



Primary School 5th and 8th Graders' Understanding and Mental Models about the Shape of the World and Gravity*

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Abstract

This study investigated primary school 5th and 8th graders' understanding and mental models related to the shape of the world and gravity, and how these models reflected the fact and what kind of a change there is from 5th to 8th graders. This research is based on a cross-sectional design. The study was conducted in a low socio-economic level school and 105 students -52 girls and 53 boys- participated in the study. The data were collected through interviews, one of the qualitative research methods. As a data collection tool, a semi-structured Conceptual Models interview form about the Shape of the World and Gravity (SWGCCIF) was used. The results of this study showed that 5th and 8th graders have seven different understandings and mental models about the shape of the world and gravity, one of which was scientific. The scientific approach and understanding were low in both 5th and 8th graders but a slight increase was observed towards 8th graders. In order for a meaningful learning through conceptual change, it can be suggested that these abstract concepts should be concretized by means of visual and audio materials and models. Also, studies with extensive samples should be conducted in order to provide a more comprehensive understanding of the situation.

Key Words

Gravity, the Shape of the World, Conceptual Misunderstandings, Science Education, Mental Models.

Astronomy, one of the oldest branches of sciences, is in direct relation with most of sciences (physics, mathematics, chemistry etc.). Recently, it has played a leading role among nature sciences as well (Trumper, 2006). Astronomy is a field in which information is gathered and made meaningful through personal experiences (Hannust & Kikas, 2007). Children receive information about astronomy in two ways; by means of their daily

life observations and their communications with people around them (Hannust & Kikas, 2007; Vosniadou & Brewer, 1990). However; this information that children get through experience is mostly far away from scientific facts and cause conceptual misunderstandings (Sewell, 2002).

One of the aims of science education is to change students' unscientific views about the world, in other words, their conceptual misunderstandings,

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and to replace them by scientific information (Brunsell & Marcks, 2007). Although students have been thought a lot of astronomy-based topics such as the shape and actions of the world (night and day, seasons formation), and gravity since primary school, learning difficulties about these topics have been observed during all education levels (Brunsell & Marcks, 2007; Vosniadou & Brewer, 1990). In countries where the problems about teaching astronomy-related concepts and events were realised, a lot of studies were conducted with children and adults about observable astronomy events. In these studies, it was aimed to determine the difficulties of teaching these concepts and events (Baxter, 1989; Bisard, Aron, Francek, & Nelson, 1994; Blown & Bryce, 2006; Hannust & Kikas, 2007; Mali & Howe, 1979; Nussbaum, 1979; Nussbaum & Novak, 1976; Sneider & Pulos, 1983; Stahly, Krockover, & Shepardson, 1999; Trumper, 2000, 2001; Vosniadou & Brewer, 1994; Zeilik, Schau, & Mattern, 1998). These studies showed that students at different education levels had a great number of alternative perspectives and intellectual models about observable astronomy events and some parts of these models do not change and exhibit continuity although students passed from one year into another. Among all this research, studies about the shape of the world and gravity have taken a significant place (Baxter, 1989; Blown & Bryce, 2006, 2010; Bryce & Blown, 2006; Lidar, Almqvist, & Ostman, 2010; Nussbaum, 1979; Nussbaum & Novak, 1976; Sadler, 1992; Sharp & Sharp, 2007; Vosniadou & Brewer, 1990, 1992). The reason why these concepts have been given much importance is the difficulties encountered during the learning process. For children, it requires to develop a scientific understanding about the shape of the world, to combine both the flatness and roundedness characteristics of the world and finally come into a synthesis. In other words; a children walking on a flat surface has an approach that the world is flat through his observations but he has to change his perspective, employ a scientific point of view and to consider flatness and roundness properties of the world. This process of gaining a different view is difficult (Sadler, 1992; Vosniadou & Brewer, 1990, 1992). Also, various studies indicated that students developed a lot of alternative understanding about gravity, an abstract concept (Baxter, 1989; Bryce & Blown, 2006; Nussbaum & Novak, 1979; Vosniadou & Brewer, 1990, 1992). Moreover; it was observed that even science and physics teachers and teacher trainees had some conceptual fallacies about gravity (Burgoon, Heddle, & Duran, 2010).

