MISCONCEPTIONS OF SENIOR HIGH SCHOOL SCIENCE STUDENTS ON EVAPORATION AND WATER CYCLE

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ABSTRACT

Science educators agree that everyday activities enable children to learn some science even before entering preschool education and that children's ideas are part of the classroom. Some of these ideas will not be completely correct. Misconceptions refer to children's incorrect or incomplete ideas. This study conducted was based on students' drawings and interviews. It was held with the aim of determining the misconceptions of science students receiving education in Senior High Schools in Ghana about evaporation and water cycle. There are a number of techniques that can be used to indicate misconceptions of students. These include open ended questions, two-stage diagnosis tests, concept maps, word association and interviews. In addition, science educators have started to use drawing methods in order to ensure that students 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 that students have comprehensive or partially conceptual knowledge, but approximately one fourth of students have misconceptions about this subject. 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. This will provide fundamental instruments for students to appreciate that these concepts deal with both ecology and environment.

Keywords: Water cycle, evaporation, ecology, environment, misconception.

INTRODUCTION

Human environment and ecology are words used as a whole today. Regular relationship exists 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 20-25 years as well as improvement in industry and technology has led to environmental degradation. This means that some significant matters must be produced in an equal amount as they are exploited in order to lead liveliness in nature without any interruption. These matters which have an ecological significance in 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 & Hu, 2003). All matters are continuously reused by living things through a cycle. Most significant ones of them 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 & Orion, 2005; Kali, et. al., 2003).

Rain as far as evaporation and water cycle are concerned is a part of children's everyday-life experience; however, even though children are very familiar with it, they are not aware of the 'hidden' and abstract mechanisms of rain. According to Bar (1989), in order for children to understand the water cycle, they need to already have an understanding of the concepts of evaporation, condensation and free fall (gravity). Concepts such as evaporation, condensation and gravity can be abstract for children, and subsequently challenging to comprehend. Previous studies identified that children construct their own explanations as to how rain is formed from a very young age, by involving certain entities that can be seen when it rains; such as clouds, the sun and the sky (Christidou & Hatzinikita, 2006).

Research throughout the last fifty years identified certain patterns in children's understanding of rain. Although the majority of children in early years view rain as water, they fail to link clouds with the rain; instead they believe that rain comes merely from the sky (Inbody, 1963; Christidou & Hatzinikita, 2006). Findings from previous studies also identified that children's accuracy of scientific explanations about rainfall increases with age (Bar, 1989; Inbody, 1963; Sackes, Flevares, and Trundle, 2010). Bar's report (1989) based on 300 Israeli children from ages five to fifteen, identified the age of nine as the appropriate age when children are capable of developing a scientifically acceptable conception of the water cycle. However, the children in Bar's research were picked at random, and all 300 came from an advantaged background instead of a variety of children from different socioeconomic backgrounds, or children from different ability groups. Bar's methodology was also limited to a single method, of oral interviews. One may argue that these questions the origins of the age of nine as the appropriate age to learn about the water cycle. When studying children's understanding of evaporation and condensation, Tytler (2000) indicated that at the age of six, children have the cognitive ability to grasp basic concepts about the water cycle.

Similar limitations to Bar's research were also identified in Sackes et al. (2010) study; where the sample size of children was small, they were not of equal gender and there was a lack of children from different socioeconomic backgrounds. In addition, their research was based solely on semi-structured interviews with children. Sackes et al. (2010) identified that a single method in a research triggers limitations, whereas more than two methods enable the researcher to examine how consistent and articulate children are with their responses.

One of the most important factors which prevent students' meaningful and permanent learning is misconception. Misconceptions are what students themselves develop erroneously and different from scientifically accepted concept. In view of this; it is necessary to determine the misconceptions that students already have. Majority of the 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 (Osaki 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, 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 and environment in science. It is significant in terms of the constructivist perspective that students should have meaningful knowledge about ecological and environmental concepts like the water cycle.

Smith & 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 & 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 & Brinkman (1995) determined in their study on students in 18-20 age group that is early university students do not have sufficiently effective mental models in subjects like evaporation, water cycle, climate changes and carbon cycle. Bar & 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 & Galili (1994) detected in their study that students have difficulties in understanding related with the difference between water vapor and air. Furthermore, Ben-Zvi- Assaraf & 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 & 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 that 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). While many children dislike answering questions, drawings can be completed quickly, easily and in an enjoyable way.

