally increases too. That is, the horizontal range (x) is directly proportional with the horizontal velocity (V_0). Ball moves <u>with constant velocity</u> in x-direction.

- Why and how does the height of the table affect the horizontal distance of the ball?
  The height of the table affects the time of flight of the ball and so the horizontal distance traveled by the ball.

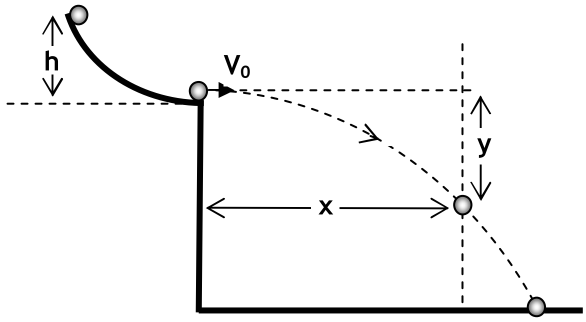
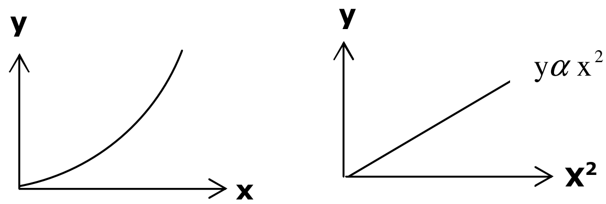


Figure 4: The motion schema of Experiment 2

- Why is the graph of vertical distance versus horizontal distance of the ball a parabola?
  This shows that the vertical distance (y) is directly proportional with the square of horizontal distance (x). Moreover, y-x^2 graph is a straight line graph.



- What can you conclude about the variation of vertical distance (y) depending on time?
  The ball moves with constant velocity in x direction. Therefore, equal distances refer to equal time intervals. If the distance (y) is directly proportional with the square of horizontal distance (x), it must be also directly proportional with the square of time of flight.

$$x \propto t \text{ and } y \propto x^2 \text{ then } y \propto t^2$$

- What can you conclude about the vertical motion of the ball by using these proportionalities?
  Since the vertical distance is directly proportional with the square of time, the vertical motion of the ball is uniformly accelerated motion.

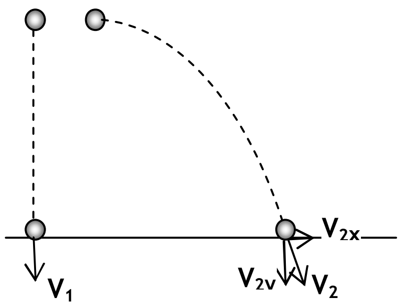
$$y \propto t^2 \quad \Rightarrow \quad y = \frac{1}{2}at^2$$

- What causes ball to accelerate vertically?
  Gravitational force (or its weight)

- Therefore, what does the acceleration of the motion equal to?
  Gravitational acceleration (g)

$$F = W$$
$$m.a = m.g$$
$$a = g$$

- Assume that one of the objects is released and other is thrown horizontally at the same time from the same height. Which one hits the ground first? What about their velocities?



$t_1 = t_2$

$V_1 = V_{2v}$

Since they have equal accelerations, they hit the ground at the same time. The velocity of released object will be equal to the vertical velocity of other object when they hit the ground. But the velocity of thrown object will also have a horizontal component.

$t_1 = t_2$

- What are the factors that affect the time in flight for these objects? Do their masses have an influence?
  Since the acceleration of motion is independent of mass and equal to "g", the time in flight does not depend on mass too. The factors that determine the time of motion is the gravitational acceleration (g) and height at which object was fired.

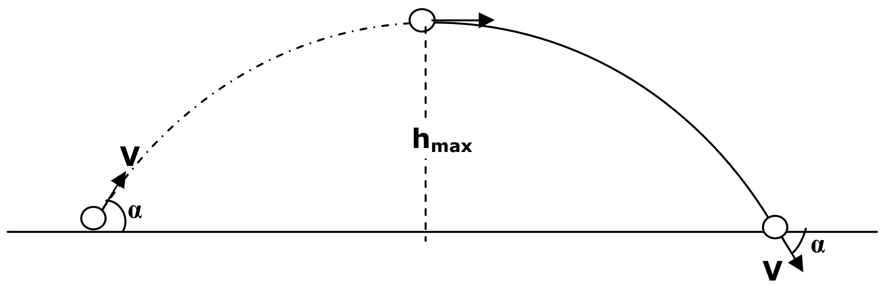


Figure 5: The symmetry in projectile motion

- The concept symmetry in projectile motion is extremely useful. Students should be encouraged to use it in their advantage. The projectile launched over level ground will spend as much time on the trip up as on the trip down. Students should discuss how the acceleration, velocity and horizontal and vertical distances of such an object vary with time. They should predict the related graphs (a-t, V_x-t, V_y-t, x-t, h-t) and drive related equations.