As the problems have been encountered during the process of learning about the shape of the world and gravity and alternative approaches have been emerged about these concepts at different levels of education, it has been realised that more studies are needed in this field (Burgoon et al., 2010).

For an effective teaching of these concepts, classroom activities should be organized and should start from the primary school and continue in the following years (European Association for Astronomy Education [EAAE], 1994). In line with this, firstly, alternative approaches students have formulated related to these concepts should be investigated. Extensive studies at different education grades in the primary schools were carried out abroad in order to see what intellectual models were developed by students, what kind of conceptual misunderstandings students had and whether these fallacies were continuous or not (Baxter, 1989; Bryce & Blown, 2006; Nussbaum & Novak, 1976; Vosniadou & Brewer, 1990, 1992). However, in Turkey, it was seen that astronomy-based research is generally quite limited, especially at a specific education grade at schools and mostly at higher education levels (Cin, 2007; Ekiz & Akbaş, 2005; Emrahoğlu & Öztürk, 2009; Gönen, 2008; Orbay & Gökdere, 2006; Güneş, Ünsal, & Ergin, 2001; Kalkan, Ustabaş, & Kalkan, 2007; Korkmaz, 2009; Şahin, 2001). Upon the limits of our literature review in the field, no studies have been seen related to the students' understandings and misunderstandings, their intellectual models about the shape of the world and the continuity of these beliefs, focusing on various students at different education levels. However; when the science and technology course curriculum were considered regarding the shape of the world and gravity, it was seen that there were activities both in the first and second grade of primary school about teaching these concepts (Millî Eğitim Bakanlığı [MEB], 2005, 2006). Therefore; for an effective teaching of concepts about the shape of the world and gravity, the meaning and intellectual models students have developed since the primary school should be investigated and which alternative models have been developed by students and which of these models have been used in both grades and transferred into the next education level ought to be analyzed. It has been believed that such a study will contribute into the related research field significantly, will provide a strong background and detailed information to improve astronomy-based topics teaching and will help curriculum development studies. In addition, national and international research domain will be supported by

the results of these studies in terms of science and astronomy teaching field. In line with these ideas; the research questions of our study are as follows:

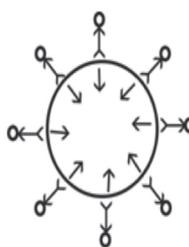
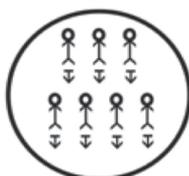
- 1- What are primary school 5th and 8th graders' understanding and mental models about the shape of the world and gravity?
- 2- To what extent do these understanding and mental models reflect the fact?
- 3- What kind of change can be observed about students' understanding and mental models between 5th and 8th graders if they have developed alternative understanding and mental models?

Method

This cross sectional study (Büyükoztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2008; Cohen & Manion, 1994) was conducted in a primary school which mostly students from low socio-economic class attended through transportation. 105 students –52 of them were 5th graders and 53 of them were 8th graders- participated in the study. High attention was given that students had very similar educational family structures and socio-cultural characteristics except their school levels. Personal information about students' background

was gathered, their teachers' notes about their home visits were considered and some of them students were visited at their home for further information. The participant students' parents were either primary school graduates or illiterate. Also, the students did not receive any further education in any private courses and they did not have any opportunities for supplementary education or access to internet, journals or encyclopedia. Their educational background was based on lecture-type teaching-learning experiences, not experiments and simulations in order to concretize astronomy-based topics. For data collection, a semi-structured Conceptual Models Interview Form about the Shape of the World and Gravity (SWGCIFF), developed through the data in the related literature (Hannust & Kikas, 2007; Vosniadou & Brewer, 1992) was used. The interviews were video-recorded. Content analysis was conducted on the data collected by using explicitly and selectively coding (Strauss & Corbin, 1990). For the analysis of the data, reliability and validity studies were done and coder reliability of the interview data was found to be 92.38% by using Miles and Huberman's (1994) reability formula.

