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Science Students' Misconceptions of the Water Cycle According to their Drawings

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Abstract: This study conducted by based on student drawings and interviews was held with the aim of determining misconceptions of science students receiving education in universities about the water cycle. There are a number of techniques to indicate misconceptions of students. Open ended questions, two-stage diagnosis tests, concept maps, word association and interviews are some of these techniques. In addition, science educators have started to use drawings methods in order to ensure students to understand science and to obtain knowledge about their misconceptions recently. As a result of analysis of drawings and interviews, it was seen that more than half of students has comprehensive or partially conceptual knowledge, but approximately one fourth of students has misconceptions about this subject. In addition, it was determined that students have misconceptions like water cycle is only evaporation of water from the earth to the atmosphere and its return to the earth from the atmosphere by condensing.

Key words: Water cycle, drawing, misconception, student teachers, interview

INTRODUCTION

The words human, environment and ecology are used as a whole today. There is a regular relationship among all living things and non-living beings from continents to oceans, lakes to streams, underground waters to atmosphere, microorganisms to human and plants kingdom (Cetin, 2007; Leach *et al*., 1996). Rapid increase in the world population within the last 30-35 years, improvement in industry and technology, natural resources started to extinct have let environmental problems to come to the agenda. Some significant matters must be produced in an equal amount they are exploited in order to lead liveliness in the nature without any interruption. These matters having an ecological significance in the nature are given and taken between living beings and their environment. These matters complete their circulation by following certain orbits by means of solar energy. This circulation of matters in the ecosystem is the matter cycle (Lin and Hu, 2003). All matters are continuously reused by living things through cycle. Most significant ones of these matter required for living things and to be transferred are water, oxygen, nitrogen, carbon, phosphorus and sulphur. Matter loss is never concerned in the nature (Leach *et al*., 1996). Circulation of matters in cells, tissues, system and organism, chemical reactions, sustainability and consistency of the structure are ensured with water. Water is so significant from this point. Water is in a continuous cycle (Ben-Zvi-Assarf and Orion, 2005a; Kali *et al*., 2003).

Majority of studies held on field of science now focus on students' understanding of science and their misconceptions. Because, misconception is one of the significant factors which affect learning. Misconception implies thinking patterns which do not overlap with scientific realities with general meaning, rather contradicted with them and are developed or made sense of by individuals specific to them in their minds (Bahar, 2003). Since these thinking patterns developed by students mostly based on their own interpretations are contrary to scientific realities, they constitute a significant barrier against science education (Tekkaya, 2003; Wandersee *et al*., 1994). Students usually develop misconceptions as a result of their own interpretations or from some contradictory explanations in school or out of school environments in early periods of their school years (Bahar, 2003; Wandersee *et al*., 1994). Expressions of teachers or those in text books also may lead to concept mistakes or may enhance existing misconceptions of students in some circumstances (Sewell, 2002). Misconceptions are considerably widespread in formal education and significantly resistant against change (Model *et al*., 2005; Bahar, 2003). If they are not detected and compensated, they continue for long years and constitute significant barriers in understanding process. If science teachers and curriculum designers knew students' misconceptions ideas related to science concepts, it might be helpful to prepare effective teaching schemes. In this situation, teachers can play an important role in teaching these concepts (O-Saki and Samiroden, 1990).

Many misconceptions and understanding difficulties have been stressed in many studies held related with ecology and environmental issues in recent years (Cetin, 2007; Sander *et al*., 2006; Ekborg, 2003, 2005; Kali *et al*., 2003; Carlsson, 2002). However, any detail research was not found related with the water cycle which is actually one of significant concepts of ecology. Whereas the water cycle is among the most significant concepts in ecology and environment. It is significant in terms of constructivist perspective that students should have meaningful knowledge about ecological and environmental concepts like the water cycle.

