TURKISH STUDENTS' FORCE MEANINGS

Muhsin Menekse
Arizona State University

Douglas B. Clark
Vanderbilt University

Gökhan Özdemir
Niğde University

Cynthia D'angelo
Arizona State University

Sharon Scheligh
East Carolina University

Publication date: September, 2009
Final version

Abstract

What are Turkish pre, elementary, middle, and high school students' force ideas? And, how do Turkish students' non-normative force ideas differ or be similar to the well-known force misconceptions reported in the literature?

Students have false and persistent beliefs about the physical world and they struggle with challenging misconceptions based on their perceptions of everyday experiences. The current study applied the coding schemes from diSessa, Gillespie, and Esterly (2004) to interviews conducted with 78 students from two cities in Turkey in order to investigate students' understandings of force concept. Specifically, this study focuses on Turkish students' force meanings in different situations and the commonalities of the ideas at various age groups. The results show that there are significant differences, in terms of force meanings, among grade levels and high school tracks but no difference by gender nor city students live. Also, the distribution of force meanings across grade levels indicate remarkable findings, such as force meanings are uniformly distributed for both middle and high school students. Overall, this study, with its large sample size and in-depth interview questions, offers a significant contribution to the limited literature of Turkish students' force-meanings.

Background and Purpose

The force concept is one of the most important and complex topics in physics. All physics curricula, at various grade levels, require the normative understanding of this fundamental concept in order to comprehend advanced concepts (such as linear momentum or rotational dynamics). However, many highly cited studies show that force-related concepts are not well understood by the majority of students (e.g., Chi, 2005; Clement, 1982; Cooke & Breedin, 1994; diSessa, Gillespie and Esterly (henceforth referred to as DG&E), 2004; Halloun & Hestenes, 1985; Ioannides & Vosniadou (henceforth referred to as I&V), 2002; McDermott, 1984; Gilbert & Watts 1983). Students have false and persistent beliefs about the physical world and they struggle with challenging misconceptions based on their perceptions of everyday experiences. For example, many students demonstrate the misconception that an increasing force is required in order to accelerate objects horizontally (e.g., Watts & Zylbersztajn, 1981). Also, as another example, students think a heavier object exerts greater force on the lighter one in an interaction because it dominantly affects the lighter's opposition (e.g., Gunstone & Watts, 1985). Students acquire these naive conceptions from the physical world and these ideas are strengthened by everyday experiences and actions like throwing, lifting, pulling, or pushing and observing objects in action. These observations and experiences strongly shape students' perceptions and understanding about scientific knowledge, and causing difficulties to develop normative concepts (Anderson, 2007).

The current study uses the set of ten interview questions, which DG&E condensed and modified from I&V for their quasi-replication research, in order to investigate Turkish students' understandings of force. The main purpose of this study is to document Turkish students' force ideas and to compare the findings with core alternative frameworks stated frequently in the literature. Specifically, this study focuses on students' force ideas in different situations and the commonalities of the ideas at various age groups. The two main research questions of this study

therefore investigate: (1) what are Turkish pre, elementary, middle, and high school students' force ideas? (2) How are Turkish students' non-normative force ideas similar and/or different from the misconceptions observed in the studies of English-speaking students?

Rationale

Research show students have or develop many force related misconceptions based on their everyday experiences and intuitive ideas. One can classify these misconceptions in different categories, such as ideas specific to certain age groups, or ideas ordered from most resistant to easy to change. Duit's (2007) excellent bibliography documents hundreds of research studies regarding misconceptions and conceptual change. Unfortunately, however, the majority of these studies have been conducted with English speaking students and there is limited number of studies with Turkish students regarding force concept. Thus, it is difficult to draw strong conclusions about Turkish students' force meanings with the existing literature. Also, the differences in age-groups and research methods among the studies with Turkish kids make it difficult to generalize.