Children's 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 misconceptions about evaporation and the water cycle among first year Senior High School science students.

MATERIALS AND METHODS

A total of 86 first year Senior High School science students participated in this study. The average age of students was 16.2 year (range 15-17). At the time of the data collection, the majority of the participants were in their third term of the academic year. The participants' demographics were almost similar to the general Senior High Schools population in Ghana. Participants had been previously studying about the water cycle in integrated science, natural science as a school subject in their various Basic Schools.

The study was conducted in September 2017. The Form One Science students' understanding of the evaporation and 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 FancovicovaAi, 2006; 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 & 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 included 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.**

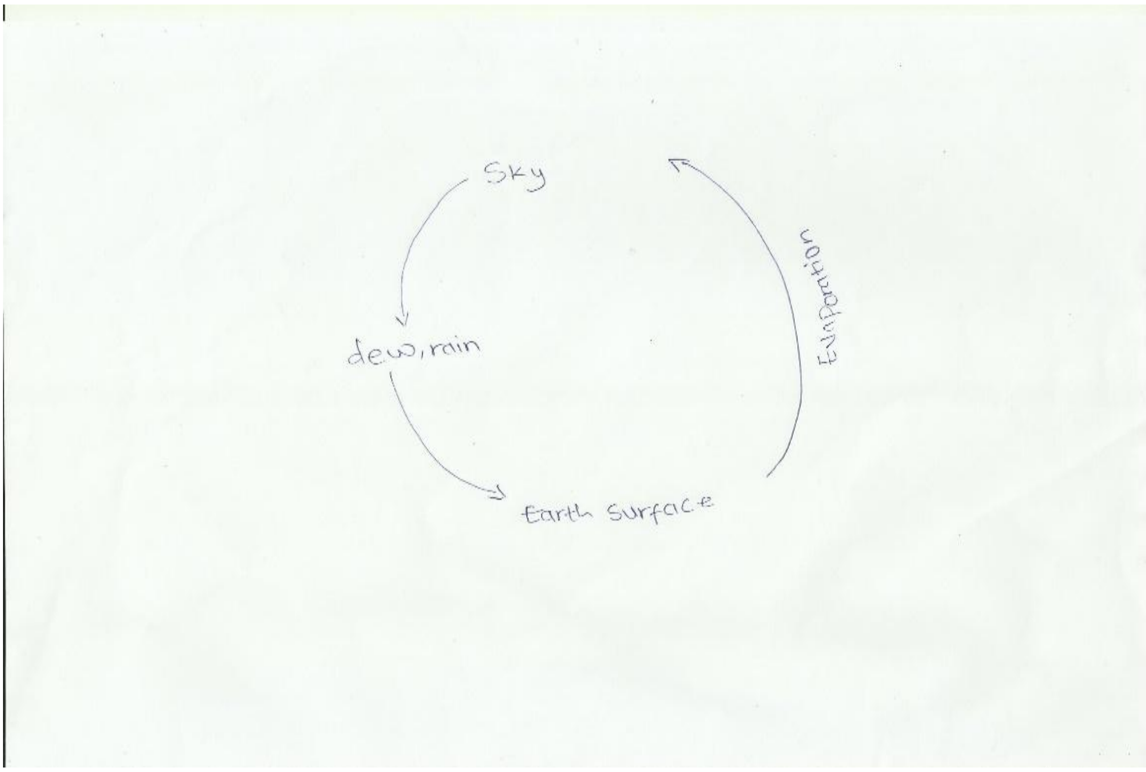

Fig 1: Non Representation Drawing (Example of level 2)

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. It included 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 12 students, who demonstrated misconceptions. The purpose was to check the validity of the interpretation of the drawings.