Smith and Anderson (1986) researched alternative concepts of students related with matter cycles in the ecosystem. Students' conceptions of matter cycling processes remained fragmented even after instruction; only 4% of students understood that matter is converted back and forth between organisms' bodies and substances (carbon dioxide, water and minerals) in the environment. Lin and Hu (2003) have caused 106 students from 7th class drawn concept maps about energy flow and matter cycle and then analyzed them. Results of their analysis evidenced that majority of students failed in defining relations between different concepts about matter cycle and energy flow. Boschhuizen and Brinkman (1995) determined in their study held on students in 15-17 age group that high school students do not have sufficiently effective mental models in subjects like water cycle, climate changes and carbon cycle. Bar and Travis (1991) determined in their study held on children from 5-15 age group relating to atmospheric components of water cycle that concepts like condensation and evaporation may be perceived in about 11 years old. Bar and Galili (1994) detected in their study that students have difficulties in understanding related with the difference between water vapor and air. Ben-Zvi Assaraf and Orion (2005a) evidenced in the study they held on students from 7th and 9th class in 6 central schools of Israel relating to perceiving water cycle that students understand hydro-bio-geological processes but most of them have insufficiency in perceiving cyclical and dynamical perception of the system. Agelidou *et al*. (2001) reported that most of the students in their research held a perception of the groundwater as static, sub-surface lakes. Marques and Thompson (1997) found that students incorporate a resemblance of a bowl in order to explain that the depth and mass of water become greater toward the center of oceans.

There are a number of techniques used to determine misunderstandings and misconceptions of students. Open ended questions (Ozay and Oztas, 2003), two-stage diagnosis tests (Treagust, 1988), concept maps (Novak and Canas, 2004; Mason, 1992), word association (Torkar and Bajd, 2006; Ben-Zvi Assaraf and Orion, 2005b; Bahar *et al*., 1999) and interviews (Abdullah and Scaife, 1997) may be given as examples of these techniques. In addition, science educators also use drawings methods in order to ensure students to understand science and to obtain knowledge about their misconceptions. It was evidenced in some researches used this method that they ensure reliable information about perception way of students against a biological concept (Kose, 2008; Prokop and Fancovicová, 2006; Reiss and Tunnicliffe, 2001; Tunnicliffe and Reiss, 1999). Drawings have been considered as simple research instruments that enable easy comparisons at the international level (Kose, 2008; Prokop and Fancovicová, 2006; Reiss *et al*., 2002). While many children dislike answering questions, drawings can be completed quickly, easily and in an enjoyable way. Childrens' drawings provide a window into their thoughts and feelings, mainly because they reflect an image of his/her mind (Thomas and Silk, 1990).

This study was conducted to assess the effect of drawing method in combination with interview on determining Turkish university science students' misconceptions about the water cycle.

MATERIALS AND METHODS

A total of 156 university students who have been studying to become science students' participated in this study. All students studied at Selcuk University Education Faculty in Turkey. The average age of students was 21.1 year (range 20-26). The majority of students were females (105 of 156). But, this study was not focused on gender differences. At the time of the data collection, the majority of the participants were in their final semesters of undergraduate science education. The participants' demographics were similar to the general pre-service primary science teacher population in Turkey. Participants had been previously studying about the water cycle in general biology, environment science as a school subject in various semesters.

Research was conducted in March 2008. Turkish university science students' understanding of the water cycle was examined by two different methods that are not mutually exclusive: (1) students' drawings (2) by individual interviews. The participating students were asked to draw the water cycle on a blank piece of A4-sized paper. There is evidence that students' drawings may serve as a useful tool for probing their level of understanding of natural phenomena and as a tool for identifying the gap between students' alternative conceptions and the scientific view (Kose, 2008; Prokop

and Fancovicova, 2006; Reiss *et al*., 2002; Reiss and Tunnicliffe, 2001; Tunnicliffe and Reiss, 1999). Students' responses to the drawing activity were analyzed using a coding framework prepared by Kose (2008) and Reiss and Tunnicliffe (2001). Drawings were dealt with as a whole and analyzed with the method of point scoring by taking into account units on drawings. Units on drawings were taken into account in evaluation of drawings instead of painting skills. Five levels of conceptual understanding were identified for this investigation: no drawing, non-representational drawings, drawings with misconceptions, partial drawings and comprehensive representation drawings. Details of the levels are as follows:

Level 1: No drawing: Students replied, I don't know, or no response was given to the statement.

Level 2: Non-representational drawings: These drawings were including identifiable elements of the water cycle. Also the answers, which include diagrams or formulations instead of the drawings, were evaluated in this category. This category is shown by example in Fig. 1.