In this study, we interviewed Turkish students of various ages, with a large sample size (N = 78), to investigate their ideas related to force concept. We hypothesized that because culture and language related factors might potentially influence students' interpretation of force, interview analysis may indicate diverse results for Turkish students. They may express some force ideas different (or same) than those previously documented in the literature.

Methods

Participants

This study involves 78 students from two cities in Turkey, 32 from Ankara and 46 from Gaziantep. The students were from four different grade levels including: 8 pre-school students per city, 8 elementary students per city, 8 middle students per city, and 8 high school students from Ankara and 23 from Gaziantep. The mean student ages were 5, 10, 13, and 16 years,

respectively. Half of the students were girls and half were boys. The interviewers were two Turkish native speakers, and doctoral students. No more than three students at any age group were selected from the same school. All students were interviewed individually for about 20-25 minutes. All interviews were videotaped, transcribed, and translated into English.

Instrument

This study uses the set of ten questions that DG&E condensed and modified from I&V for their quasi-replication research (see figure 1). Each set involves three questions: two simple yes/no questions and one comparison question. The simple questions directly asking for whether there is force on a specified stone or not. The comparison questions consist of two drawings comparing the different situations to investigate the contexts in which the students would refer to force/s and how they would explain those force/s.

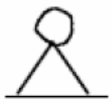
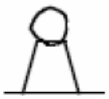
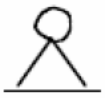
Question Set	Drawing A	Question A	Drawing B	Question B	Comparison Question
1		"This stone is standing on the ground. Is there a force on this stone? Why?"		"This stone is standing on the ground. Is there a force on this stone? Why?"	"Is the force on this stone the same or different than the force on this stone Why"
2		"This stone is standing on a hill. It is unstable. That means it could easily fall down. Is there a force on the stone? Why?"		"This stone is standing on a hill. It is stable. That means it won't easily fall down. Is there a force on the stone? Why?"	"Is the force on this stone the same or different than the force on this stone? Why"
3		"This stone is standing on a hill. It is unstable. That means it could easily fall down. Is there a force on the stone? Why?"		"This stone is standing on a hill. It is unstable. That means it could easily fall down. Is there a force on the stone? Why?"	"Is the force on this stone the same or different than the force on this stone? Why"

Figure 1. Question Sets 1, 2 & 3 (total of 10) combined by DG&E based on I&V's questions.

In each set, the typical question was, "Is there a force on this stone? Why?" and the specific drawing was shown while asking the question. After asking the same questions for the second drawing in each set, students were asked, "Is the force on this stone (in the first picture) the same or different than the force on this stone (in the second picture)? Why?" Such comparison questions were asked as long as students say "yes" for both of the simple questions.

The comparison question, when applicable, provides more information related to the student's understanding of force in terms of strength and contextual-related differences.

Analysis

Interviews were analyzed by using DG&E coding scheme, which was adapted from I&V's coding schema. DG&E' schema does "not include consideration of explanations, as I&V did" (p.867) in order to avoid possible bias in coding. Instead, they used more "holistic model mapping" technique to code interviews. According to DG&E's schema students' responses to each set of questions assigned one of the seven force meanings categories: (1) internal force (2) internal force affected by movement (3) internal and acquired (4) acquired (5) acquired and force of push-pull (6) force of push-pull (7) gravity and others. Table 1 represents a sample coding schema for question set 1. Each question set coded by comparing of amount of force on each stone with possible caveats and all possible matches calculated for each the seven force meanings (see Özdemir & Clark 2009 for more details in coding). Each interview was coded individually by two different coders (inter-rater reliability was approximately 93%) and then any differences were discussed. The final code was agreed upon for each student for each question set.

Table 1. DG&E sample coding schema for question set 1.

