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EFFECTS OF BRIDGING ANALOGIES ON STUDENTS' MISCONCEPTIONS ABOUT GRAVITY AND INERTIA

BAĞDAŞTIRICI BENZETMELERİN ÖĞRENCİLERİN ÇEKİM VE EYLEMSİZLİK KONULARINDAKİ KAVRAM YANILGILARINA ETKİSİ

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ABSTRACT: The purpose of this study is to find out the effects of bridging analogies on students' misconceptions in gravity and inertia. Mechanics Diagnostic Test developed by the researchers was applied twice as a pretest and a posttest to the 67, 9th grade students in a nearby high school. In the period between the pretest and the posttest gravity and inertia were instructed to the students by using bridging analogies.

The findings of the pretest have shown that the students actually have misconceptions about gravity and inertia. By comparing the results of the pretest and the posttest, it is seen that these misconceptions can be remediated by using bridging analogies.

KEY WORDS: *Bridging analogies, anchoring analogies, misconceptions in gravity, misconceptions in inertia, treatment of misconceptions.*

ÖZET: Bu çalışmanın amacı bağdaştırıcı benzetmelerin öğrencilerin çekim ve eylemsizlik konularındaki kavram yanılgılarına etkilerini ortaya çıkarmaktır. Araştırmacılar tarafından geliştirilen Mekanik Konuları Kavram Yanılgıları Testi yakın bir lisede 67, 9. Sınıf öğrencisine öntest ve sontest olarak iki kez uygulanmıştır. Öntest ve sontest arasındaki dönemde çekim ve eylemsizlik konuları öğrencilere bağdaştırıcı benzetmeler kullanılarak anlatılmıştır.

Öntestin sonuçları öğrencilerin çekim ve eylemsizlik konularında kavram yanılgılarının gerçekten varolduğunu göstermiştir. Öntest ve sontest sonuçlarının karşılaştırılmasıyla bu kavram yanılgılarının bağdaştırıcı benzetmelerin kullanılmasıyla düzeltilebileceği görülmüştür.

ANAHTAR SÖZCÜKLER: *Bağdaştırıcı benzetmeler, çekimle ilgili kavram yanılgıları, eylemsizlikle ilgili kavram yanılgıları, kavram yanılgılarının düzeltilmesi.*

1. INTRODUCTION

Physics is the study of laws of nature and their application to living things. In other words, it is the amount of knowledge gained from the nature. In fact, it is not possible to explain the meaning and the content of physics in a few sentences. It is not a set of facts and rules to be memorized. On the contrary, it is a useless way to use memorization in learning physics. However, to construct meaningful learning in this course is very difficult. That's why many studies concerned the physics. The major concern of these studies is introductory physics. Mechanics, being the main part of the introductory physics, is the basis of the further physics knowledge. Because of being the first course in physics, it may be troublesome to many students. Therefore, many studies have been performed to identify what affects the students' achievement in introductory mechanics. Many of these studies [1, 2, 3] are concerning one of the effects; preconceptions, meaning the previous conceptions of the students before the instruction. It is possible to classify these studies into three main groups as descriptive studies, explanatory studies and intervention studies.

Descriptive studies [1, 2, 4, 5], are made to identify and fully describe the students' preconceptions. Explanatory studies [2, 3] intend to explain conceptual study and conceptual change meaning the commitment to a new belief about a principle or a phenomenon, and the abandoning of the old one. In conceptual change approaches students should be given the opportunity to express and discuss their ideas.

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Conceptual change models were developed to overcome misconceptions, meaning the preconceptions that are conflicting with the accepted scientific phenomena.

Intervention studies [6, 7] intend to test the explanations made by explanatory studies and form conceptual change. They assess the effectiveness of various teaching methods, classroom arrangements, and the other effects. However, these studies are not common in the literature. To investigate the effects of one thing on another, researchers conduct intervention studies. This intervention study basically concerns a teaching method-technique, named as bridging analogies (anchoring analogies).