  - What is the angle of initial velocity that will maximize the horizontal range of a projectile?

    Since horizontal range depends on both horizontal component of initial velocity and time of flight, which is related with the vertical component of velocity, both components are needed to be big in order to maximize range. Therefore it should be fired approximately at 45^0 with ground.

- Grading is done regarding the group presentations, class activity and the lab notebooks of individuals.

STAGE 2: MODEL DEPLOYMENT *(2 teaching periods)*

- The model deployment stage is carried out in the class and with experiment groups. It is a kind of problem solving study and its purpose is the disposition of models elaborated by the students to new situations in different ways. It is important to work as many examples as possible so that students can see how to apply these models in a variety of situations.

- A problem set is handed out to class. Each group is assigned the first problem and one of the remaining problems in the set.

- Each group develops solutions to their problems and presents this solution to class. During the presentation, class and instructor might ask questions. These presentations are graded.

- If there is no pressure of time, a class activity may be organized and each group may be asked to determine the vertical acceleration of the motion by using data obtained in the experiment. This includes making necessary calculations, forming required tables and drawing suitable graphs.
  They are expected calculate the take off velocity of the ball by using conservation of energy and find the time of ball to take each distance in data. Then they should make a table including height of fall and square of time of fall. At the end, they are expected to draw height versus time square graphs to determine the vertical acceleration (g) of motion by using slope of this graph. It is a good idea to talk about the sources of error in their measurement.

$$V = \sqrt{2gh}$$

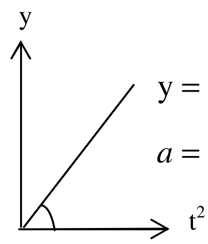
$$t = \frac{x}{V} = \frac{x}{\sqrt{2gh}}$$

$$t^2 = \frac{1}{2gh} x^2$$

→

x	t^2	y

→



$$y = \frac{1}{2} a t^2$$

$$a = 2 \times slope$$

APPENDIX J

PERCENTAGES OF STUDENTS RESPONSES ON PROJECTILE MOTION CONCEPT TEST

Table J.1 Percentages of student's responses to pre-PMCT items

EXPERIMENTAL GROUP						CONTROL GROUP					
Item	A%	B%	C%	D%	E%	**Item**	A%	B%	C%	D%	E%
1	45.5	38.6	0.0	*11.4*	4.6	**1**	31.8	29.5	0.0	*36.4*	2.3
2	40.9	*50.0*	0.0	4.1	0.0	**2**	43.2	*43.2*	0.0	13.6	0.0
3	50.0	*15.9*	11.4	22.7	0.0	**3**	38.6	*27.3*	11.4	22.7	0.0
4	0.0	*86.4*	6.8	6.8	0.0	**4**	22.7	*59.1*	2.3	13.6	2.3
5	59.1	0.0	9.1	*29.5*	2.3	**5**	47.7	9.1	9.1	*27.3*	6.8
6	29.5	0.0	*20.5*	29.5	20.5	**6**	18.2	2.3	*43.2*	29.5	6.8
7	4.5	0.0	15.9	*79.5*	0.0	**7**	2.3	0.0	6.8	*81.8*	9.1
8	4.5	36.4	*52.3*	6.8	0.0	**8**	2.3	43.2	*52.3*	0.0	2.3
9	*4.5*	50.0	22.7	11.4	11.4	**9**	*11.4*	52.3	20.5	11.4	4.5
10	*2.3*	43.2	38.6	6.8	9.1	**10**	*9.1*	36.4	36.4	9.1	9.1
11	4.5	20.5	0.0	*27.3*	47.7	**11**	4.5	38.6	0.0	*25.0*	31.8
12	0.0	*52.3*	31.8	11.4	4.5	**12**	0.0	*72.7*	18.2	9.1	0.0
13	*31.8*	6.8	50.0	6.8	4.5	**13**	*45.5*	6.8	45.5	2.3	0.0
14	25.0	25.0	*22.7*	25.0	2.3	**14**	25.0	15.9	*27.3*	22.7	9.1
15	18.2	*56.8*	2.3	13.6	9.1	**15**	15.9	*40.9*	11.4	20.5	11.4
16	*20.5*	0.0	56.8	4.5	18.2	**16**	*13.6*	0.0	52.3	4.5	29.5
17	4.5	*20.5*	75.0	0.0	0.0	**17**	20.5	*15.9*	54.5	0.0	9.1
18	61.4	*34.1*	4.5	0.0	0.0	**18**	47.7	*34.1*	11.4	6.8	0.0
19	4.5	*31.8*	0.0	9.1	54.5	**19**	9.1	*29.5*	4.5	2.3	54.5
20	59.1	2.3	*27.3*	0.0	11.4	**20**	47.7	0.0	*38.6*	0.0	13.6

