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DEALING WITH MISCONCEPTIONS ABOUT FORCE AND MOTION CONCEPTS IN PHYSICS: A STUDY OF USING WEB-BASED PHYSICS PROGRAM

FİZİKTE KUVVET VE HAREKET KONULARINDAKİ KAVRAM YANILGILARININ ÜSTESİNDEN GELME: BİR WEB TABANLI FİZİK PROGRAMININ KULLANILMASI İLE İLGİLİ ÇALIŞMA

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ABSTRACT: The aim of this study was to deal with misconceptions about force and motion concepts in physics. A total of 125 subjects, in Brevard County, Florida were selected by a sample of convenience to participate in this study during the fall of 1999-2000 academic years.

The Multiple Analysis of Covariance (MANCOVA) analysis yielded a significant interaction for pretest and gender for dependent variable of Misconceptions. As a result of this, Attitude Treatment Interaction (ATI) was performed for dependent variable of misconceptions. ATI between pretest and gender relative to misconception was significant. When dependent variable is analyzed, there was a significance difference between treatment and control groups relative to misconceptions score. Group membership contributed 12.6% additional knowledge of posttest score variability, which was statistically significant for misconceptions ($F_{1,9} = 20.03$, $p < .05$). Based on this result, it can be concluded that incorporating the web-based physics program with traditional lecturing did have a significant effect on dispelling students' misconceptions about force and motion concepts.

Keywords: science education, physics education, web-based instruction, computer based physics teaching.

ÖZET: Bu çalışma, fizikte kuvvet ve hareket konuları hakkındaki kavram yanılgıları ile ilgilidir. 1999-2000 öğretim yarıyılında Florida/USA "Brevard County'de" toplam 125 öğrencinin katılımıyla gerçekleşmiştir. Çoklu Kovaryet Analizi (MANCOVA) bağımsız değişken olan kavram yanılgıları için cinsiyet ve ön test sonuçları arasında bir ilişkiyi anlamlı çıkardı ve buna bağlı olarak da Tavır Davranış Etkileşimi (ATI) analizi yapıldı. ATI analizini kullanarak kavram yanılgıları için ön test sonuçları ile cinsiyet arasındaki ilişki incelendi. İncelemeler sonucu, öğrencilerin kuvvet ve hareket konulandaki kavram yanılgılarının giderilmesinde deneysel grubun sonuçları ile diğer grubun sonuçları arasında anlamlı bir fark bulundu. Deneysel grupta bulunan öğrencilerin son teste katkısı %12.6 olarak bulundu ve bu sonuç istatistiksel olarak anlamlı bir sonuçtu ($F_{1,9} = 20.03$, $p < .05$). Bu sonuçlar baz alındığında sonuç olarak denilebilir ki normal dersle birleştirilen web tabanlı fizik programı öğrencilerin bu konulardaki kavram yanılgılarını gidermede etkili olmuştur.

Anahtar Sözcükler: fizik eğitimi, web tabanlı öğretim, bilgisayarla fizik öğretimi.

1. INTRODUCTION

During the last two decades, physics education research has shown many surprising things about the difficulties introductory university students have because they lack the ability to perform formal operations inherent to learning physics. This suggested a need for a more interactive and problem-solving teaching methodology in introductory physics. At the same time, the ongoing revolution in information technology has led to new tools for creating innovative educational environments. In response to these two developments, a wide variety of new models of physics instruction are beginning to appear and have potential for challenging the way physics has been traditionally taught. Does traditional physics teaching "work" in the introductory physics classroom? Unfortunately, detailed explanations by many physics education researchers have shown that it does not work well for a large portion of students. When many students fail, faculties or teachers might be pressured to pass more students, thus, lowering of the standards.