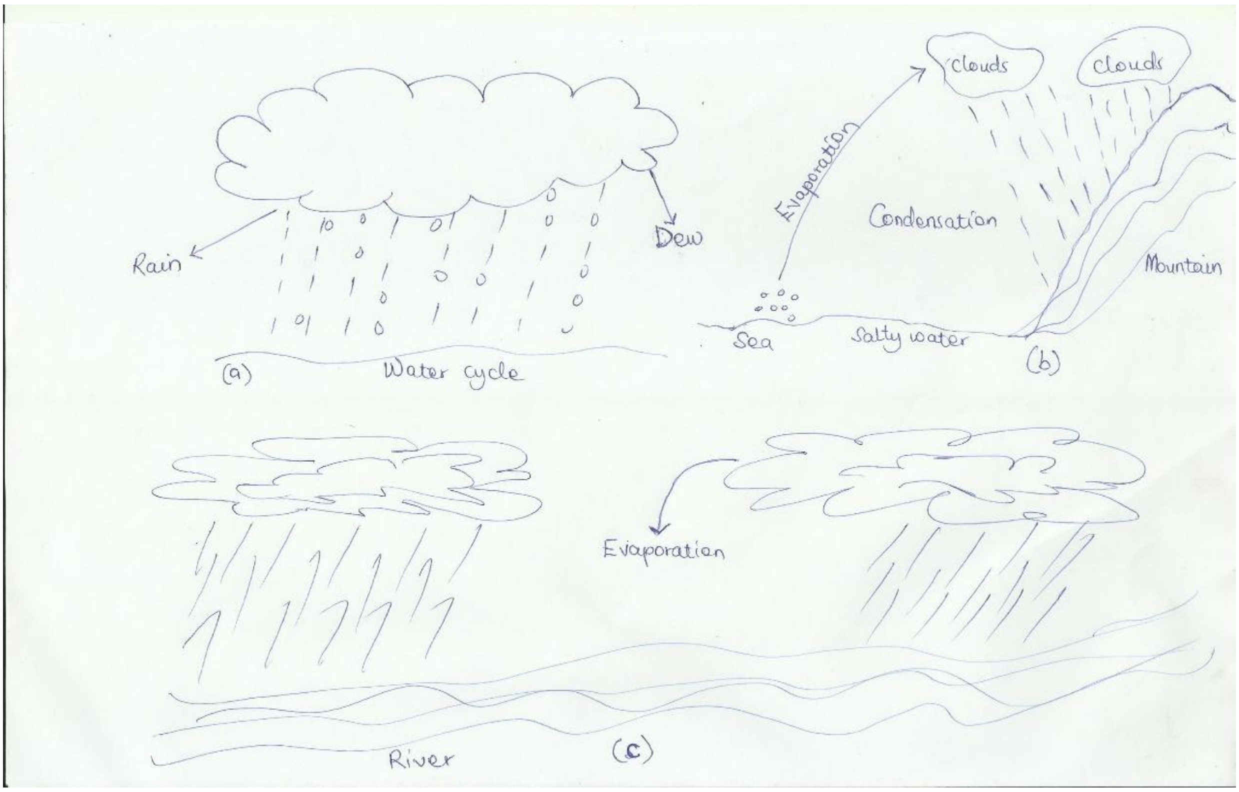

Fig. 2: (a,b,c) Drawings of Misconception (Example of level 3)