The italic number in each row is the average percentage of correct response of related item.

Table J.2 Percentages of student's responses to post-PMCT items

EXPERIMENTAL GROUP						CONTROL GROUP					
Item	A%	B%	C%	D%	E%	**Item**	A%	B%	C%	D%	E%
1	31.8	2.3	0.0	*65.9*	0.0	**1**	15.9	20.5	6.8	*52.3*	4.5
2	27.3	*45.5*	4.5	20.5	2.3	**2**	29.5	*45.5*	0.0	25.0	0.0
3	34.1	*25.0*	9.1	29.5	2.3	**3**	22.7	*47.7*	11.4	15.9	2.3
4	2.3	*95.5*	0.0	0.0	2.3	**4**	2.3	*90.9*	0.0	4.5	2.3
5	9.1	0.0	2.3	*88.6*	0.0	**5**	13.6	2.3	0.0	*75.0*	9.1
6	0.0	0.0	*40.9*	52.3	6.8	**6**	6.8	2.3	*56.8*	25.0	9.1
7	4.5	2.3	18.2	*72.7*	2.3	**7**	2.3	4.5	6.8	*81.8*	4.5
8	0.0	4.5	*95.5*	0.0	0.0	**8**	2.3	13.6	*81.8*	0.0	2.3
9	*22.7*	20.5	4.5	47.7	4.5	**9**	*25.0*	27.3	13.6	29.5	4.5
10	*15.9*	13.6	11.4	54.5	4.5	**10**	*15.9*	18.2	22.7	34.1	9.1
11	4.5	25.0	0.0	*25.0*	45.5	**11**	0.0	36.4	0.0	*31.8*	31.8
12	0.0	*90.9*	6.8	2.3	0.0	**12**	2.3	*81.8*	13.6	2.3	0.0
13	*84.1*	0.0	6.8	9.1	0.0	**13**	*77.3*	6.8	13.6	2.3	0.0
14	9.1	18.2	*70.5*	2.3	0.0	**14**	13.6	9.1	*68.2*	6.8	2.3
15	0.0	*81.8*	0.0	13.6	4.5	**15**	6.8	*65.9*	11.4	13.6	2.3
16	*22.7*	0.0	56.8	20.5	0.0	**16**	*22.7*	0.0	54.5	0.0	22.7
17	18.2	*59.1*	22.7	0.0	0.0	**17**	27.3	*22.7*	43.2	2.3	4.5
18	50.0	*45.5*	4.5	0.0	0.0	**18**	34.1	*59.1*	4.5	2.3	0.0
19	0.0	*77.3*	2.3	2.3	18.2	**19**	11.4	*56.8*	9.1	6.8	15.9
20	15.5	2.3	*73.1*	0.0	9.1	**20**	34.1	4.5	*52.3*	0.0	9.1

The italic number in each row is the average percentage of correct response of related item.

APPENDIX K

PERCENTAGES OF STUDENTS RESPONSES ON T-VOSTS TEST

Table K.1 Percentages of experimental group student's responses to T- VOSTS items