1.1 Bridging Analogies

There are several ways to use analogies to facilitate and deepen students' understanding [9]. Especially in complex concepts, a single analogy that can completely explain the scientific concept is not always accessible. However, Brown and Clement [10] suggest the successive presentation of familiar cases for meaningful learning. They introduced a series of bridging analogies to form further reasoning about the problem without telling the students that the situations were similar.

As Clement, Brown and Zeitsman [11] mentioned, the logic underlying this approach is: Examples formed a connected sequence, starting from an anchoring conception (a situation which most students believe correct), through intermediate situations (facilitator analogies), to the desired target situation [6]. These series of bridges between the misunderstood case and the anchoring example helps the student to transform his or her mental model to match the accepted scientific one.

Brown and Clement [10] described the bridging strategy. According to them the strategy has four steps:

1. Students' misconceptions, belonging to the topic under consideration are made clear with the help of the target question.

2. Instructor proposes such a case that he or she views it both analogous and appealing to students' intuitions. These common sense concepts, being compatible with accepted physical theory are termed as an anchor.

3. Students are asked to make a comparison between the anchor and target cases in an attempt to establish an analogy relation.

4. Instructor goes to find an intermediate analogy between the target and the anchor, when the student does not accept the analogy. It could be either a single bridging analogy or a series of bridging analogies. The important point here is that these intermediate analogies should be responsible to provide a perfect link between the anchor and the target.

1.2 Misconceptions in Introductory Mechanics

The studies in the literature show that students at different ages and with different educational backgrounds, even physics teachers may have misconceptions about mechanics [12].

The misconceptions that this study dealt with are given as the followings:

1. Inertia:

a. Motion implies force: Studies, like Champagne [4] and Clement [2] show that the students have the idea that continuing motion, even at a constant velocity, in frictionless medium there is a force in the direction of the motion.

b. Proportionality of force to velocity rather than acceleration: Students think that there is a linear relation between force and velocity rather than force and acceleration. As a consequence of this situation, these students expect a constant velocity from a constant force.

2. Gravity: Some students assume a great difference in gravitational attraction. Some

believe that gravity is caused (or partly caused) by air pressure while the others believe that gravity is caused (or partly caused) by rotation of the earth. And some others believe that gravity is significantly different on different parts of the earth and even small changes in altitude changes gravity significantly.

3. Impetus view: The students believe that velocity of the object is proportional to a force and it is necessary for the object to continue its motion.

1.3 The Main Problem and Sub-problems

1.3.1 The Main Problem

The problem of the study is:

Do bridging (anchoring) analogies have an effect on 9th grade students' misconceptions about gravity and inertia in mechanics?

1.3.2 The Sub-problems and Null Hypothesis

The sub-problems are stated as follows;

1. What are the students' misconceptions about gravity and inertia?
2. What is the effect of bridging analogies on students' misconceptions about gravity and inertia?

The null hypothesis is stated as;

There will be no significant mean difference between students' pretest and posttest scores.

2. METHODOLOGY

2.1 Subjects

The sample selected for the study is sample of convenience consisting of 9th grade students at a nearby high school. The sample consists of 3 classes and 67 students. 46% of our sample either does not love physics or are neutral to physics as seen from Figure 1.

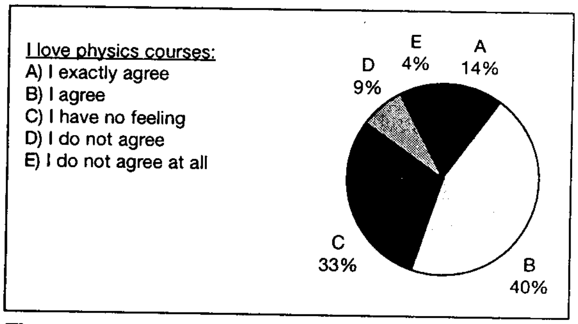


Figure 1. Percentages of the Students' Attitudes Towards Physics

2.2 Measuring Tool and Procedure

Many diagnostic questions have been developed and validated as a result of studies done to describe students' misconceptions in introductory mechanics [3, 12, 13]. The questions in the mechanics diagnostic test are adapted from the quiz and test questions in the book named "Preconceptions in Mechanics", by Camp and Clement [14]. First, all the questions (approximately 45) and the materials were translated from English to Turkish. Then, the appropriate questions were selected and were adapted to test form. The test consisting of five questions is administered to the sample of 67 students twice as pretest and post-test (See Appendix for the test). The questions are related to the subjects' gravity and inertia. These questions measure the following misconceptions:

M1: Gravity is caused (or partly caused) by air pressure.