Force Meanings	Internal	Internal/ Move	Internal/ Acquired	Acquired	Acquired/ Push-Pull	Push-Pull	Gravity and Other
Set 1-Big vs. small stones standing on the ground.	-Force only on the big stone, but not due to air, gravity or ground. -Force on both stones but greater force on the big stone, but not due to air, gravity or ground.	-Force only on the big stone, but not due to air, gravity or ground. -Force on both stones but greater force on the big stone, but not due to air, gravity or ground.	-Force only on the big stone, but not due to air, gravity or ground. -Force on both stones but greater force on the big stone, but not due to air, gravity or ground.	-No force on any stone.	-No force on any stone. -Force only on the small stone but not due to gravity	-No force on any stone.	-Equal force on both stones -Force on both stones but greater force on the big stone.

Results

The preliminary results show the variation in force meanings across grade levels. Figure 2 below indicates that pre-school students mostly state *internal*-related force meanings. The elementary, middle and high school students mostly express *acquired*-related meanings. However, the *gravity and other* meanings scores are significantly higher for middle and high school students than the elementary school students' score.

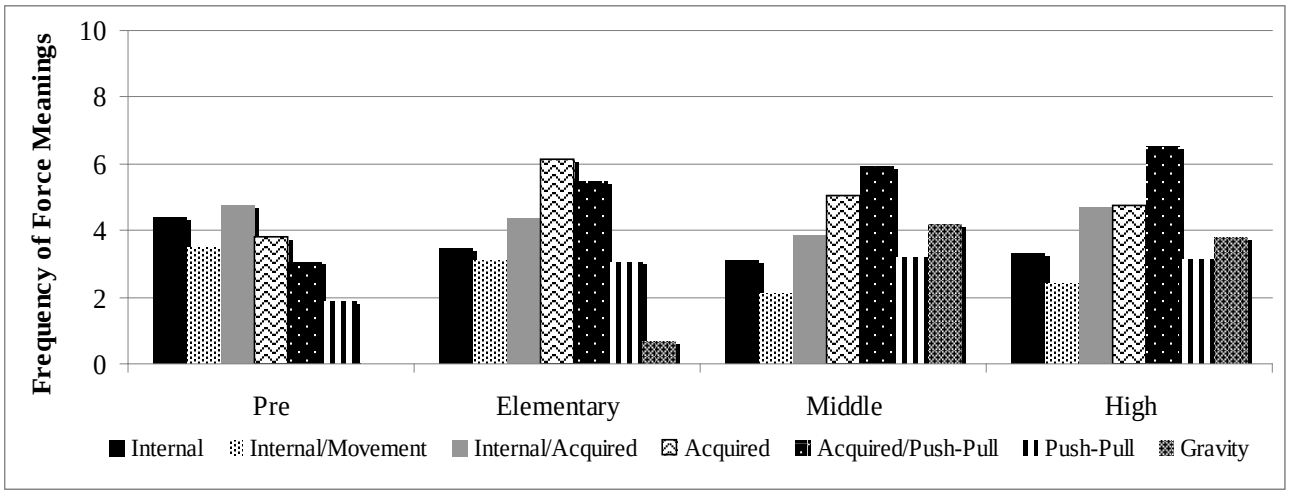


Figure 2. Turkish students' force meanings across grade level.

Also, one way multivariate analysis of variance (MANOVA) was conducted to determine the effects of differences in grade levels (pre, elementary, middle, high) on the seven dependent variables, force meaning categories. Significant differences were found among the grade levels on force meaning categories, Wilks' lambda $\Lambda = .36$, $F(21, 195) = 3.90$, $p < .01$. The multivariate η^2 based on Wilks' lambda was strong, .29. Table 2 contains the means and standard deviations on the dependent variables for four grade levels.