Item	A%	B%	C%	D%	E%	F%	G%	H%	Other%
1	0	25.0	38.6	0	4.5	25.0	4.5	0	2.3
2	0	13.6	0	18.2	34.1	25.0	4.5	-	4.5
3	9.1	11.4	2.3	27.3	22.7	18.2	4.5	-	4.5
4	0	6.8	45.5	13.6	20.5	11.4	0	0	2.3
5	27.3	13.6	27.3	20.5	0	0	11.4	-	0
6	52.3	2.3	9.1	20.5	6.8	-	-	-	9.1
7	0	27.3	54.5	6.8	9.1	0	-	-	2.3
8	18.2	25.0	34.1	6.8	13.6	-	-	-	2.3
9	2.3	4.5	31.8	0	15.9	9.1	36.4	-	0
10	34.1	13.6	18.2	20.5	4.5	-	-	-	9.1
11	50.0	11.4	13.6	9.1	11.4	-	-	-	4.5
12	40.9	38.6	15.9	4.5	-	-	-	-	0
13	4.5	9.1	6.8	15.9	22.7	29.5	9.1	-	2.3
14	9.1	9.1	13.6	36.4	15.9	11.4	4.5	-	4.5
15	54.5	38.6	4.5	0	0	-	-	-	2.3
16	65.9	11.4	4.5	11.4	2.3	-	-	-	4.5
17	11.4	0	13.6	38.6	25.0	9.1	-	-	2.3
18	11.4	40.9	25.0	9.1	6.8	6.8	-	-	0

Table K.1 (Continued)

Item	A%	B%	C%	D%	E%	F%	G%	H%	Other%
19	22.7	9.1	36.4	22.7	4.5	-	-	-	4.5
20	2.3	6.8	20.5	22.7	45.5	-	-	-	2.3
21	59.1	18.2	2.3	6.8	11.4	-	-	-	2.3
22	31.8	6.8	4.5	9.1	47.7	-	-	-	0
23	13.6	9.1	13.6	4.5	27.3	31.8	-	-	0
24	9.1	13.6	15.9	11.4	45.5	4.5	-	-	0
25	22.7	11.4	4.5	2.3	56.8	0	-	-	2.3

Table K.2 Percentages of control group student's responses to T-VOSTS items

Item	A%	B%	C%	D%	E%	F%	G%	H%	Empty%
1	0	25.0	31.9	0	4.5	25.0	2.3	2.3	9.1
2	0	6.8	2.3	9.1	29.5	25.0	25.0	-	2.3
3	4.5	22.7	2.3	34.1	15.9	11.4	4.5	-	4.5
4	0.0	4.5	45.5	20.5	15.9	2.3	9.1	0	2.3
5	31.8	6.8	18.2	27.3	0	6.8	6.8	-	2.3
6	56.8	4.5	4.5	20.5	9.1	-	-	-	4.5
7	11.4	20.5	50.0	2.3	11.4	4.5	-	-	0
8	14.5	15.9	29.5	27.3	6.8	-	-	-	6.0
9	7.0	11.6	25.6	7.0	25.6	23.3	0	-	0
10	25.0	15.9	22.7	20.5	9.1	-	-	-	6.8
11	34.1	4.5	29.5	22.7	9.1	-	-	-	0
12	27.3	27.3	20.5	11.4	9.1	-	-	-	4.4
13	4.5	9.1	4.5	20.5	15.9	38.6	4.5	-	2.3
14	4.5	11.4	20.5	29.5	18.2	13.6	-	-	2.3

Table K.2 (Continued)

Item	A%	B%	C%	D%	E%	F%	G%	H%	Empty%
15	45.5	36.4	6.8	4.5	2.3	-	-	-	4.5
16	63.6	2.3	15.9	13.6	-	-	-	-	4.6
17	4.5	2.3	18.2	27.3	43.2	2.3	-	-	2.3
18	9.1	40.9	25.0	9.1	4.5	6.8	-	-	4.5
19	38.6	4.5	31.8	13.6	6.8	-	-	-	4.5
20	2.3	2.3	9.1	38.6	45.5	-	-	-	2.3
21	50.0	11.4	15.9	6.8	11.4	-	-	-	4.5
22	52.3	15.9	2.3	2.3	25.0	-	-	-	2.3
23	20.5	4.5	4.5	11.4	20.5	36.4	-	-	2.3
24	13.6	34.1	4.5	2.3	36.4	9.1	-	-	0
25	20.5	11.4	4.5	0	61.4	0	-	-	2.3