It is evident from the literature that students of different educational backgrounds and

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different ages have basic preconceptions or misconceptions about force and motion concepts (Clement, 1982; Halloun & Hestenes 1985b, Maloney, 1984). Misconceptions are necessary and valuable to further learning in physics (Brouwer, 1984). Many scholars have called these preconceptions by many different names. For example, Pines and West (1986) call them "spontaneous knowledge." Driver and Easley (1978) refer to them as "alternative conceptions." Helm (1980) calls them "misconceptions." Gilbert, Watts and Osborne (1982) call them "children's science."

1.1. Purpose

The aim of this study was to examine on high school students' misconceptions in force and motion concepts using a Web-Based Physics Software Program. Active engagement in learning, and, hence, increased learning, is more likely to occur in such instructional methods as computer-based instruction than in other instructional methods.

1.2. Variables

Dependent Variable: Misconceptions

Independent Variables: Priory Physics Knowledge, Gender, Group membership, Location, Ethnicity, and their interaction with each other.

1.3. Hypotheses

The null hypotheses that corresponds to this study are as follows:

1. Incorporating the web-based physics program with traditional lecturing will have no effect on students' misconceptions in force and motion concepts among high school students as compared to traditional lecturing alone.

2. There will be no significant difference between male and female students' misconceptions scores in force and motion concepts.

2. LITERATURE REVIEW

2.1. Constructivist Learning Theory

There is no essential conflict between science and constructivism at the operational level. In fact, scientists readily admit that all we can ever do is construct a *model* of external reality, assuming it exists. Thus, all that we *know* is actually a set of stimuli and experiences. This is totally in accord with the scientific view. So, at the level of epistemology—how we know or learn anything—science and constructivism are in complete harmony.

The constructivist perspective is clearly divergent from earlier views of education that presumed we could impose information directly onto a student. Starting from constructivism, real learning can occur only when the learner is actively engaged in operating on, or mentally processing, incoming stimuli. Furthermore, the interpretation of stimuli depends upon previously constructed learning

2.2. Technology Use in Education

Today's technologies have the potential to transform the relationship between students and teachers and to change how schools operate (Bagley & Hunter, 1992; Sheingold & Hadley, 1990). The assumption of these claims is that computer-related technologies —unlike older forms of media, like TV and film projectors—are learning devices rather than teaching devices (Boysen, 1992). The computer's capacity to interact with students and react to their individual needs has the potential to provide a student-centered context that can assist students in learning. Papert (1993) discusses that computers offer progressive educators the tools that can bring and shape qualitative changes in education.

Educators must go beyond computer literacy to achieve technological competence if successful integration of technology into the classroom is to occur. Technological competence also requires a transition from using the computer as an instructional delivery system to one of using the computer as a learning tool (computer-supported instruction) (Lowther, 1998).Yet, Clark (1985, 1991, 1994), Morrison (1994), and Ross and Morrison (1989) explained that technology or media does not affect learning. Rather, it is the specific instructional strategy that the instructional designer or teacher designs and implements which affect learning. Also, the computer should be viewed simply as another medium that is capable of accomplishing certain tasks well and others poorly or not at all (Hagler & Knowlton, 1987).

2. 3. Misconceptions and Physics Education

During the past two decades, many studies by numerous physics education researchers have shown that students enter physics classes with many preconceived ideas. These preconceptions are often misconceptions in that they do not provide a correct description of the behavior of the physical world that is consistent with the laws of physics. Whenever these ideas are misconceptions, teachers should try to challenge and discuss them immediately, otherwise students will find it very difficult to understand completely, and they cannot process and model in the physical world.

Tao and Gunstone (1999) investigated the process of students' conceptual change during a computer supported physics units in a 10th-grade science class (N = 27). Their study took place over a period of 10 weeks. Data were collected at the various juncture on only 14 students. These students were subsequently used for case studies of conceptual change. Of the 14 students, six showed substantial conceptual changes, one showed some change, and the remaining seven showed no change.