M2: Gravity is different on different parts of the earth.

M3: Gravity is caused (or partly caused) by rotation of the earth.

M4: A constant force causes a constant velocity.

The questions and their alternatives as shown in table 1 measure these misconceptions:

Table 1. Misconceptions and the corresponding alternatives to the Questions

Misconception	Question
M1	1a,c
M2	2a,b,c,e,
M3	3a,b,c,d
M4	4a,d
M4	5a,b,e

Additionally, the students were assigned homework to help the instruction during the treatment period in which bridging analogies were used. The homework had a great contribution to the following day's discussions. The homework questions were also taken from the same book.

2.3 Treatment

In the first day, to overcome M1 first we made a public vote drawing Figure 2 on the board and asked the following question:

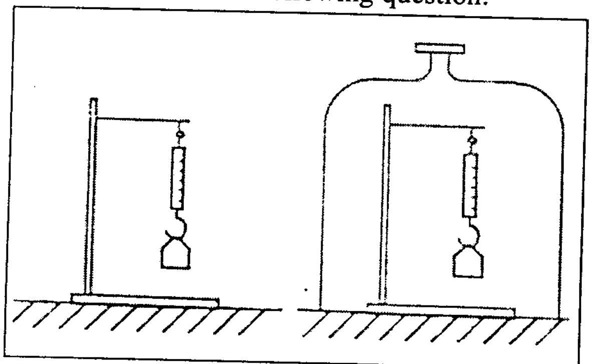


Figure 2. A Scale and a Bell Jar

"If we place the apparatus under a bell jar and we remove almost all of the air, what scale reading would you predict?"

Then, making a table on the board we have recorded the number of students' responses. After the public vote, the students defended their answers in the discussion. Then, the demonstration of hanging mass with a spring scale in a bell jar was made. The air is taken out by a vacuum pump while the students were observing it. After the demonstration, a discussion is made. To summarize the lesson the students were asked the following questions:

"Did the bell jar experiment tell us what causes gravity?"

"What did it tell us?" Then, the following challenging question is asked.

"If the gravity is not caused by air pressure, then what does cause gravity?"

The helpful answers to the question are paraphrased and the students' desire for the right answer is deferred by assuring them it will become clear later. The students were convinced that air pressure has no effect on gravitation after the first part of the lesson.

Then, Figure 3 is drawn on the board and the students voted the following question to overcome M2:

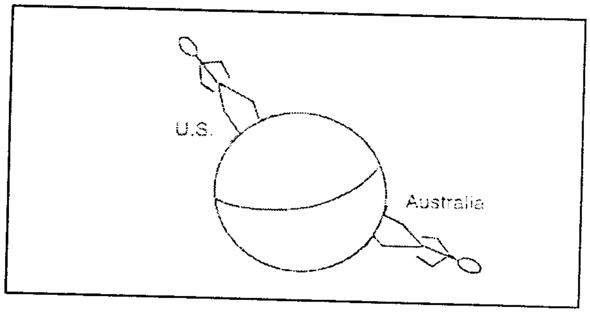


Figure 3. Gravity in Different Parts of World

"Compared to the United States, the strength of gravity in Australia is:

a) a little less

b) equal

c) a little more".

The students explained the reasons for their answers in the discussion. After some discussion, Figure 4 is drawn on the board and it is clearly stated that, " gravity is a force that points toward the center of the Earth and does not change significantly with the altitude." The above question is used as an anchor.