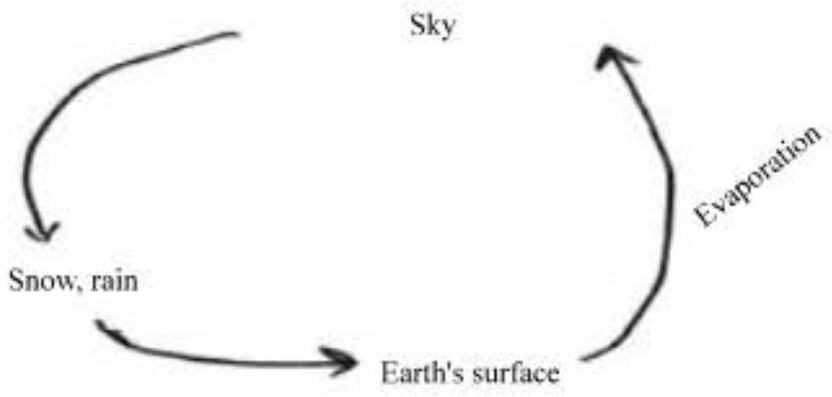

Fig. 1: Non-representational drawings (Example of level 2)

Level 3: Drawings with misconceptions: These types of drawings showed some degree of understandings on the water cycle concepts but also demonstrated some misconception; however, these drawings were misconceptions not understandings held by scientists or stated in science texts. This category is shown in Fig. 2a-c.

Level 4: Partial drawings: The drawings in this category were demonstrating partial understanding of the concepts. Includes the drawings of the water cycle elements like cloud, evaporation, raining and atmosphere (Fig. 3).

Level 5: Comprehensive representation drawings: Drawings in this category were the most competent and realistic drawings of the water cycle (Fig. 4). Drawings showing sound understanding, contained seven or more elements of the validated response for that particular statement.

After the drawings were evaluated according to the criteria above, individual interviews were conducted about the detailed subjects with randomly chosen 15 students (9 female, 6 male) who demonstrated misconceptions. The purpose was to check the validity of the interpretation of the drawings. In the interview, students were asked to answer the questions like; .....