Table 1.
Fifth and Eighth Graders' Understandings and Mental Models Related to Shape of The World and Gravity Concepts

Understandings	Mental Models	Features of Mental Model
<p>The scientific understanding is that the world is round like a ball, oblate and bulging equator, people stand on the surface of the world and thanks to gravity, we have been pulled towards the center of the worlda</p>	 <p>Drawing 1</p>	<p>Shape: Round, oblate and bulging equator Model: Ball Walking and Falling: Arriving to starting point and not falling down Gravity Force: Gravity pulls towards the center of the world Location and Standing: Human beings are on the surface of the world and human's standing is towards the center of world</p>
	 <p>Drawing 2</p>	<p>Shape: Round Model: Ball Walking and Falling: Arriving to starting point and not falling down Gravity Force: Gravity pulls towards the center of the world Location and Standing: Human beings are on the surface of the world and human's standing is towards the center of world</p>
Mental Model 1	5th Grader	8th Grader
	f	f
	%	%
Drawing 1	5	10
	9,61	19,23
Drawing 2	6	14
	11,53	26,92
Total	11	24
	21,15	45,28

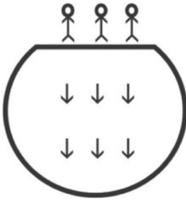
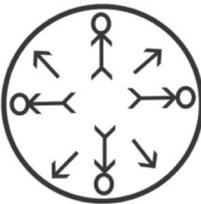
Results

As a result of the analysis, it was seen that primary school 5th and 8th graders had seven different understandings and intellectual models; one of them was a scientific one, about the shape of the world and gravity. Findings of students' understandings and mental models related to shape of world and gravity are presented in Table 1.

This understanding and models have been as follows: the scientific view and mental model is that the world is round like a ball, oblate and bulging equator, people stand on the surface of the world and thanks to gravity, we have been pulled towards the center of the world (5th graders 21.15%, 8th graders 45.28%).

The first alternative understanding and mental model The first alternative understanding in which the world is like a flattened ball, the human beings are either out of or only on the top of the world and gravity pulls from the North to the South (5th graders 19.23%, 8th graders 16.98%). The second alternative understanding and mental model is that the world is like a ball, people are in the world and gravity works from north to South (5th graders 13.46%, 8th graders 24.52%). This was found with both 5th and 8th graders. The third alternative understanding an model in which the world is round like a ball, the human beings are in the world and gravity shows the movement from the center of the world to the outer side of the world that the world is

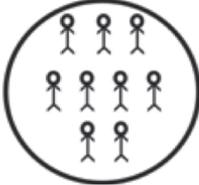
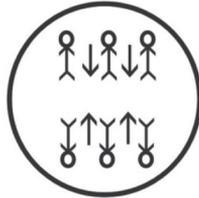
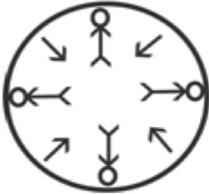
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Understandings	Mental Models	Features of Mental Models															
<p>The first alternative understanding in which the world is like a flattened ball, the human beings are either out of or only on the top of the world and gravity pulls from the North to the South</p>		<p>Shape: Flattened round Model: Ball Walking and Falling: Arriving to edge of world and falling down Gravity Force: Gravity pulls from North to South Location and Standing: Human beings are either out of or only on the top of the world</p>															
	<table border="1"> <thead> <tr> <th>Mental Models</th> <th colspan="2">5th Grader</th> <th colspan="2">8th Grader</th> </tr> <tr> <td></td> <th>f</th> <th>%</th> <th>f</th> <th>%</th> </tr> </thead> <tbody> <tr> <td>Mental Model 2</td> <td>10</td> <td>19,23</td> <td>9</td> <td>16,98</td> </tr> </tbody> </table>	Mental Models	5th Grader		8th Grader			f	%	f	%	Mental Model 2	10	19,23	9	16,98	
Mental Models	5th Grader		8th Grader														
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Understandings	Mental Models	Features of Mental Models															
<p>The second alternative understanding and mental model is that the world is like a ball, people are in the world and gravity works from north to South</p>		<p>Shape: Round Model: Ball Walking and Falling: Arriving to starting point and not falling down Gravity force: Gravity pulls from North to south Location and Standing: Human beings are in the world and human's standing is towards from north to south</p>															
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Understandings	Mental Models	Features of Mental Models															
<p>The third alternative understanding in which the world is round like a ball, the human beings are in the world and gravity shows the movement from the center of the world to the outer side of the world</p>		<p>Shape: Round Model: Ball Walking and Falling: Arriving to starting point and not falling Gravity force: Gravity shows the movement from the center of the world to the outer side of the world Location and Standing: Human beings are in the world and human's standing is towards the center of the world</p>															
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Mental Models	5th Grader		8th Grader														
	f	%	f	%													
Mental Model 4	3	5.76	0	0													

