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ABSTRACT

The Blue Planet program aims to develop an understanding of and insight into the environment among students by introducing environmental problems such as pollution. This paper presents a study investigating junior high school students' previous knowledge and understanding of environmental issues and perceptions on the nature of the water cycle. Junior high school students (n=1000) from grades 7-9 from six urban schools participated in the study. (Contains 19 references.) (YDS)

Studying the Water Cycle in an Environmental Context: The "Blue Planet" Program

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INTRODUCTION

The end of the 20th century and the beginning of the 21th century can be defined as an era of revolution in science education all over the world. The main goal moves from educating and preparing the future scientists of the society towards the educating and preparing of the future citizens of the society (including the future scientists). This new paradigm is known by the name "Science for all" approach.

Bybee (1993), had pointed on our moral duty to prepare our students toward life in a planet in crisis. In order to acheive this goal the environmental education should be localized in the center of the school curriculum but not in its margins as it occures today. This demand is in accordance with the present goals of science teaching. Orion (1998) noted that education of earth systems should take a central place in the science curricula since the acknowledgement of the critical necessity of environmental literate citizens for our society. The educational potential of this subject is a result of its relevancy to students' daily life and its multi–disciplinary nature. The main purpose of environmental education should be the development of environmental insight. Such insight is based on understanding the systemic and cyclical mechanisms of our planet. Orion (1997) determined environmental insight in two dimensions:

A. The understanding that we are living in a cycled and recycled world which is composed of numerous sub–systems (geosphere, hydrosphere, biosphere and atmosphere), that are connected in tight interrelationship of material and energy transfer, and

B. The understanding that man is an integral part of the natural system. In order to develop such insight one should focus on teaching of geochemical and biogeochemical cycles, such as the water cycle. The study of such cycles should not be sterilized and should be conducted in the context of its influence on man's daily life.

Orion (1998), suggested that systems–thinking in the earth systems context, is fundamental to environmental literacy. He claims that understanding the reciprocal relationships within, and between each of these systems, will enable students to become thoughtful decision–makers, concerning environmental issues in the future.

In order to fulfill the above goals, the water cycle was chosen as the leading concept of the curriculum. The water cycle is a complex system and in order to meaningfully understand it, students must understand the following relationships between the Earth's spheres: (a) hydrosphere and geosphere (e.g. chemical weathering by dissolution, precipitation of minerals from seawater); (b) hydrosphere and atmosphere (e.g. evaporation and condensation); (c) hydrosphere, biosphere and atmosphere (e.g. transpiration). Such understanding, which can be described as "understanding the Earth as a system", may serve as a basis for developing environmental literacy (Kali, Orion, & Eylon, 2000b). Environmental problems are presented within the context of the relationships between the hydrosphere and the other components of the earth's systems. These relationships should also be presented as a matter transformation (especially water) between the different systems.

Despite of the crucial importance of water, it is surprizing to observe that relatively little research has been published concerning the teaching and learning aspects of this topic. Moreover, most of the studies that have been conducted in this area had concentrated on students' perceptions of the physical aspects the water cycle namely, changes in the water state (Bar, 1989; Bar & Travis, 1991; Johnson, 1998a, 1998b).

Brody (1993), had reviewed 51 studies on childrens concept regarding water reservoirs, water characteristics and water cycle. He concluded that a large portion of middle school and high school students, have difficulties in understanding different subjects that are connected to water. For example:

a. Understanding chemical and physical processes such as condensation, evaporization and the molecular structure of the water.
b. The significance of water for processes that take place in living organisms.
c. Understanding of interdisciplinary subjects such as water resources and the social and scientific linkages of these topics.
d Making decisions concerning environmental interdisciplinary subjects such as water contamination, the usage of water as a resource and the preservation of the ecological systems such as the marine environment.

A similar picture was found by Fetherstonhaugh and Bezzi (1992), who reported that after 11 years in school, students present a poor and insufficient scientific conception of the water cycle.

It is worthwhile to note that we did not find any study that focused on children's perception of underground water and their availability.

The design of the "The Blue Planet" program, was based on two main factors: a) epistemological approach for curriculum development, and b) a helical model of predevelopment study, curriculum development, implementation, evaluation and modification.

THE PREDEVELOPMENT STUDY:

The predevelopment study includes the following objectives:

1. To identify junior high school students' previous knowledge and understanding in relation to environmental issues concerning the relationship between human and the water cycle.
2. To identify junior high school students' previous alternative frameworks in relation to the water cycle.
3. To explore students' perceptions of the cyclic and systemic nature of the water cycle.

The sample of the predevelopment study included about 1,000 junior high school students (7th–9th grades) from 30 classes from 6 urban schools.

The data collection was based on a series of quantitative and qualitative research tools that were specifically developed for this study. The following is a brief description of these research tools:

– A questionnaire for Assessing Students' Knowledge (ASK): This questionnaire includes three parts: Part 1 includes a Likert–type questionnaire, where students were asked to mark their level of agreement with a list of statements concerning the water cycle (Table 2). In Part 2, the students were asked to draw the water cycle. For this task, they were provided with a list of the main stages and processes that are included in the water cycle and they were instructed to incorporate as many of these items within their drawings. In part 3 the students were asked to mark in association diagram concepts which they familiar with regarding the water cycle.

– A Cyclic Thinking Questionnaire (CTQ): In this Likert type questionnaire students were asked to mark their level of agreement with a list of statements concerning the cyclic nature of the hydrosphere and the conservation of matter within the earth systems (Table 3). The validation process of the Likert type questionnaires was conducted through the method presented by Orion, Hofstein, Tamir and Giddings (1997) and included the following components: Conceptualization, Internal validation, Construct validity and Sensitivity.