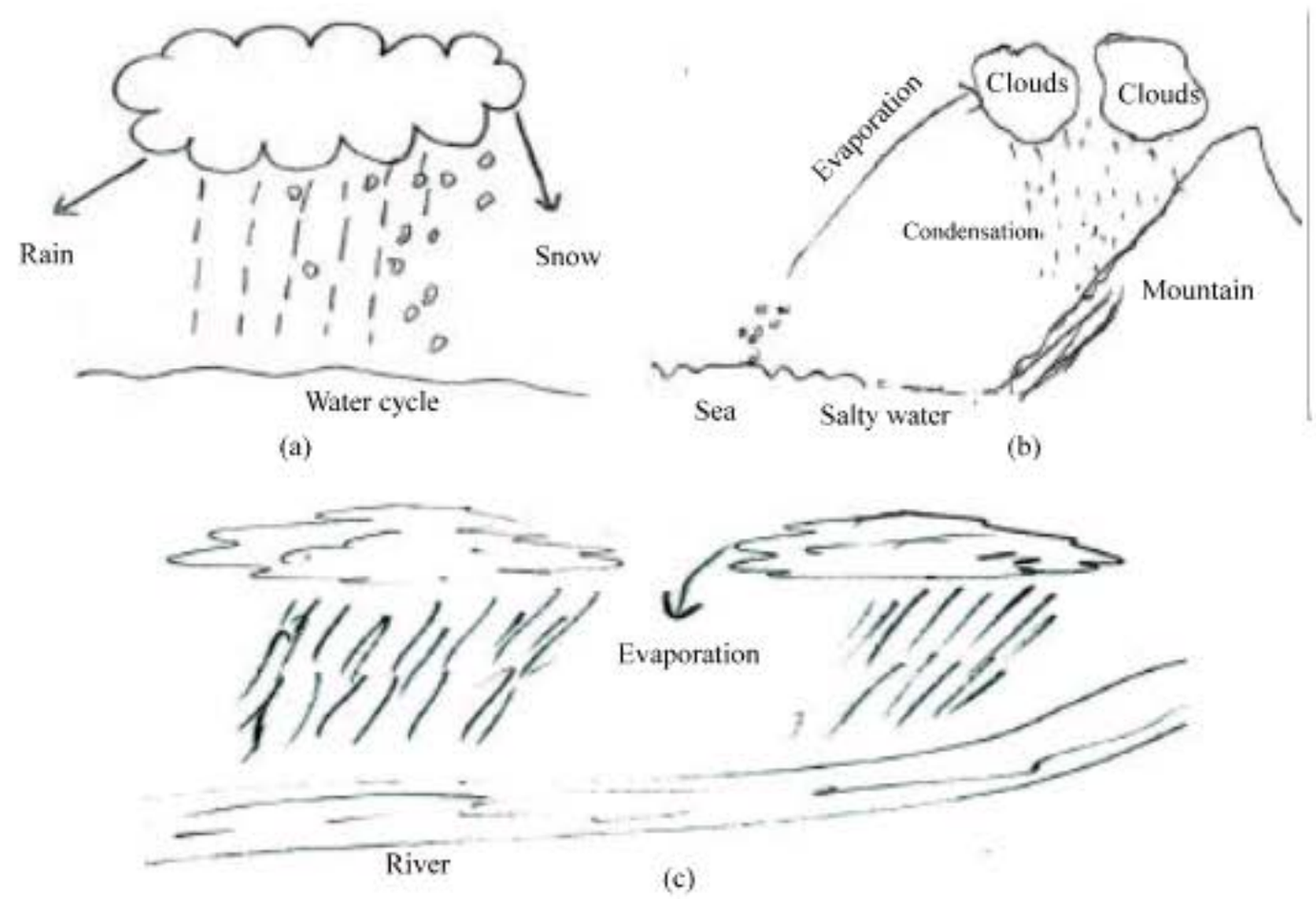

Fig. 2: (a, b, c) Drawings with misconceptions (Example of level 3)

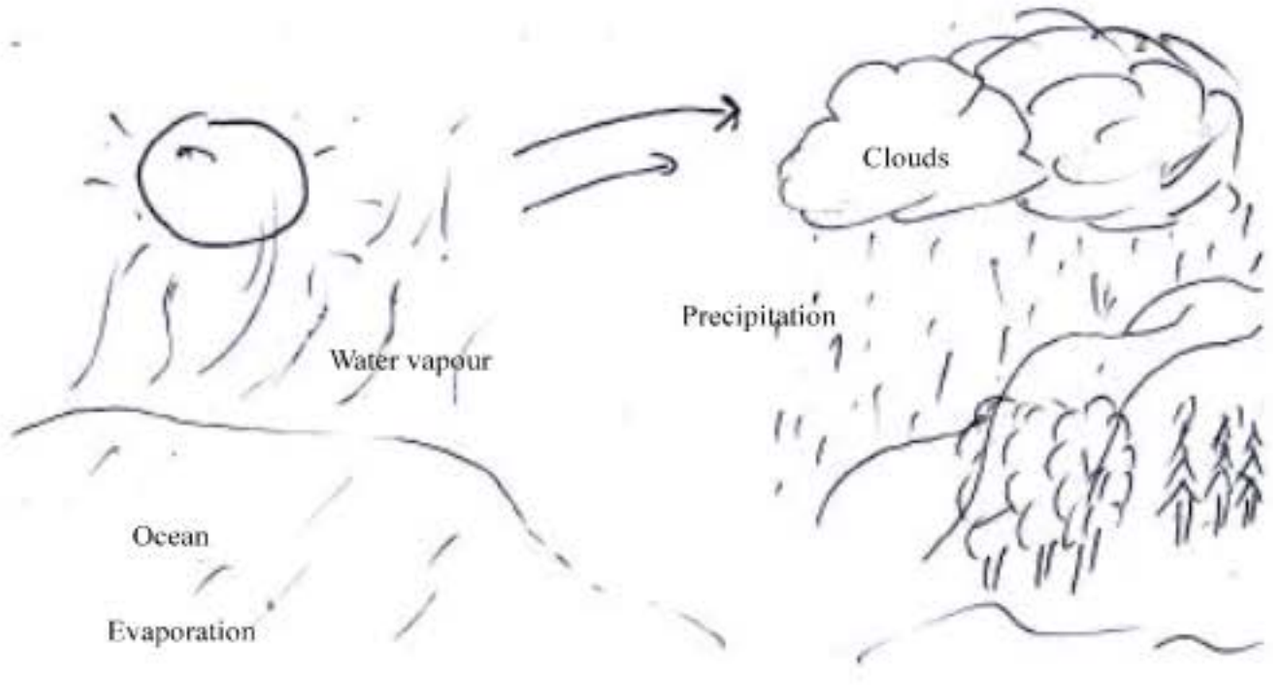

Fig. 3: Partial drawings (Example of level 4)