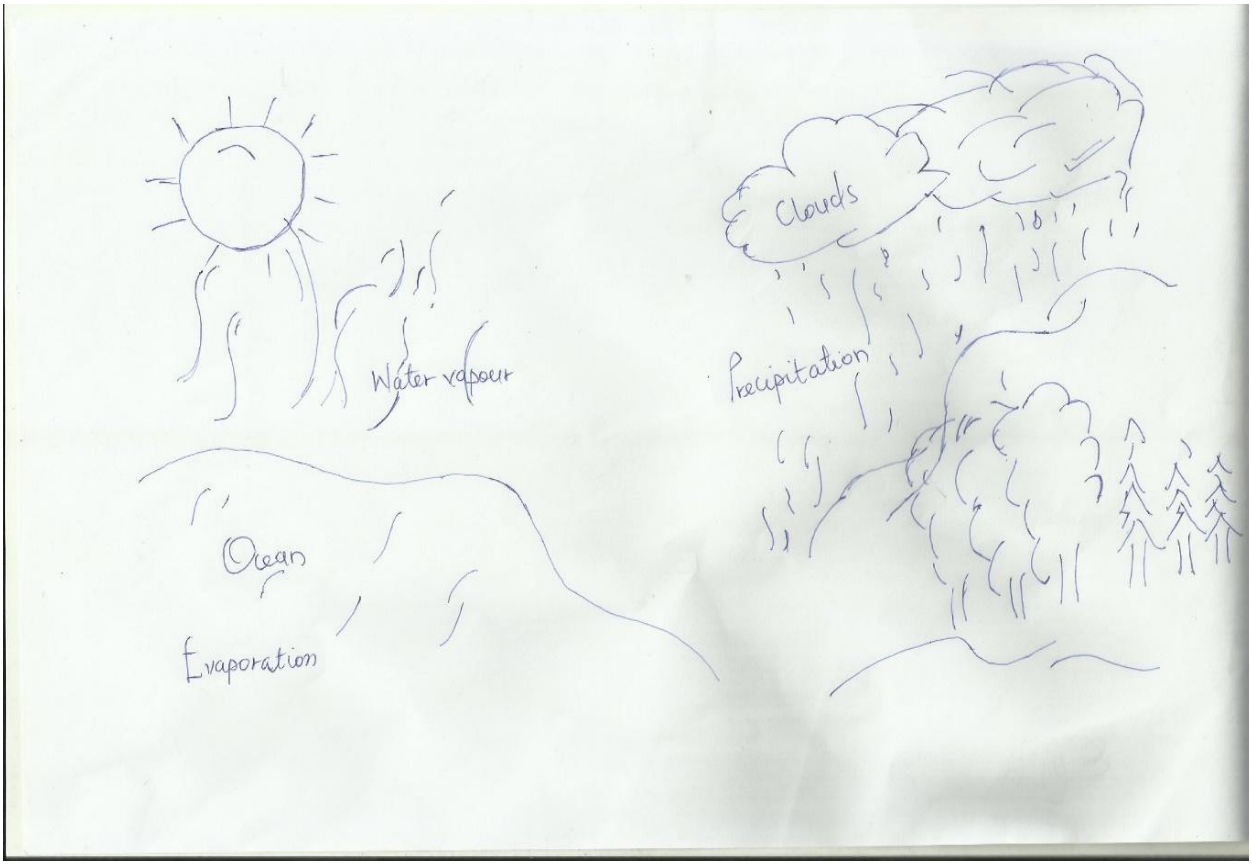

Fig. 3: Partial Drawings (Example of level 4)