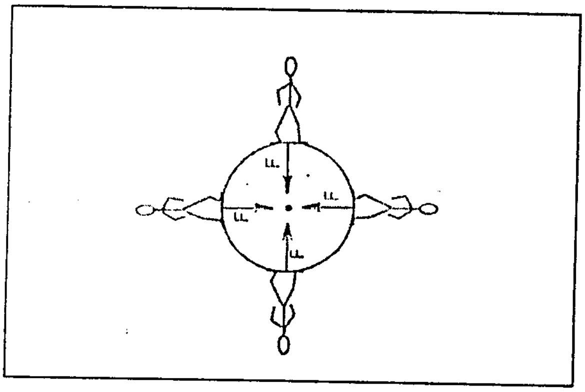


Figure 4. Direction of gravity

Then, to overcome M3 Figure 5, showing the "top view" of the Earth and the springs in the bathroom scale, is drawn on the board and the following question is asked:

If we place a person, at the Equator, standing on a bathroom scale how would the scale reading change if the Earth were to spin around on its axis much faster?

a) Scale reads the same.

b) Scale reads more.

c) Scale reads less.

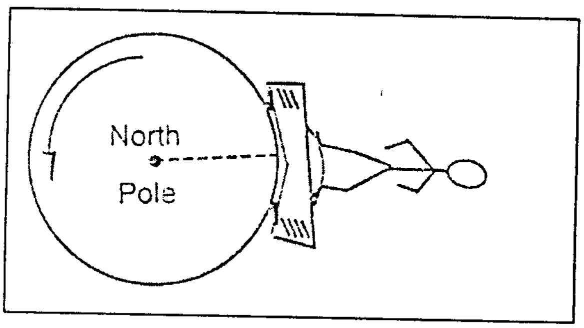


Figure 5. Earth rotation and Pole

Before the voting anchoring analogies are drawn out from the students. The hints about the merry-go-round at a playground are given to the students.

After the discussion, as shown in Figure 6 the demonstration of an actual globe and sticking a small object in clay is made.

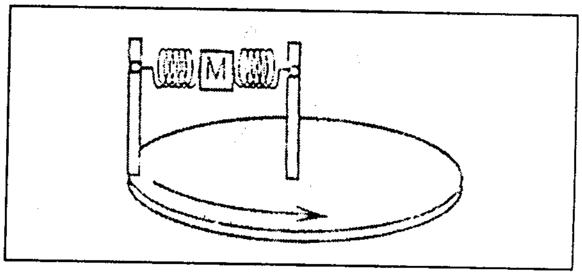


Figure 6. Earth rotation and Merry-go-round

Then, the summary question is asked:

"How would you respond to someone who says that gravity is caused by rotation of the Earth?"

After clarifying the student responses the summary of the lesson is made by the students.

In the second day, to overcome M4 the students discussed the following questions.

- What kind of motion does a constant force cause?
- What is really responsible for an object's tendency to resist change in motion?
- Is it hard to both start and stop a skateboarder?
- Is it easier to stop/start a larger or smaller mass?

Then, activities that will be made in the following day were briefly explained, and the students were expected to make predictions. After the demonstration of pulling a tablecloth under some tableware an explanation was given in terms of the hold back property which causes the object to stay nearly in the same state.

The third day's lesson started with the discussion of the homework. Then, the terms "hold back property", "hold down tendency", "keep going property" and friction are explained. Keep going and hold back properties are used instead of the inertia. Hold down tendency is used instead of gravitational force. After the terms are explained, the demonstration of skateboard was done: One student applying a steady force on another student sitting on a skateboard. Then, it is stated that a constant force causes a constant acceleration. In fact, in the actual activity it was planned to do skateboard activity as a laboratory activity rather than demonstration. However, the equipment and restricted time hampered the situation such that it was not possible to do it. Therefore, the students were not able to experience the sensation of either applying a steady force on object causes acceleration or when a steady force is applied it causes acceleration. In the actual activity all students should experience both being accelerated as sitting on the skateboard when a constant force is applied and applying a constant causes acceleration by applying a steady force on their friends sitting on the skateboard.