like a ball, people are in the world and gravity works from the center of the world (5th graders 5.76%). The fourth understanding and mental model is that the world is like a ball, people are placed in the world in the line of south to north but no explanation is given about gravity (5th graders 40.38%). This is only observed with 5th graders. The sixth alternative understanding and mental model is that the world is round like a ball and gravity works towards the center of the world (8th graders 9.43%). The fifth alternative understanding and mental model is that the world is round like a ball, people are in the world and gravity works from south to north and from north to South (8th graders 3.77%). This is only observed with 8th graders. When all findings were taken into account

as a whole, it was seen that scientific understandings and mental models about the shape of the world and gravity were quite low but an increase was observed from 5th graders to 8th graders (from 21.15% to 45.28%). Also, it was found that 40.38% of the 5th graders did not develop any understandings about gravity and 38.45% of them developed various alternative understandings. 45.27% of 8th graders had different alternative understandings about gravity. In both 5th and 8th graders –though low with 8th graders, fallacies were observed about the ideas that the top part of the world is flat, people are in the world, the world has edges, and it is possible to fall down from the world. These findings have revealed that some alternative understandings and

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Understandings	Mental Models	Features of Mental Models
The fourth alternative understanding is that the world is like a ball, people are placed in the world in the line of south to north but no explanation is given about gravity		<p>Shape: Round Model: Ball Walking and Falling: Arriving to starting point and not falling down Gravity force: No information about gravity is given Location and Standing: Human beings are located in the world and human's standing is from north to south</p>
Mental Models	5th Grader	8th Grader
	f %	f %
Mental Model 5	21 40.38	0 0
Understandings	Mental Models	Features of Mental Models
The fifth alternative understanding is that the world is round like a ball, people are in the world and gravity works from south to north and from north to South		<p>Shape: Round Model: Ball Walking and Falling: Arriving to starting point and not falling down Gravity force: Gravity pulls from north to south and from south to north Location and Standing: Human beings are in the world and human's standing is towards from north to south and from south to North</p>
Mental Models	5th Grader	8th Grader
	f %	f %
Mental Model 6	0 0.00	2 3.77
Understandings	Mental Models	Features of Mental Models
The sixth alternative understanding is that the world is round like a ball and gravity works towards the center of the world		<p>Shape: Round Model: Ball Walking and Falling: Arriving to starting point and not falling down Gravity force: Gravity pulls towards the center of the world Location and Standing: Human beings are in the world and human's standing is towards center of the world</p>
Mental Models	5th Grader	8th Grader
	f %	f %
Mental Model 7	0 0.00	5 9.43

models about the shape of the world and gravity are common for both 5th and 8th graders; in other words, they are continuous.

Discussion and Conclusion

The overall results of the study have indicated that 5th and 8th graders develop different approaches and different mental models about the shape of the world and gravity. It has been seen that intellectual models based on scientific understandings are low in both grades but as students go through from 5th to 8th grade, there is a slight increase with students' understandings. Moreover; it has been observed that some parts of alternative understandings and models about the shape of the world and gravity are continuous at both graders. This finding is in line with the results from other studies in the field.

Baxter (1989) analyzed understandings, mental models and fallacies that students developed about the shape of the world and gravity. 100 children -48 boys and 52 girls aged between 9-19- participated in his study. In his study, he categorized students into different age groups as 9-10, 11-12, 13-14, 15-16 and found that children developed four different intellectual models –one of which was scientific- about the shape of the world and gravity. He also investigated that unscientific mental models decreased as children grew older but a great number of fallacies remained unchanged and were continuous till children were 16 years old. The idea that the world was flattened and the gravity worked in the direction of north to south (up to down), found by Baxter (1989), was also observed in our study. Next, Vosniadou and Brewer (1990) carried out a study with Greek and American primary school students and analyzed their understandings about the shape, the movements of the world and gravity. In his study with 90 Greek and 90 American students, it was found that both students had the similar conceptual structures, similar fallacies and conceptual changes about the shape of the world and gravity. The results of our study are also in line with Vosniadou's study about the findings that people are in the flat surface of the world, the world has edges, people are in the world, they can fall down from the world, the gravity Works in the direction of north to south (up to down) as thought by American 5th graders and Greek 6th graders. The approach about gravity in Vosniadou and Brewer's study (1990) was also observed with American 5th graders at the rate of 55% and with Greek 6th graders at the rate of 76.7%. When these rates were compared to the findings in our study, it was seen