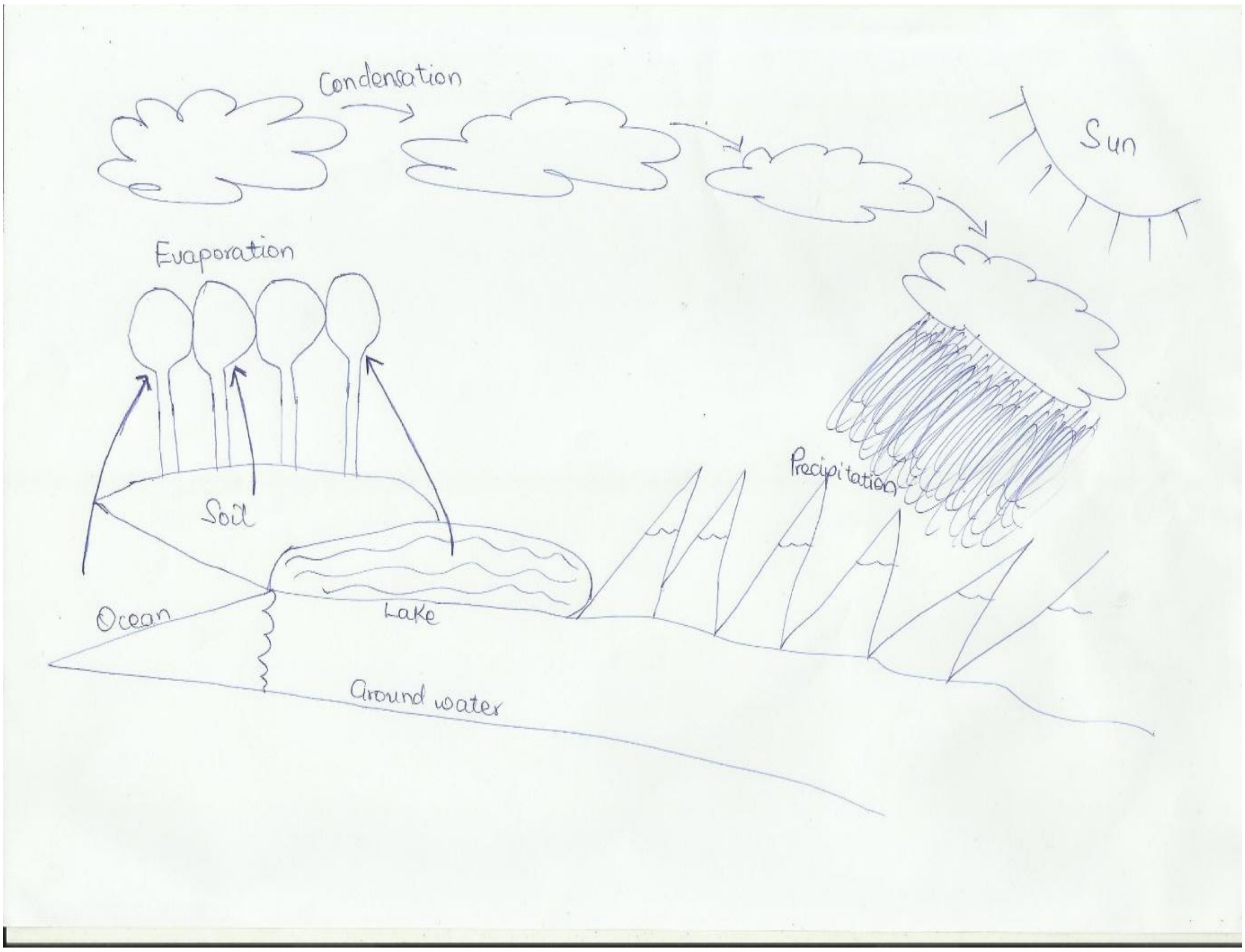

Fig. 4: Comprehensive representation drawing (Example of level 5)

In the interview, students were asked to answer the questions like:

• 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 40% concentrated on partial drawings (level 4). Ratio of misconceptions of students was determined as 30% (level 3). In addition, 15% of students made completely accurate drawings but 12% made non-representational drawings. Moreover, it was detected that 3% of students did not make any drawing.