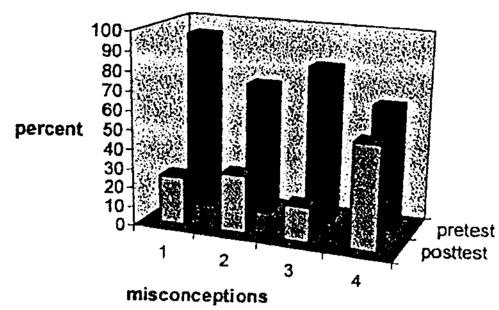
3. RESULTS

3.1 Students' Misconceptions

As shown in Table 2, there is a significant positive change, meaning that the treatment has done what is being expected. It can be clearly seen that a high percentage of the students have misconceptions in the pretest.

In the pre-test 93% of the students think that gravity is caused by air pressure. However, in the post-test the percentage decreased to 25%. Additionally, in the pre-test 69% of the students think that gravity is different on different parts of the earth. But, in the post-test the ratio has decreased to 30%. 81% of the students think gravity is caused by rotation of earth in the pre-test while only 18% of the students think like that in the post-test. Moreover, 64% of the students think that a constant force cause a constant velocity but merely 54% think likewise in the post-test.

Table 2. Comparison of the Students' Misconceptions in the Pretest and in the Posttest



	1	2	3	4
posttest	25	30	18	54
pretest	93	69	81	64

3.2 Effects of Bridging Analogies

Table 2 also made it explicit that the percentage of the students has decreased in the posttest, while a high percentage of the students had misconceptions in the pretest. These imply that bridging analogies are effective in overcoming misconceptions

The scores were between 0.0 and 4.0 in the pre-test whereas scores are between 0.0 and 5.0 having a much wider range in the post-test (Table 3). The great difference in mean shows that there is a general improvement in scores. Median also indicates the same result. In the pretest the most common score was 1.0. In the posttest it became 5.0. This result tells us that in physics instruction bridging analogies are very useful in increasing the scores.

Table 3. Descriptive Analysis of the Pretest and the Posttest

	Pretest	*Posttest*
Mean	1,2	3,3
Median	1,0	3,0
Mode	1,0	5,0
Standard Deviation	1,1	1,4
Range	4,0	5,0
Minimum	0,0	0,0
Maximum	4,0	5,0
Count	67,0	67,0

It is readily seen in Figure 7 and 8 that there is a significant increase in scores. The attention should be paid to the point that the students having the lowest score in pretest are spread through higher scores. This shows that the treatment of bridging analogies is effective in physics instruction.

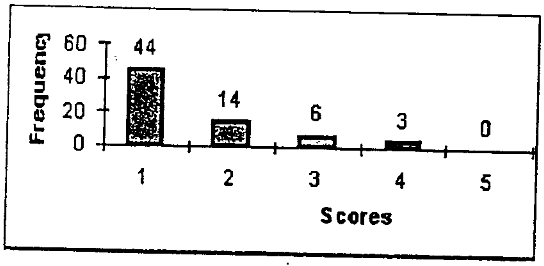


Figure 7. Histogram of the Pretest

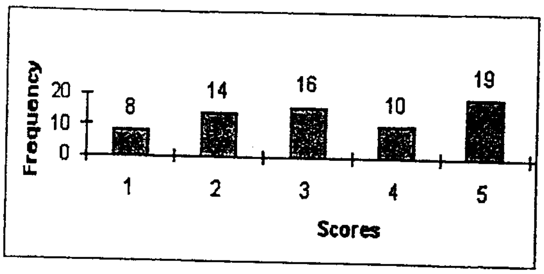


Figure 8. Histogram of the Posttest

The p-value (p=0,000) in Table 4 does mean that we reject the null hypothesis. Hence, there is a significant mean difference between students' pretest and posttest scores.