that these rates were higher than both 5th and 8th graders in our study regarding gravity. However; the findings in our study that gravity works in the manner of pushing, instead of pulling, and works from north to south and from north to south is in contrast to studies in the related field. When these findings have been taken into account in line with cognitive theories in the field and in terms of studies looking for sources for alternative approaches, it can be concluded that students have limited atmosphere around them at home, at school and during the education process and they have limitations in their educational supportive surroundings. Wessel (1999) points that the source of alternative approaches is students' personal lives and says that the science education received by students and the environment in which the students lived are also influential on their approaches. He adds that their alternative understandings may differ as students' personal lives are different from each other.

Piaget claims that children's conceptual development is in relation with objects and makes abstraction with objects. The more and the more different interaction children engage with objects, the more abstraction they will do and the more developed structures they will have, so it can be said that during the conceptual development, life experiences and variety are significant factors (as cited in Evans, 1999). In addition; Piaget mentioned that conceptual fallacies start with a gap which is based on a lack of information and this gap is filled through teaching and students' actual knowledge and experiences. If this gap is randomly filled through, then conceptual fallacies occur. Life experiences and the quality of teaching are influential on conceptual misunderstandings (cited in Rowell, Dawson, & Harry, 1990). Vygotsky highlights the socio-cultural aspect of learning in cognitive development theory and he says that the source of children's concepts is social surrounding. In this process, the environment and culture in which the child lives, life type and quality given to the child, the interaction that the child is engaged with adults and other children and his learning and teaching are also influential factors (cited in Senemoğlu, 2004; Wood, 2005). Therefore, it can be said that the child's interaction with his family, his school experiences and his socio-cultural environment and interaction with his friends are significant in conceptual development and conceptual fallacies. Recalling that in our study, the children came from low socio-economic level and they had nearly no access to the internet, encyclopedia and television, their parents were

illiterate or primary school graduates and they were exposed to lecture-type teaching style, it can be said that they have limitations both at home and at school about educational experiences in terms of the shape of the world and gravity concepts and these limitations can be influential on the fact that these astronomy related concepts are not scientifically acquired and children's alternative understandings are quite different.

The findings of this study can be evaluated in terms of the science and technology course curriculum of primary school. There are content organizations to teach these concepts both in the first and second level of primary school. However, in the first level of elementary school (primary school), there is no information connecting the shape of world, human's standing and gravity. The second level (middle school) science and technology course curriculum contains content organization related to the shape of the world, human's standings on the world and effect of gravity force. In this case, a deficiency occurs about this connection until second grade. This deficiency may be an important factor for alternative understandings of these concepts. Lack of knowledge is an important factor for misconceptions and if misconceptions occur, they often resist changing (Eryılmaz, 2002). Due to these reasons, content organization of science and technology course curriculum of primary school may be an efficient factor for students' alternative understandings and mental models about the shape of world and gravity.

In the related field, it was said that students carried various alternative understandings and models about these concepts (Bryce & Blown, 2006; Nussbaum, 1979; Sadler, 1992; Vosniadou & Brewer, 1992) and these alternative understandings decreased as students went from one year into next in their schools but some of them seemed to be continuous (Bisard et al., 1994; Lightman & Sadler, 1993; Trumper, 2001)

The findings of this study should be evaluated cautiously. It must be kept in mind that these results are only valid for the students who participated in this study and the students in the 5th year were not the same students in the 8th year as it was cross-sectional study, so it can cause some limitations in terms of longitudinal deduction. The students in this study came from a special background regarding socio-cultural environment and educational facilities. These should be taken into consideration while talking about the overall results of the study. The results of this study showed that students could

not acquire a scientific understanding at a high level about these concepts. In order to provide meaningful learning for conceptual change, effective teaching methods should be chosen. For a more holistic vision about the shape of the world and gravity, people's actual position in the world should be taught in line with the gravity and for more comprehensive knowledge, extensive data should be collected with wider samples.

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