Harrison (1999) focused on one-student cognitive and affective changes, which occurred during the 11th grade in heat and temperature concepts. Classes of five grade 11 boys were taught heat and temperature using the physics by inquiry materials (McDermott, 1996) during 40-45 minutes periods over eight weeks. Three of the five students demonstrated conceptual development whereby their understanding of heat and temperature was restructured in a scientific direction. Four of the five students progressively adopted scientifically precise language, and the consistent verbal and written use of scientific terminology by three of the students supported the belief that they understood the concepts they described (Harrison, Grayson, & Tregust, 1999). They indicated that students had difficulty differentiating such as heat and temperature and that there naïve conception were robust and resist change.

3. METHODOLOGY

There was one instrument in the study: The Force Concept Inventory test (Hestenes, Swackhamer, and Wells, 1992) to use as a pre- and posttest to measure students' achievement and misconceptions scores in force and motion comcepts. According to Force Concept Inventory (FCI) test results, the total number of students used in the study was 125 public high school students of 11th (93 %) and 12th (7 %) grades. The ages of students ranged from 15 to 18 years old (total distribution of students: 2.4 % of the students was 15 years-old, 52.8 % of the students was 16 years-old, 40 % of the students was 17 years-old, and 4.8 % of the students was 18 years-old or older). Also 54.4 % of the students were female and 45.6 % of students were male.

3. 1. Web-Based Physics Software Program

Anderson (2001) developed the web-based instruction program that was used in the study. Although the program includes many concepts and topics in physics I chose only the first three units (Kinematics, Force and Motion, and Vector and two-dimensional Kinematics), for my research purpose. The program titled "The Physics Classroom".

The Web-based physics program was incorporated with the normal lecture. Specifically, 30% of class time was allocated to using this tutorial program, and 70 % of class time was used for normal lecture. These percent allocations were aggregated on two-week schedule.

Misconception scores were graded on a scale from one to 30. Given the 30 misconceptions from FCI test, students' misconception scores could range from 0 (no misconceptions) to 30 (high level of misconceptions).

4. RESULTS

4.1. MANCOVA Overview

MANCOVA is a special case of the more general analysis of partial variance, and involves a quantitative covariate set, and a nominal scale research factor set that describes group membership. This study included a covariate set and involved multiple independent and dependent variables. Thus, for the purpose of this study, MANCOVA was the primary statistical strategy used.

4. 2. Homogeneity of Regression

In analysis of covariance (ANCOVA or MANCOVA) there is an underlying presumption that the relationship between dependent (set D) and covariate (set A) sets is the same for all values of the research factor set (set B).

To test the homogeneity of regression assumption, a hierarchical Multiple Regression Correlation (MRC) analysis was conducted for dependent variable of misconceptions. Thus, dependent variable (Y) was regressed hierarchically using the variable entry order of Set A (covariate), Set B (research factors), and Set C = AxB (interactions). The results of the test for homogeneity are given in Table 1.

Table 1: Hierarchical Cumulative R^2 Analysis of the Homogeneity of Regression Assumption in the MANCOVA Model

IV Set Added	df	Cum R^2	I	F_I
Set A	2, 122	Y=Misconceptions		
Set B	7, 115	.280		
Set AxB	15, 109	.419	.139	3.72*

Note: N = 125; I = Increment in R^2; F_I = F–value of the increment; *p < .05; Set A = Covariate (pretest); Set B = independent variables (research factors); Set AxB = interaction between set A and set B.

To test for homogeneity, Y (dependent variable = misconception) was hierarchically regressed on the model containing set A (covariate = pretest), set B (independent variables = research factors), and set AxB (interactions), and the unique or incremental variance attributable to set AxB was subjected to an F test. As can be seen from Table 1, the increment (I) or increase in total variance (R^2) due to the addition of interaction variables (AxB) was significant ($F_{(15,109)} = 3.72$, $p < .05$) for the dependent variable of misconception. Because these interaction terms were significant, the test for homogeneity of regression failed rendering an invalid MANCOVA model. Consequently, Attribute-Treatment Interaction (ATI) analysis was performed for dependent variable to examine this significant interaction.