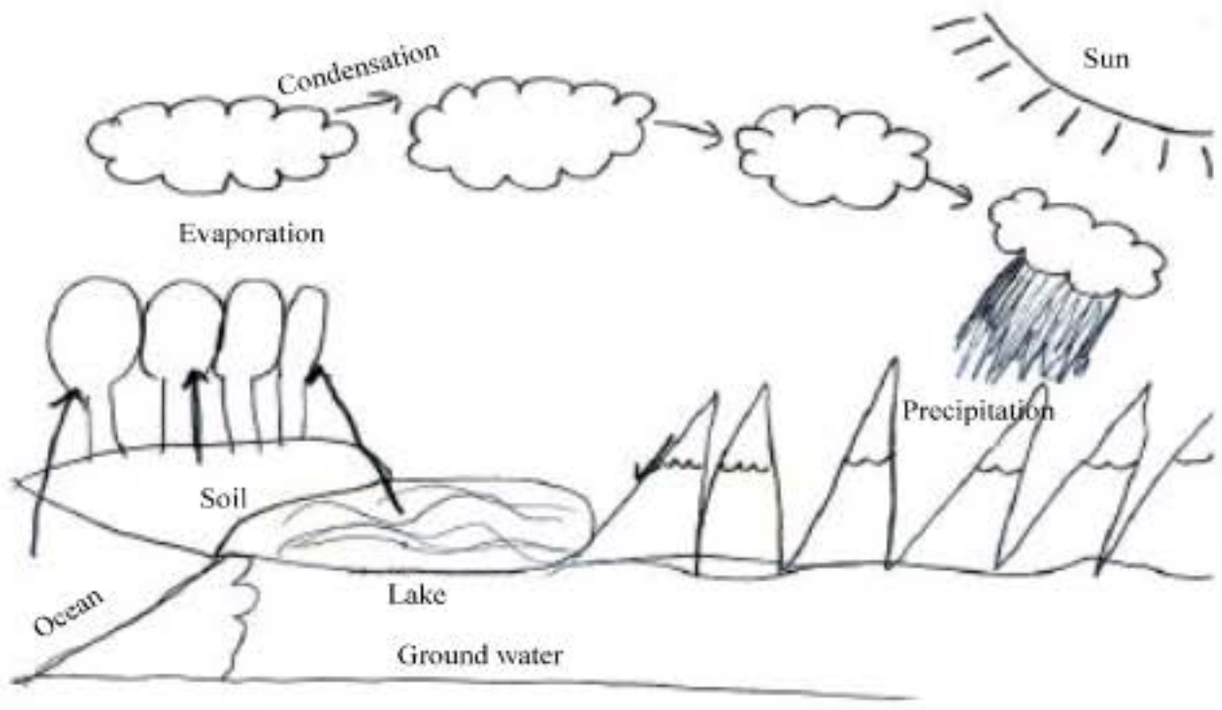

Fig. 4: Comprehensive representation drawing (Example of level 5)

- What is the water cycle in your opinion?
- What are the effects of human activities on water cycle in your opinion?
- What do you think about starting and end points of water cycle?

The obtained answers were given below by comparing with the drawings.

RESULTS

In order to determine understanding of students attitudes against the water cycle shown in Fig. 5. It represents that majority of students (44%) concentrated on partial drawings (level 4). Ratio of misconceptions of students was determined as 26% (level 3). In addition, 18% of students made completely accurate drawings but 10% made non-representational drawings. Moreover, it

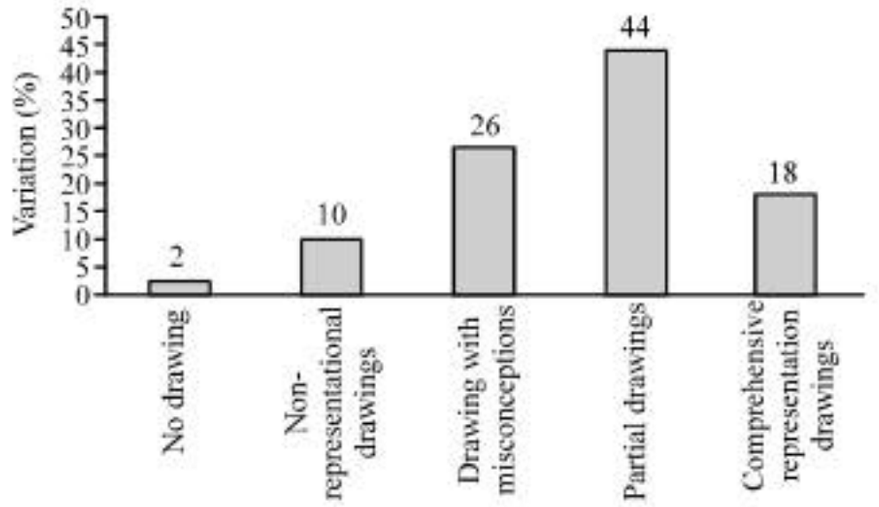

Fig. 5: Levels of science students' conceptual understanding for water cycle

was detected that 2% of students did not make any drawing. These results evidence that more than half of students has comprehensive or partially conceptual knowledge, but approximately one forth of students has misconceptions about this subject.