Table 2. Means and standard deviations for the force meaning categories

	Pre		Elementary		Middle		High	
Force Meanings	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Internal	4.40	3.07	3.47	1.94	3.13	2.90	3.32	2.15
Internal/Movement	3.53	1.81	3.12	2.36	2.13	1.41	2.42	1.54
Internal/Acquired	4.73	2.55	4.35	1.57	3.87	2.33	4.71	1.79
Acquired	3.80	1.32	6.12	2.49	5.07	1.94	4.74	1.78
Acquired/Push-Pull	3.07	1.87	5.47	2.06	5.93	1.71	6.55	1.67
Push-Pull	1.87	2.36	3.06	1.44	3.20	1.74	3.16	1.21
Gravity	.00	.00	.71	1.99	4.20	4.00	3.81	3.52

Analyses of variances (ANOVA) on the dependent variables were conducted as follow-up tests to the MANOVA. In order to control Type I error, the Dunnett's *C* method was used. ANOVA on the *acquired, acquired/push-pull* and *gravity* scores were significant, $F(3, 74) = 4.02$, $p < .01$, $F(3, 74) = 12.82$, $p < .01$, $F(3, 74) = 9.16$, $p < .01$, respectively.

Post hoc analyses to the univariate ANOVA for the *acquired, acquired/push-pull* and *gravity* scores consisted of conducting pair-wise comparisons to find which grade level scores were higher on these categories. In terms of *acquired* category, the elementary school students got the higher force meaning scores than the pre and high school students. In terms of *acquired/push-pull* category, high, middle and elementary school students received significantly higher scores than the pre school students. Finally, in terms of *gravity* scores, high and middle school students received significantly higher scores than the elementary and pre school students. The middle and high school students were not significantly different from each other.

We also conducted a one way MANOVA to determine whether there is a difference between boys and girls for the force meaning categories. The MANOVA results was not significant at alpha level .05, Wilks' lambda $\Lambda = .91$, $F(7, 70) = .97$, *n.s.* Next, another one way MANOVA was conducted to evaluate the differences between students from Ankara and Gaziantep. Results indicate no significant differences between students from Ankara and Gaziantep in terms of force meaning categories, Wilks' lambda $\Lambda = .83$, $F(7, 70) = 2.02$, *n.s.* Therefore, we can conclude that either gender or the cities where students live were not the factors effecting for Turkish students force meanings.

Finally, we specifically analyzed the high school students' data from different content tracks. Twenty-three of the high school students in Gaziantep were from three different tracks as Math & Science, Math & Literature, and Social Sciences. A one way MANOVA was conducted to determine the effects of differences in tracks on the seven dependent variables, force meaning categories. Significant differences were found among the students from different tracks on force

meaning categories, Wilks' lambda $\Lambda = .16$, $F(14, 28) = 2.97$, $p < .01$. The multivariate η^2 based on Wilks' lambda was quite strong, .59. The multivariate partial eta squared indicates 59% of multivariate variance of the dependent variables is associated with the track factor.

Separate ANOVAs also conducted on the dependent variables as follow-up tests to MANOVA. In order to control for Type I error across multiple ANOVAs, Holm's Sequential Bonferroni method was used. The ANOVA on *internal/acquired*, *push/pull* and *gravity* categories were significant.

Post-hoc analyses to the univariate ANOVAs for the scores from these three categories were conducted to find which track level affected the scores most strongly. First, math and science students received significantly higher scores than the math and literature students in the *internal/acquired* category. Second, social science students received significantly higher scores than the both math and science, and math and literature students for the *push/pull* ideas. Finally, in terms of *gravity* meaning scores, math and science students received significantly higher scores than the math and literature and the social science students.

Conclusion and Implications

The current study provides important results regarding Turkish students force meanings. The detailed analyses show that there are significant differences, in terms of force meanings, among grade levels but no difference by gender or the city students live. Also, the distributions of force meanings across grade levels indicate remarkable findings: First, force meanings are uniformly distributed for both middle and high school students. Especially, high school students demonstrated more consistent responses across question sets compared to the other group of students. Second, the pre-k students are spread across all of the force meanings categories except *gravity and other*. Third, the elementary school students are mostly clustered in the *acquired* related meanings. Finally, Turkish students are more evenly distributed across force meanings categories than U.S. students (diSessa, Gillespie, & Esterly, 2004; Özdemir & Clark 2009).