4.3. ATI for Dependent Variable of Y (Misconceptions)

The interaction results relative to misconceptions (Y) are shown in Table 2. Table 2 shows that there were two significant interactions relative to misconceptions: The first one (X_9) involved an interaction between pretest (X_1) and gender (X_2). The second one involved an interaction between pretest (X_1) and ethnicity (X_3-X_6)

Table 2: ATI Analysis of Set C Interaction Variables Entered Independently of Each Other in the Presence of the Covariate and the Research Factor Set for Y = Misconceptions.

Set C	CumR^2	I	df	F_I
$X_9 = X_1X_2$	.389	.109	1,115	20.60*
$X_{10}=X_1X_3$, $X_{11}= X_1X_4$, $X_{12}= X_1X_5$, $X_{13}=X_1X_6$	0.345	.065	4.112	2.78*
$X_{14}=X_1X_7$	.282	.002	1,115	.299
$X_{15}=X_1X_8$	.282	.002	1,115	.321

Note. N = 125; $R^2_{Y.AB}$ = .280; *p < .05; I = Increment (sr^2); F_I = F value of Increment; X_7: Location; X_8: grup membership; X_{10-13} represent effect-coded ethnicity.

Examining the pretest-gender interaction first, we get the following regression equation:

$\ddot{Y} = .015X_1 + 6.22X_2 - .2X_9 + 12.78$

(where X_1= pretest, X_2 = Gender, X_9 = X_1X_2). Substituting the individual independent variables that make up the interaction, namely, $X_1$and X_2, we get:

$\ddot{Y}_2 = .015X_1 + 6.22X_2 -.2X_1X_2 + 12.78$

The separate regression equations necessary for the ATI were derived by inserting male (X_2) = 1, and female (X_2) = 0:$\ddot{Y}_{male}$= -.185X_1 + 19 (4.3)

for female (X_2 = 0): $\ddot{Y}_{female}$= .015X_1 + 12.7 (4.4)

By setting equations (4.3) and (4.4) equal to each other and solving for X_1, the X_1-value of the point of intersection is 31.Thus, when graphed on the same set of axes equations (4.3) and (4.4) intersect at the point (31, 13.25).

Figure 4.1 The ATI Interaction Graph Between Pretest and Gender Relative to Misconceptions Scores

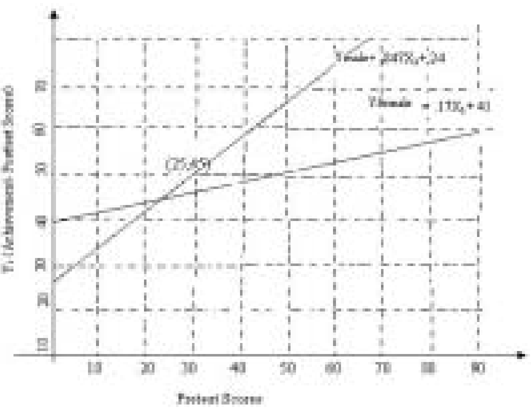

Figure 4.1 illustrates this interaction result. This means that the rank order of pretest scores changes within the range of misconceptions scores. As pretest scores increase beyond a score of 31, females score higher than males on misconceptions indicating that females have higher misconceptions than males. As the pretest scores decrease below 31, males have higher misconceptions than females. Thus, achievement pretest scores have a differential effect on gender relative to misconception posttest scores. This interaction is discussed in more detail in discussion section.

4. 4. Analyses of the Null Hypotheses

When examining the data in terms of the null hypotheses, it should be noted that alpha and power were preset at .05 and .80 respectively.

4. 4. 1. Null Hypothesis 1

Incorporating the web-based program with traditional lecturing will have no effect on dispelling misconceptions about force and motion concepts among high school students as compared to traditional lecturing alone ($\mu_{control\text{-}Y2} = \mu_{treatment\text{-}Y2}$).