Table 1: The most frequent elements for water cycle drawn by students

Elements for water cycle	n	%
Ground water	142	91
Evaporation	134	86
Precipitation	130	83
Atmosphere	117	75
Condensation	65	42
Underground water	64	42
Living things	43	28
Soil	42	27
Sun	23	15
Respiration	11	7
Photosynthesis	10	7
Transpiration	8	5
Waste water	7	4

The elements most frequently repeated by students related with the water cycle are shown in Table 1. As shown in Table 1, more than half of students concentrated on elements like ground waters, evaporation, precipitation and atmosphere. On the other hand, it is reported that less than half of students display the elements like condensation, underground water, living things, soil, sun, respiration, photosynthesis, transpiration, waste water in their drawings. These results evidence that knowledge of students related with the water cycle is limited with flow of water in non-living systems. Students think that water cycle is only evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing. More than half of students do not take into account the sun which activates water cycle. Moreover, most of students do not take into account that narrow underground water is received by plant roots and re-involved in the atmosphere from leaf surfaces by way of transpiration and photosynthesis event realized in plants. A great majority of students did not also emphasize respiration event realized in living organisms.

Five misconceptions related with water cycle were determined in total as a result of analysis held on students' drawings. These misconceptions are shown in Table 2.

In addition, number of misconceptions were found as a result of interviews held on randomly selected among students having misconceptions in their drawings. Misconceptions obtained from interviews are shown in Table 3. Students in whom misconceptions were determined thing that water cycle is only composed of the process of evaporation of water from the earth to the atmosphere and return to the earth from the atmosphere by condensing. Moreover, some misconceptions were also determined from students regarding as follows: water cycle only includes freezing and melting processes of water, water only evaporates from seas and oceans, water cycle only includes rain and snow, rain falls only when clouds evaporate. Students were not aware of significant factors in occurrence of water cycle like gravity, air currents, surface flows etc.

Table 2: Misconceptions about the water cycle obtained in the drawings

Misconceptions	n
Water cycle only includes the process of evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing	37
Water cycle only includes freezing and melting processes of water	31
Water only evaporates from seas and oceans	29
Water cycle is only composed of rain and snow	24
Rain falls when clouds evaporate	11

Table 3: Misconceptions about the water cycle obtained in the interviews

Misconceptions
Amount of water vapor in the air always remains unchanged
Water amount in the biosphere differs according to climate conditions
The process of evaporation of water from the earth is only determined by the sun
Soil water only exists in regions with great rain areas
Starting point of the water cycle is seas and end point of it is uncertain
Water amount in biosphere is gradually declining due to melting of glaciers
Living things cannot exploit waters in seas and oceans since they are salty
Water amount in biosphere is gradually declining due to global warming
Underground water cannot be drunk since they are polluted, they can only be drunk after being purified
Rain falls when clouds evaporate
Water cycle includes the process of evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing
Water cycle includes freezing and melting processes of water
Water only evaporates from seas and oceans
Water cycle is only composed of rain and snow
Rain falls when clouds are completely filled up with water

Fig. 6: A drawing of misconceptions water cycle only includes freezing and melting processes of water

It is seen that misconceptions obtained from interviews overlap with misconceptions detected on drawings. This situation verifies the validity of misconceptions obtained from drawings.

Five among students interviewed stated that water cycle only includes freezing and melting processes of water (Fig. 6). These students thought the influence of only non-living water atmospheres in the water cycle. Four among students interviewed thought that water amount in the biosphere differs according to climate conditions. However, they were not aware that water amount in the biosphere remains unchanged. Two among students interviewed thought that living things cannot