APPENDIX L

THE NUMBERING SYSTEM FOR THE VOSTS ITEM POOL

TABLE L.1 VOSTS conceptual scheme

		Definitions
1.		Science and Technology
	01.	Defining science (e.g., instrumentalism, curiosity satisfaction, social enterprise).
	02.	Defining technology (e.g., social and human purposes; hardware, socioeconomic & cultural components).
	03.	Defining research & development (R&D).
	04.	Interdependence of science & technology (e.g., rejection that technology is simply applied science).
		External Sociology of Science
2.		Influence of Society on Science/Technology
	01.	Government (e.g., control over funding, policy & science activities; influence of politics).
	02.	Industry (e.g., corporate control dictated by profits).
	03.	Military (e.g., utilization of scientific human resources).
	04.	Ethics (e.g., influence on research program).
	05.	Education institutions (e.g., mandatory science education).
	06.	Special interest groups (e.g., health societies; nongovernmental & nonindustrial groups).
	07.	Public influence on scientists (e.g., upbringing, social interactions).
3.		(future category)
4.		Influence of Science/Technology on Society
	01.	Social responsibility of scientists/technologists (e.g., communicating with public, concern & accountability for risks & pollution, "whistle blowing").
	02.	Contribution to social decisions (e.g., technocratic vs. democratic decision making, moral & legal decisions, expert testimony, lobbying for funds).

TABLE L.1 (Continued)

		Definitions
	03.	Creation of social problems (e.g., trade-offs between positive & negative consequences, competition for funds).
	04.	Resolution of social & practical problems (e.g., technological fix; everyday type of problems).
	05.	Contribution to economic well-being (e.g., wealth & jobs).
	06.	Contribution to military power.
	07.	Contribution to social thinking (e.g., lexicon, metaphors).
5.		<u>Influence of School Science on Society</u>
	01.	Bridging C. P. Snow's two cultures.
	02.	Social empowerment (e.g., consumer decisions).
	03.	School characterization of science.
		Internal Sociology of Science
6.		<u>Characteristics of Scientists</u>
	01.	Personal motivation of scientists.
	02.	Standards/values that guide scientists at work & home (e.g., open-mindedness, logicality, honesty, objectivity, skepticism, suspension of belief; as well as the opposite values: closed-mindedness, subjectivity, etc.).
	03.	Ideologies of scientists (e.g., religious views).
	04.	Abilities needed to do science (e.g., commitment, patience).
	05.	Gender effect on the process & product of science.
	06.	Under representation of females.
7.		<u>Social Construction of Scientific Knowledge</u>
	01.	Collectivization of science (e.g., loyalties to research team & employer).
	02.	Scientific decisions (e.g., disagreements among scientists, consensus making).
	03.	Professional communication among scientists (e.g., peer review, journals, press conferences).
	04.	Professional interaction in the face of competition (e.g., politics, secrecy, plagiarism.
	05.	Social interactions.
	06.	Individual's influence on scientific knowledge.
	07.	National influence on scientific knowledge & technique.
	08.	Private vs. public science.
8.		<u>Social Construction of Technology</u>
	01.	Technological decisions.
	02.	Autonomous technology (e.g., technological imperative).

TABLE L.1 (Continued)

		Epistemology
9.		Nature of Scientific Knowledge
	01.	Nature of observations (e.g., theory ladenness, perception bound).
	02.	Nature of scientific models.
	03.	Nature of classification schemes.
	04.	Tentativeness of scientific knowledge.
	05.	Hypotheses, theories & laws (e.g., definition, role of assumptions, criteria for belief).
	06.	Scientific approach to investigations (e.g., nonlinearity, rejection of a stepwise procedure, "the scientific method" as a writing style).
	07.	Precision & uncertainty in scientific/technological knowledge (e.g., probabilistic reasoning).
	08.	Logical reasoning (e.g., cause/effect problems, epidemiology & etiology).
	09.	Fundamental assumptions for all science (e.g., uniformitarianism).
	10.	Epistemological status of scientific knowledge (e.g., ontology as an assumption, questioning logical positivism).
	11.	Paradigms vs. coherence of concepts across disciplines.

APPENDIX M

CODES OF T-VOSTS ITEMS AND PERCENTAGES OF CATEGORIES FOR EACH ITEM

Table M.1 Percentages of experimental and control group student's categorized views on nature of science relative to the T-VOSTS items.