Relative to Y = Misconceptions, group membership contributed 12.6% additional knowledge of posttest score variability, which was statistically significant at .05 for misconceptions ($F_{1,9} = 20.03$, $p < .05$). Based on these data, it can be concluded that null hypothesis 1 should be rejected at .05 for misconceptions. In another words, incorporating the web-based program with traditional lecturing had a statistically significant effect on dispelling students' misconceptions about force and motion concepts when compared to traditional lecturing alone in the presence of all other variables.

4.4.2. Null Hypothesis 2

There will be no significant difference between males and females on their misconceptions in force and motion concepts ($\mu_{male\text{-}Y2} = \mu_{female\text{-}Y2}$).

Relative to Y_2 = Misconceptions, gender contributed 0.6% additional knowledge of posttest score variability, which was not significant ($F_{1,9} = .966$, $p > .05$). Based on these data, null hypothesis 2 failed to be rejected at the .05 level.

5. DISSCUSSION AND CONCLUSION

5. 1. Implications for Prior Research and Educational Practice

Before taking the introductory physics course, students have many misconceptions related to their own previous experiences or knowledge, and normal traditional lecturing fails to overcome and take this into account. Based on data from this study, incorporating the web-based physics program decreases students' misconceptions. We can imply that using new instructional methods such as incorporating the web-based programs for the traditional lecturing can dispel students' misconception in physics. A study from White (1993) on force and motion of sixth graders with computer based micro world for two months compared their science class with eighth graders who experienced more conventional instruction. He concluded that the computer-based micro world students performed better on a written posttest examining their ability to transfer the underlying Newtonian principles to real-world context.

5.1.1. Misconceptions

The significant difference between groups relative to misconceptions supports findings of previous studies that most students have misconceptions (Trowbridge and McDermott, 1980; Terry & Jones, 1986; Brown, 1989; Gunstone 1987; Berry and Graham, 1992). The result from this study showed —as Hicks and Laue (1989); Finegold and Grosky (1992); and Scott (1992) concluded— that the use of Computer Based Instruction dispels students' misconception about force and motion. Based on data from this study, incorporating the web-based program was effective in significantly dispelling students' misconceptions in force and motion concepts in physics.

5.1.2. Gender

A gender difference was observed in misconceptions in terms of interaction between pretest and posttest scores. An implication of this is that males and females have different prior physics knowledge that influences their further learning. According to this interaction between pretest and gender in misconceptions, the gender differences play very important implications. Lower pretest results obtained from males resulted in fewer misconceptions. An implication of this result is before taking the physics class, males need less instruction, and female students need more instruction in order to get fewer misconceptions. Further research on this issue may provide more detailed explanations and suggestions.

5.2. Recommendations for Future Research Relative to Study Limitations

For those considering similar studies, several factors should be considered to improve or strengthen such research.

In this study, it was hypothesized that incorporating the web-based physics program with traditional lecturing will have no effect on misconceptions about force and motion concepts among high school students as compared to traditional lecturing alone. For readers who are interested in conducting further research on determining the effects of constructivist teaching methods with incorporating web-based physics program in their instruction, the following recommendations, based on this study's limitations, are offered so that significance may be improved.

All results were based on the FCI test. Although the FCI test has a high reliability and validated to many research results, using other instruments could yield more significant results.

Using intact groups appeared to limit research findings; more diverse random samples could improve students' achievement and dispel their misconceptions significantly. In this study, the accessible population was public high school students enrolled in introductory physics courses in Brevard County, Florida. The subjects were not randomly selected from the accessible population. Subjects who volunteered for this study were chosen as a sample of convenience.

Teachers were trained for one to two hours prior to the study period. Although I observed classes once a week for treatment verification through the study period, however, one can not give any guarantee that this kind of training could affect the teachers' behavior or attitude toward students in both control and treatment groups. A suggestion is to gather anecdotal data by asking teachers to maintain journals in which they can record their comments or personal reflections.

Using 100% the web-based program vs. lecture only could give different results on students' misconceptions about force and motion concepts. Also, using a different web-based physics program could produce different and possibly more significant results.

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