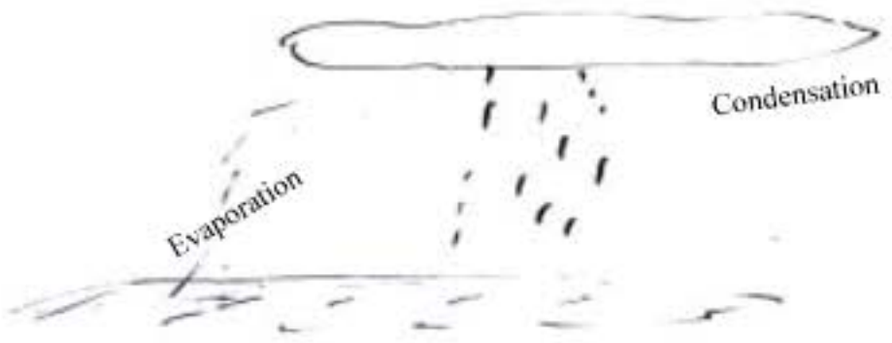

Fig. 7: A drawing of misconceptions of water cycle only includes the process of evaporation and condensation

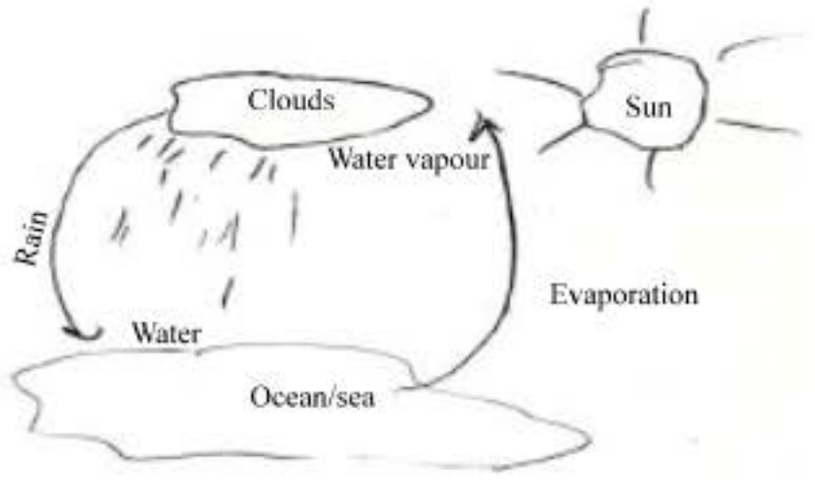

Fig. 8: A drawing of misconceptions of water only evaporates from seas and oceans

exploit waters in seas and oceans since they are salty. However, living things have the characteristic of exploiting all water resources in the nature in different ways. Students considered water which can be exploited as just drinking waters. Four among students interviewed stated that water amount in biosphere is gradually declining due to global warming. It can be thought that students have this viewpoint since there is water shortage in some regions of Turkey especially in the last 10 years. Seven among students interviewed thought that water cycle is only the process of evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing (Fig. 7). Three among students interviewed stated that water only evaporates from seas and oceans (Fig. 8). One among students interviewed stated that rain falls when clouds are completely filled up with water.

In addition to these, one among students interviewed stated that water cycle is only composed of rain and snow (Fig. 2a).

DISCUSSION

It was determined that students have various misconceptions about water cycle in this study held through based on drawings of university science students and interviews held with them. Analysis of drawings evidences that conceptual understandings of students are not adequate in terms of especially atmospheric cycle of water and connection between this and geospheric underground water, circulation of water cycle, flow of water between living and non-living systems, significant water resources. Approximately one forth of students made drawings including misconception. Majority of misconceptions determined are similar to misconceptions mentioned in earlier researches held other countries on some periods of school life (Ben-Zvi-Assarf and Orion, 2005a, b; Agelidou *et al*., 2001; Dove, 1997; Bar and Galili, 1994; Brody, 1993; Bar and Travis, 1991; Bar, 1989). However, some misconceptions determined in this research have emerged for the first time. These are as follows: The process of evaporation of water from the earth is only determined by the sun. Water amount in biosphere is gradually declining due to melting of glaciers. Underground water cannot be drunk since they are polluted, they can only be drunk after being purified, living things cannot exploit waters in seas and oceans since they are salty. Water amount in biosphere is gradually declining due to global warming etc.

These alternative conceptions result from education received by students in different education stages beginning from childhood. Studies held in Turkey evidence that the teachers giving lectures in primary and secondary education use traditional teaching methods instead of alternative teaching approaches. Moreover, Asci *et al*. (2001) stated that students coming from secondary education to universities come with a number of misconceptions. Continuance of misconceptions during university education shows that how misconceptions are resistant against change (Model *et al*., 2005; Bahar, 2003; Wandersee *et al*., 1994). For this reason, teachers working in primary and secondary education and instructors giving courses in universities have a great duty in terms of using new teaching strategies which will remove or minimize these misconceptions. If we consider that these students will graduate from university and start to teach within one year, being graduated from university with misconceptions is also so significant in terms of problems to occur during their teaching process. University students should be educated with effective teaching methods which will prevent misconceptions. By this way, misconceptions of teachers will be changed and they will be ensured to have scientifically valid concepts. Conceptual change strategies like concept maps, concept networks and conceptual change texts are the methods which will reduce or eliminate misconceptions of students (Novak and Canas, 2004; Tekkaya, 2003; Sungur *et al*., 2001; Wandersee *et al*., 1994; Novak *et al*., 1983).