Table 4. Paired T-Test for Two Sample Means

	Posttest	*Pretest*
Mean	3,25	1,19
Variance	2,01	1,28
Observations	67	67
Pearson Correlation	0,33	
Hypothesised Mean Difference	0,00	
df	66	
t Stat	11,27	
P(T<=t) two-tail	0,000	
t Critical two-tail	2,00	

4. CONCLUSIONS AND SUGGESTIONS

Physics is troublesome to many students. To construct meaningful learning in this course is very difficult. Moreover, most of the students do not understand physics because the methods being used are not appropriate. However, when the appropriate methods are used it is observed that success in this course increases. Additionally, physics become an enjoyable course.

There are many studies in the literature about physics. Some of these studies are about the effects that are influencing physics education. One of the factors influencing physics instruction is preconceptions. Some of the preconceptions are misconceptions. Misconceptions make it difficult to construct meaningful learning. A method of instruction is developed to overcome misconceptions in this study. It is called bridging analogies. Bridging analogies are used for establishing analogical connections between situations in which students initially believe that they are not analogous.

In this study, bridging analogies about gravity and inertia are used in instruction to high school students. The results indicate that students have misconceptions about gravity and inertia. The results also point out that bridging analogies are effective in overcoming the students' misconceptions about gravity and inertia. Being a very limited study the results were satisfactory enough. There may be much wider studies on bridging analogies and should become a common method especially in mechanics courses and all physics subjects.

The followings are suggested to the high school teachers and teacher trainers:

1. To define the students' misconceptions before the instruction.
2. To use bridging analogies in instruction.

This will help students to understand the whole physics much easily and clearly. The responses we get while talking to the students were also in this way. While using bridging analogies the materials we have developed can be used.

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APPENDIX: MEKANİK KONULARI KAVRAMYANILGILARI TESTİ:

1. Bir sabah kalktığınızda dünyanın bütün atmosferini kaybettiğini (bütün hava gidiyor) varsayalım. O sabah, herhangi normal bir basküll tartıldığınızda aşağıdakilerden hangisini beklersiniz?

(A) Tartının sıfırı göstermesini
(B) Tartıda gözüken değerin artmasını
(C) Tartıda gözüken değerin azalmasını
(D) Tartıda gözüken değerin değişmemesini
(E) Olaya tepki olarak önce değerin artmasını sonra azalmasını

2. Bir önceki soruda, eğer tartıldığınız yerde değilde çok daha yüksek bir binanın veya bir dağın üstünde tartılmış olsaydınız aşağıdaki seçeneklerden hangisinin doğru olmasını beklerdiniz?

(A) Tartının sıfırı göstermesini
(B) Tartıda gözüken değerin artmasını
(C) Tartıda gözüken değerin azalmasını
(D) Tartıda gözüken değerin değişmemesini
(E) Olaya tepki olarak önce değerin artmasını sonra azalmasını

3. Dünya, ekseni etrafında daha hızlı dönmeye başlayıp 24 saat yerine 12 saatte bir dönüşünü tamamlamaya başlasaydı dünyanın çekim kuvvetinin vucudumuzun üzerindeki etkisi ile ilgili aşağıdaki seçeneklerden hangisi doğru olurdu?

(A) 2 kat artar
(B) 2 kat azalır
(C) bir miktar artar
(D) bir miktar azalır
(E) değişmez

4. Sema bir kaykayın üzerinde oturmaktadır. Serdar 20 N'luk sabit bir kuvvetle Sema'yı çekerse Sema'nın hareketi için ne söylenebilir? **(Ortamdaki bütün sürtünmeler önemsizdir.)**

(A) Sabit hızla hareket eder.
(B) Sabit ivme ile hızlanır.
(C) Artan bir ivme ile hızlanır.
(D) Önce hızlanır sonra sabit hızla hareket eder.

5. Bir önceki soruda, eğer Sema olduğundan 10 kg daha ağır olsaydı, Sema'nın hareketi için aşağıdaki seçeneklerden hangisi doğru olurdu?

(A) Daha küçük sabit bir hızla hareket ederdi.
(B) Daha büyük sabit bir hızla hareket ederdi.
(C) Daha küçük bir ivme ile hareket ederdi.
(D) Daha büyük bir ivme ile hareket ederdi.
(E) Ortam sürtünmesiz olduğu için hızı değişmezdi.