Number of Item in T-VOSTS	Code in VOSTS Item Pool	Percentages of Categories					
		R (%)		HM (%)		N (%)	
		EG	CG	EG	CG	EG	CG
1	10111	38.6	31.9	54.5	52.3	4.5	6.8
2	20411	31.8	15.9	34.1	31.8	29.5	50.0
3	20711	45.5	45.5	43.2	43.1	6.8	6.8
4	40111	34.1	36.4	45.5	54.6	18.2	6.8
5	40213	20.5	27.3	54.6	50.0	25.0	20.4
6	40431	52.3	56.8	29.6	25.0	9.1	13.6
7	60211	81.8	70.5	15.9	13.7	0.0	15.9
8	60411	59.1	45.4	20.4	34.1	18.2	14.5
9	60511	25.0	48.9	36.4	0.0	38.6	51.2
10	70412	4.5	9.1	54.6	45.5	31.8	38.6
11	70511	50.0	34.1	34.1	56.7	11.4	9.1
12	90111	79.5	54.6	20.4	31.9	0.0	9.1
13	90211	29.5	38.6	31.8	20.4	36.3	38.6
14	90311	50.0	50.0	15.9	18.2	29.6	29.5
15	90411	93.1	81.9	0.0	4.5	4.5	9.1
16	90511	11.4	13.6	0.0	0.0	81.8	81.8
17	90521	25.0	43.2	63.6	50.0	9.1	4.6

Table M.1 (Continued).

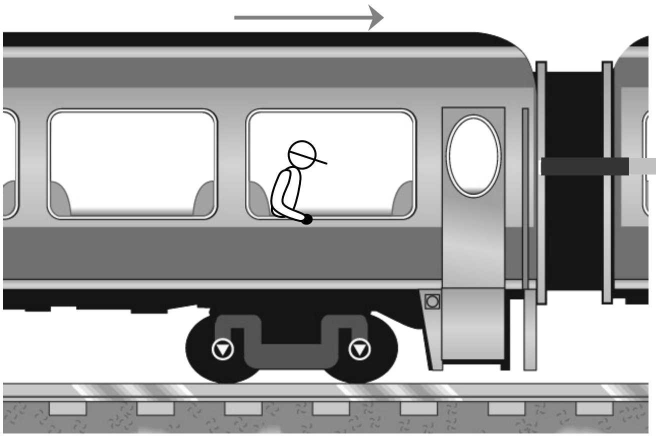
Number of Item in T-VOSTS	Code in VOSTS Item Pool	Percentages of Categories					
		R (%)		HM (%)		N (%)	
		EG	CG	EG	CG	EG	CG
18	90541	36.4	34.1	50.0	50.0	13.6	11.3
19	90621	36.4	31.8	31.8	43.1	27.2	20.4
20	90651	20.5	9.1	29.5	40.9	47.8	47.8
21	90711	65.9	56.8	20.5	27.3	11.4	11.4
22	91011	47.7	25.0	36.3	54.6	15.9	18.2
23	91012	31.8	36.4	40.9	25.0	27.2	36.4
24	91013	45.5	36.4	29.5	38.6	25.0	25.0
25	91111	22.7	20.5	63.6	65.9	11.4	11.4

R: Realistic, HM: Has Merit, N: Naïve, CG: Control Group, EG: Experimental Group

APPENDIX N

FIGURES USED DURING THE INTERVIEW AND RELATED QUESTIONS

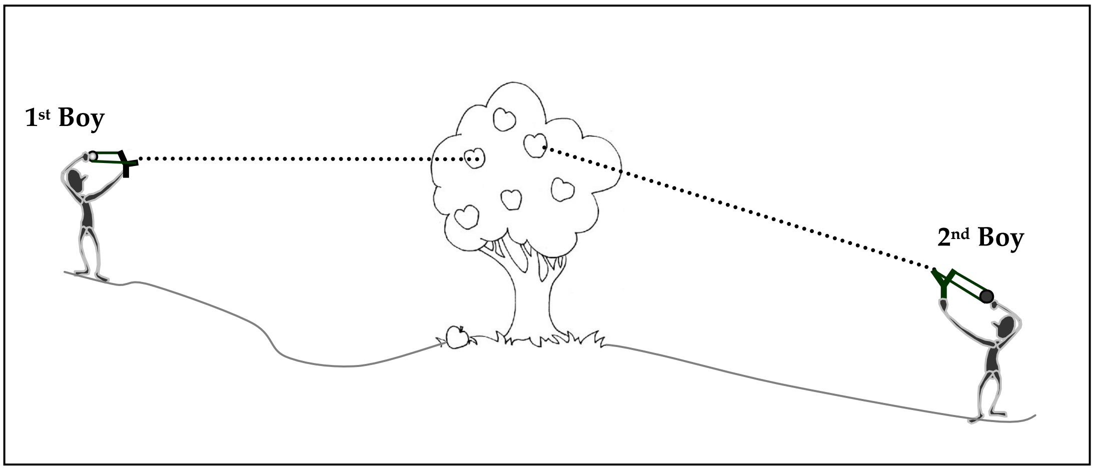
QUESTION 1:



One of the arms of a boy who sits in a train leans out of the window and he has a small metal ball in his hand.