Misconceptions university students have related with water cycle focus on following statements (Table 2, 3): these are as follows; amount of water vapor in the air remains unchanged, water cycle only includes the process of evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing, water amount in the biosphere differs according to climate conditions, water cycle includes freezing and melting processes of water, water only evaporates from seas and oceans, water cycle is only composed of rain and snow, rain falls when clouds are completely filled up with water etc. Such misconceptions are seen in students in every stage of school life from primary education to university (Brody, 1993; Munson, 1994).

Use of student drawings and interviews with appropriate sampling sizes ensured determination of many alternative viewpoints science students have related with the water cycle. The most remarkable evidence of the existing study is that majority of students start university with misconceptions or partial knowledge about the water cycle and graduate from university with almost same misunderstandings. This evidence is surprising since the subject of the water cycle exists in primary and secondary school curriculum. Evidences obtained from drawings and interviews of students indicate that majority of students cannot establish a correlation between the water cycle and steps of this cycle. It was seen that science students participated in this study has a divided knowledge framework concerning the water cycle.

The most common misconception noted from drawings and interviews with students is their perception as follows: Water cycle includes the process of evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing. This misconception may result from students themselves, their teachers or text books. Dikmenli and Cardak (2004) emphasizes that a significant source of misconceptions is text books. For this reason, awareness of teachers in this type of misconceptions and misconceptions in text books is considerably important. These and similar misconceptions may be overcome especially with concept maps or models stressing inter conceptual relations. Novak *et al*. (1983) stated that concept maps are good methods in elimination of misconceptions. Moreover, students may encounter with misconceptions during their own researches by means of educators and unconfigured activities while studying with models. By this way, students confront with misconceptions they have and may attempt to correct them after entering into a conceptual conflict.

Analysis indicate that students perceive the water cycle as an unconcerned series of knowledge. Students understand various processes related with the water cycle but they do not understand systematic structure of the water cycle as a whole. A significant segment of students was aware of the components of the water cycle related with the atmosphere but was not aware of the significance of underground water in the water cycle. Moreover, students more stressed the influence of human factor on the water cycle in interviews rather than drawings. These results displayed a close similarity with the studies of Ben-Zvi-Assarf and Orion (2005a).

Understandings of students related with cyclical structure of water are affected with their ability of synthesizing water elements in a system. Specifically cycle is can be formed by determining relations and connections between these elements. These connections serve as a mechanism by which students can form a whole cycle (Orion, 2002). Drawings and interviews also displayed misconceptions of students regarding effects of human activities on the water cycle and relative amounts of different water reservoirs on the earth. These evidences are similar to the evidences of the study held by Gudovitch (1997) relating to the carbon cycle between classes 11 and 12. Analysis of students' drawings evidenced the difficulties experienced by students in associating formal education with real world phenomenon. While most students disregard the effect of humans on the water cycle, interviews evidenced that most of students are aware of the increase in water pollution caused by humans. These results are similar to results of Dove *et al*. (1999).

CONCLUSION AND RECOMMENDATIONS

Following results were displayed with this study:

Majority of students could not establish correlation between atmospheric water cycle and geospheric underground water cycle. Most students perceived underground water as a lake without any connection between water and rocks on ground and as a separate system. Moreover, students more stressed the influence of human factor on the water cycle in interviews rather than drawings. Most students correlated relative size of oceans with rain amounts fallen on these regions. Most students experienced difficulty in perceiving moving of water in reservoirs on ground and gathering the elements in a whole system. Moreover, it was again evidenced that drawing method along with interviews is an effective method in discovering concepts students have difficulty in understanding and misconceptions. In this regard, use

of drawing method in determination of misconceptions or preliminary knowledge is recommended in following studies.

It is recommended that science education should focus on studying natural cycles in context of their effects on daily lives of humans instead of separating these cycles into specific scientific fields with the aim of providing fundamental instruments for citizens to ensure them dealing with ecology and environment.

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