The school specific variations (e.g. Math & Science track) illustrate more important differences in terms of force meanings than the region specific variations (e.g., Ankara vs. Gaziantep). The results show that there are significant differences among students from different tracks in the high school. In order to understand the possible reasons, the analysis of the curricula (e.g., the degree in which students are exposed to the concepts of force in physics or science courses) and the school specific variations for different tracks (e.g., regular public schools versus anatolian high schools) are needed to be investigated and the study should be replicated with a much larger sample size.

No differences between pre-k students and middle-high school students in some categories are highly interesting results to look at. For example, observing no significant differences in terms of *internal* related force ideas between 5-6 years old pre-k students (with no formal schooling) and 13-16 years old middle and high school students with formal schooling (including many science courses) may illustrate thought provoking but disappointing implications for the implementation and the quality of Turkish science curriculum.

In addition to the limitations in the coding schema (read Özdemir & Clark 2009 for detailed analysis and limitations for the coding schema), the number of students involved in this study is not sufficient to generalize findings across Turkey. Also, all students in this study were attending urban schools; therefore, we do not have any data from rural or suburban schools. Finally, further analyses are needed to investigate the possible effects of culture and language in conceptualization of different science ideas.

Lastly, this study validates the general progressions outlined in the literature but suggests possibility of specific variations for Turkey. Overall, this study, with its relatively large sample size and in-depth interview questions, offers a significant contribution to the limited literature of Turkish students' force-meanings.

References

Anderson, C. W. (2007). Perspectives on Science Learning. In S. K. Abell & N. G. Lederman (Eds). *Handbook of research on science education*. (pp. 3-31). Mahwah, NJ: Lawrence Erlbaum.

Chi, M.T.H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *Journal of the Learning Sciences, 14*(2), 161-199.

Clark, D. B., D'Angelo, C., & Schleigh, S. & Menekse, M. (2008). International comparison of knowledge structure coherence: Cultural, semantic, and educational differences. In *Proceedings of the Eighth International Conference of the Learning Sciences*. Utrecht, Netherlands.

Clark, D. B., Menekse, M., Özdemir, G., & D'Angelo, C. (in preparation). Comparison of knowledge structure coherence and force meanings across sites in Turkey.

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

Cooke, N. J., & Breedin, S. D. (1994). Constructing naive theories of motion on the fly. *Memory and Cognition*, *22*, 474–493.

diSessa, A. A., Gillespie, N., & Esterly, J. (2004). Coherence versus fragmentation in the development of the concept of force. *Cognitive Science*, 28, 843-900.

Duit, R. (2007). *Bibliography STCSE –Students' and Teachers' Conceptions and Science Education*. Kiel, Germany: IPN Leibniz Institute for Science Education.

Gilbert, J.K. & Watts, D.M. (1983). Concepts, misconceptions and alternative conceptions: changing perspectives in science education. Studies in Science Education, Vol. 10, pp. 61-98.

Gunstone, R., & Watts, M. (1985). Force and motion. In R. Driver, E. Guesne, & A. Tiberghien (Eds.), *Children's ideas in science* (pp. 85-104). UK: Open University Press.

Halloun, I., & Hestenes, D. (1985). The initial state of college physics students. *American Journal of Physics, 53*, 1043-1055.

Ioannides, C., & Vosniadou, S. (2002). The changing meanings of force. *Cognitive Science Quarterly*, 2(1), 5-62.

McDermott, L. (1984). Research on conceptual understanding of physics. *Physics Today*, *37*, 24-32.

Özdemir, G. & Clark, D. B. (2009). Coherence of Turkish students' understanding of force. *Journal of*

Research in Science Teaching, 46(5), 570-596

Watts, D. M., & Zylbersztajn, A. (1981). A survey of some children's ideas about force. *Physics Education, 15*, 360-365.