A. While the train moving with constant speed, boy throws a ball straight up. Can he catch it again?
B. If he releases a ball in air while the train is moving with constant speed, how does the ball move? Please draw it.
C. At the end, train closes the station and slows down. While the train is speeding down, boy throws another ball vertically up. Can he catch the ball this time?

QUESTION 2:

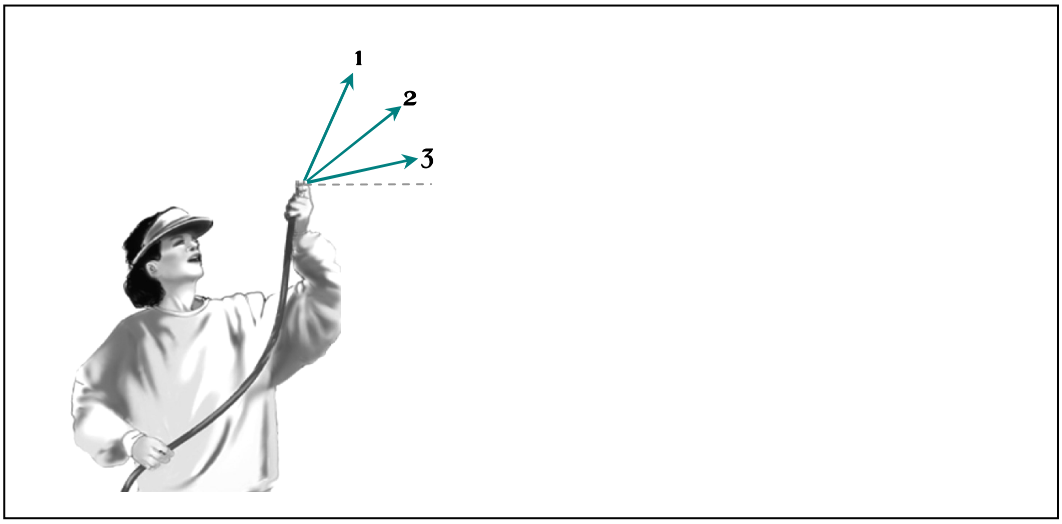


The boys are trying to hit an apple on the tree with the stone in sling. The 1st boy is at the apple's level and 2nd boy is below its position.

A. The 1st boy aims straight at apple and shouts initially. Just when he shouts, apple falls down from the tree. Does his stone hit the apple?

B. Then the 2nd boy aims straight at apple and shouts. Apple falls down from the tree just when he shouts too,. Does his stone hit the apple?

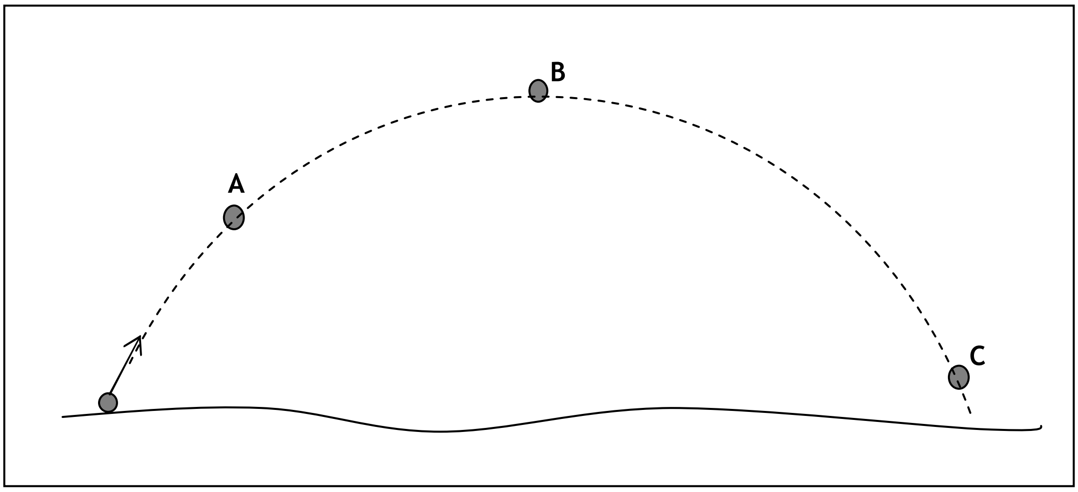
QUESTION 3:



The women in Figure adjust a garden hose nozzle for a hard stream of water. She kindly holds the end of nozzle in the positions 1, 2 and 3 seen in Figure. Assume that the water leaves the nozzle at an angle of 45^0 with the horizontal.