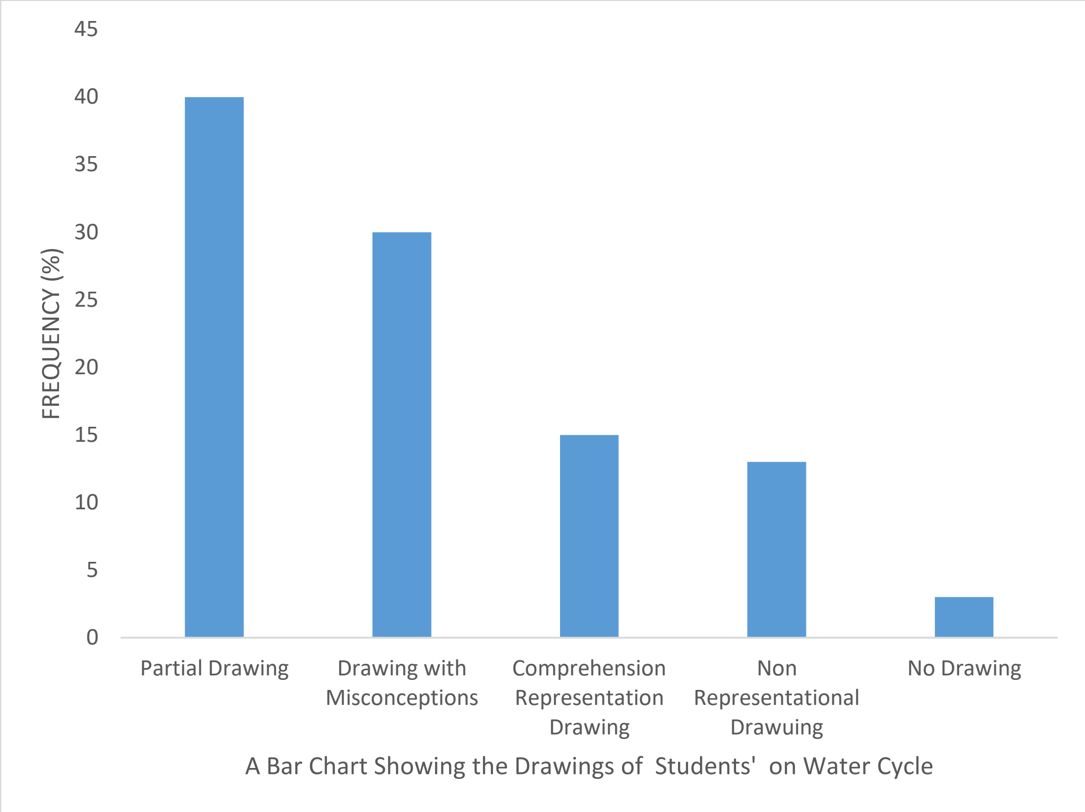

Fig. 5: Levels of science students' conceptual understanding for water cycle

These results evidence that more than half of students have comprehensive or partially conceptual knowledge, but approximately one fourth of the students have misconceptions about this subject.

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

Element of water cycle	N	%
Ground water	74	86
Evaporation	60	70
Precipitation	58	67
Atmosphere	44	51
Condensation	32	37
Underground water	26	30
Living things	24	28
Soil	22	26
Sun	18	21
Respiration	12	14
Photosynthesis	7	8
Transpiration	5	6
Waste water	2	2

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 think 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 dew, rain falls only when clouds evaporate.

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

Misconception	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	27
Water cycle only includes freezing and melting processes of water	21
Water only evaporates from seas and oceans	18
Water cycle is only composed of rain and dew	11
Rain falls when clouds evaporate	9

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

Misconception
Amount of water vapour in the air always remain unchanged.
Water amount in the biosphere differs according to climatic 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 pint of the water cycle is sea end point of it is uncertain.
Water amount in biosphere is gradually declining due to melting of glaciers.
Living things cannot exploit waters in sea and oceans since they are salty.
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 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 dew.
Rain falls when clouds are completely filled up with water.

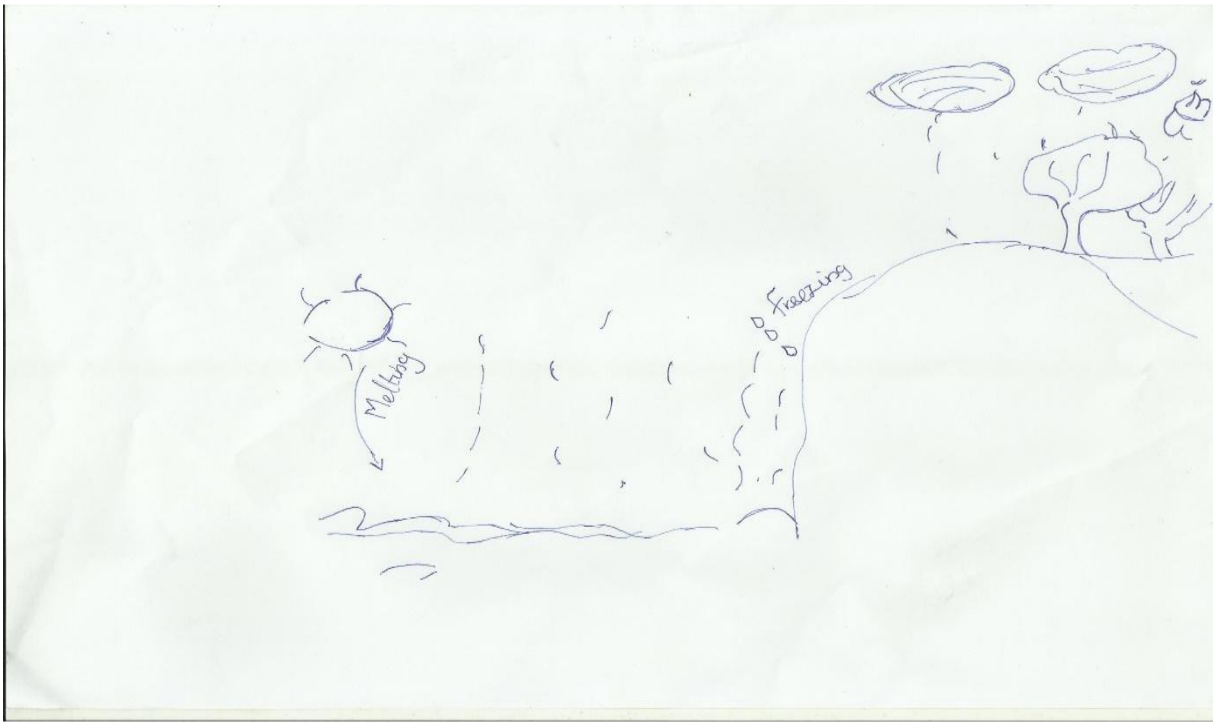

Fig. 6: A drawing of misconceptions water cycle only includes freezing and melting processes of water

Students were not aware of significant factors in occurrence of water cycle like surface flows, gravity, convectional currents (air currents), etc.
It is obvious that misconceptions obtained from interviews overlap with misconceptions detected on drawings. This situation verifies the validity of misconceptions obtained from drawings.

Four among the 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

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water atmospheres in the water cycle. Another, 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 exploit waters in seas and oceans since they are salty.

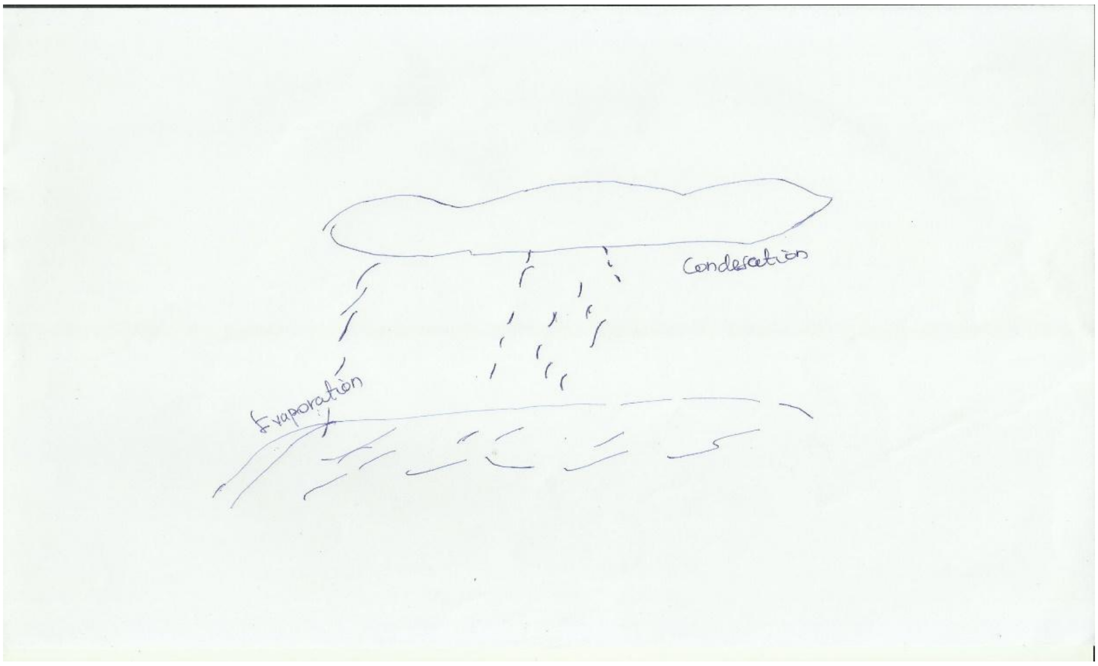

Fig. 7: A drawing of misconceptions of water cycle only includes the process of evaporation and condensation