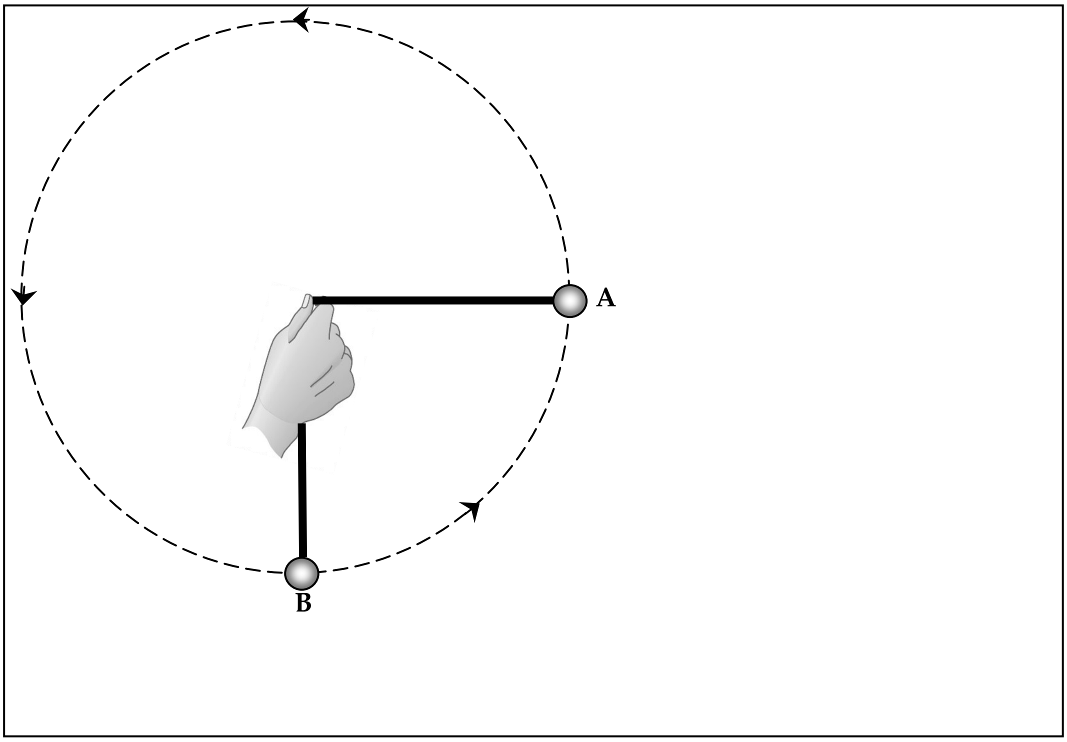
A. In which case does the water reach the highest level?
B. What are the factors that affect the maximum height of a projectile?
C. In which case does the water travel the greatest horizontal distance?
D. What are the factors that affect the horizontal range of a projectile?
E. In which case does the water hit the ground earlier?
F. What are the factors that affects the time in flight of a projectile?
G. In which case does the water have greatest speed when it hits the ground?

QUESTION 4:



A. Please draw all forces acting on the ball when it is at point A and name these forces.
B. When the ball reaches at point B, its highest point, how do these forces change? Please draw them again with their new lengths that represent the changes in forces.
C. Please draw them again at point C regarding their lengths.
D. How does the acceleration of projectile change?
E. How does the speed of projectile change?

QUESTION 5:



Assume that you are swinging a ball vertically on the end of a string.

a. Just when the string is in a horizontal position and the ball passes through point A, the string breaks down. Could you draw how the ball moves?
b. If the string broke down when the string was in vertical position and the ball passed through point B, how would the ball move? Please draw it again.

QUESTION 6:

Could you evaluate the method used in your class to teach projectile motion, please? What are the things you liked and you didn't like about the instruction?

VITA

Mine Gökçe Şahin was born in Turgutlu on October 19, 1976. She has received her B.S. degree in Faculty of Education, Department of Science Education from Middle East Technical University in July 1998. She has received her M.S. degree in Faculty of Education, Department of Curriculum Development and Instruction from Ankara University in July 2002. She worked as a physics teacher in a private high school in Ankara from 1998 to 2008. Her main area of interest is physics education, conceptual understanding, modeling and nature of science.