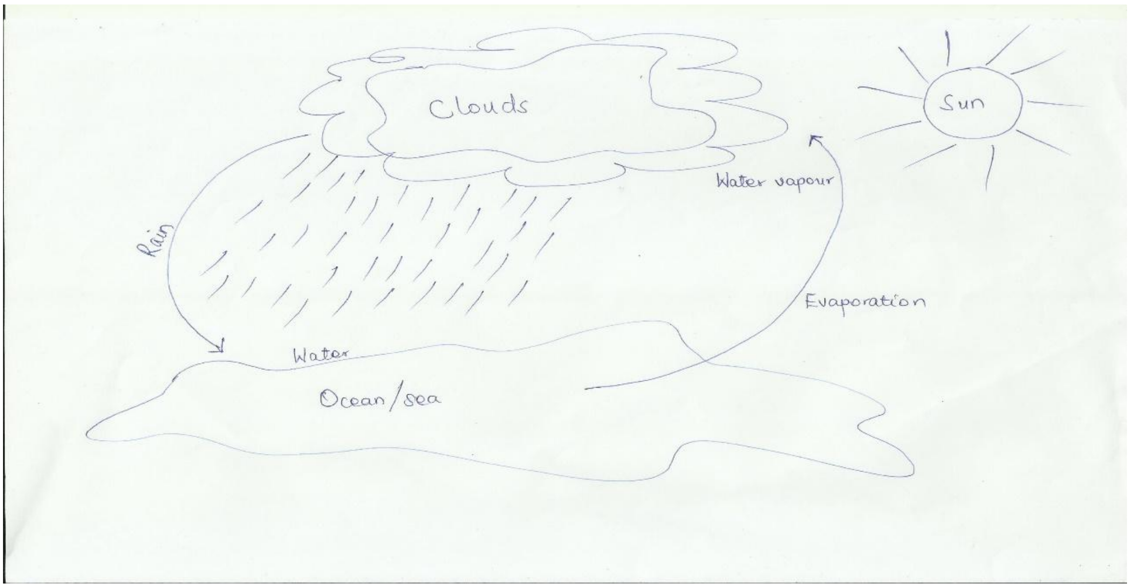

Fig. 8: A drawing of misconceptions of water only evaporates from sea and oceans

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. Three among the 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 Ghana especially in the last 8 years. Six 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).

Two among the students interviewed stated that water only evaporates from seas and oceans (Fig. 8). One among the students interviewed stated that rain falls when clouds are completely filled up with water.

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

DISCUSSION

It was realized that students have various misconceptions about water cycle in this study held through based on drawings of the Form One 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 lithospheric underground water, circulation of water cycle, flow of water between living and non-living systems, significant water resources. Approximately one fourth of the students made drawings including misconception. Majority of misconceptions determined are similar to misconceptions mentioned in earlier researches held in other countries on some periods of school life (Ben-Zvi-Assarf and Orion, 2005a; 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, and 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 Ghana evidence that the teachers in the basic school education use traditional teaching methods instead of alternative teaching approaches. Moreover, Asci, et. al., (2001) stated that students coming from the Junior High School to Senior High School come with a number of misconceptions. Continuance of misconceptions during education shows how misconceptions are resistant against change Model et al. 2005; Bahar, 2003 and Wandersee et al., 1994). For this reason, teachers working in the basic school education and science teachers in Senior High Schools have a great duty in terms of using new teaching strategies which will remove or minimize these misconceptions.

Senior High Schools science students should be educated with effective teaching methods which will prevent misconceptions. By this way, misconceptions of students 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 and Novak, et. al., 1983). From tables 2 and 3, the students related with water cycle with their focus on the following statements. These are; "*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 dew, rain falls when clouds are completely filled up with water*" etc. Such misconceptions are seen in students in every stage of school life from basic education to university (Brody, 1993 and 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 Senior High Schools with misconceptions or partial knowledge about the water cycle and complete from Senior High Schools to the university with almost same misunderstandings. This evidence is surprising since the subject of the water cycle exists in the basic 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 the form one science students participated in this study have 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 & 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 misconceptions during their own researches by means of educators and unconfirmed activities while studying with models.

Analysis indicate that students perceive the water cycle as an unconcerned series of knowledge. From this study, 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 were aware of the components of the water cycle related with the atmosphere but were not aware of the significance of underground water in the water cycle. Moreover, students mostly 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 water cycle 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. 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

It is of great importance to investigate the area of students' misconceptions, since such knowledge can advise teachers and help them plan lessons to clear them up. Instruction which fails to identify students' misconceptions can leave children unchanged; whereas curriculum, instruction and assessment are significantly improved when teachers are aware of the development considerations and the research findings on commonly held misconceptions.
From the results displayed by this study: Majority of students could not establish correlation between atmospheric water cycle and lithospheric underground water cycle. Most students perceived underground water as a lake without any connection between water and rocks on ground and also as a separate system. Moreover, students stressed more on the influence of human factor on the water cycle in interviews rather than drawings. Most of the 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 the drawing method along with interviews is an effective method in discovering misconceptions students have on concepts. 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. This will provide fundamental instruments for students to appreciate that these concepts deal with both ecology and environment.

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