– A global magnitude Questionnaire (GMQ): In order to evaluate the students conception regarding the quantity of each component of the water cycle, they have been asked to fractionate the global quantity of water amongst the water cycle components (oceans, glaciers, rock, soil, ground water, lakes, precipitation, tap water, sewage water, human) in a scale. This scale varies between 1 to 10, whereas 1 is the major component of water content on earth and 10 reflects the minor portion of water on earth.

– Interviews: The interviews were conducted with 40 students, once they had completed the questionnaires. Interviews had two main objectives. They served as a tool for validating the students' answers on the questionnaires; moreover, They provided greater insight into students' perceptions of the water cycle. During the interviews, each student was requested to read his answer, and to say whether he still agreed with his drawing and then to elaborate on his answer.

Results:

Analysis of the predevelopment questionnaires indicated the following findings:

ACQUAINTANCE WITH THE WATER CYCLE COMPONENTS.

Analysis of 956 drawings indicates that most of the students possessed an incomplete picture of the water cycle, which results in many misconceptions. Students that drew the water cycle usually represented the upper half (i.e. evaporation, condensation and rainfall) and ignored the ground water system (Figure 1).

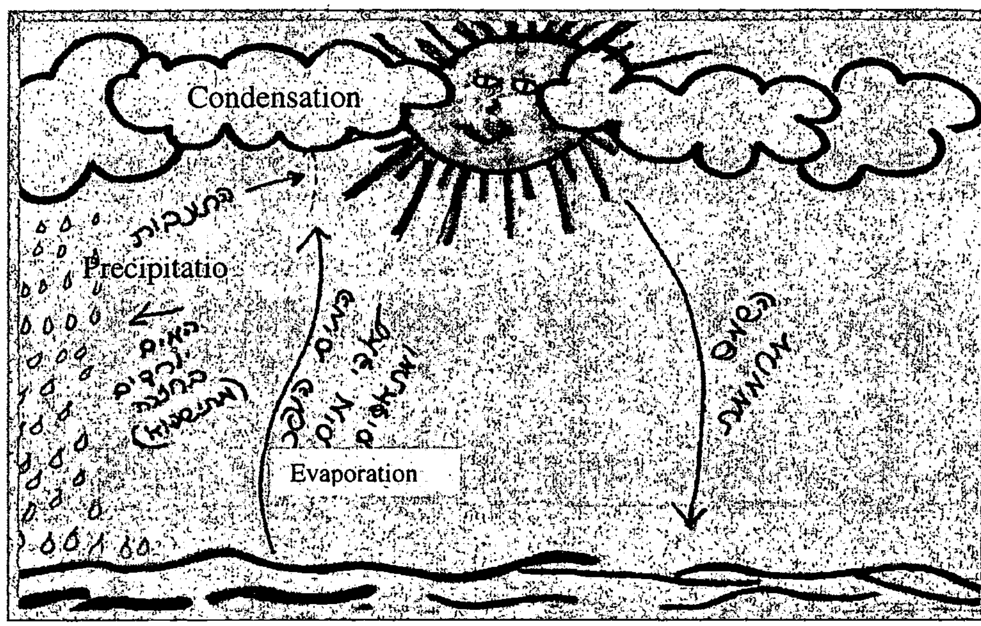

Figure 1: A drawing, which reflects a naive perception of the water cycle.

More than 50% of the students did not identify components of the ground water system even when they were familiar with the associated terminology. Similarly, the most common concepts that students marked in the association diagram were rain, cloud and evaporation that take place in the atmosphere. Less than a third of the students have marked concepts that are connected to the geosphere, biosphere or even concepts concerning to human activities and environmental aspects of the water cycle, within their association diagrams (Table 1).

Table 1 : Students preceptions as showed in a association diagram concepts, in which students were asked to mark the concepts they familiar with regarding the water cycle.

Cycle components	Examples for terms	Percentage of representative determinations among the group
Atmosphere	Rain, moisture, precipitation, cloud, snow, hale, water evaporations, sky	94.15
Hydrosphere	Fall, waves, puddle, underground water, ocean, river, streams, icebergs	88.9
Processes	Evaporation, condensation, precipitation, water flow, defreeze, flood	65.7
Rock association	Lime, mountains, soil, rocks, cracks, mineral water	27.4
Human activities	Boiling, drinking water, cooking, agriculture, shower, kettle, tap	37.9
Change of state	Gas, liquids, change of atate, temperature, solid, cold, heat	22.5
Biosphere	Food, life, thirst, human being, organisms, plants, tears, nature	19.1
Earth	Recurrence, earth, winter, summer, wind, climate, weather	23.0
Environment association	Contamination, purification, sewage water, bacteria, acid rain, economizing	22.5

UNDERSTANDING THE DYNAMIC NATURE OF THE WATER CYCLE

Understanding processes such as penetration and underground flow is highly important for the development of environmental insight. This kind of understanding may provide students with a tool to explain phenomena such as the influence of garbage dumps on the water quality, for example, in Israel, many dumps are located above sand-stone.

Compliation of the data that was collected through the various research tools indicated that most of the students showed difficulties in understanding the dynamic nature of the water cycle. They perceived the underground water as a static, sub–surface lake. Consequently, they perceived underground water as a disconnected system, wherein the water has no relationship with the surrounding rock. Only a third of the students held a vertical dynamic model of the water movement, whereas most of them described this movement in underground rivers both in there drawings and interviews (Figure 2).

"S: Underground water does not stay still, it always flows somewhere. ...I think it flows to the sea. Maybe there are kinds of openings in the earth where the water flows from the earth to the sea"

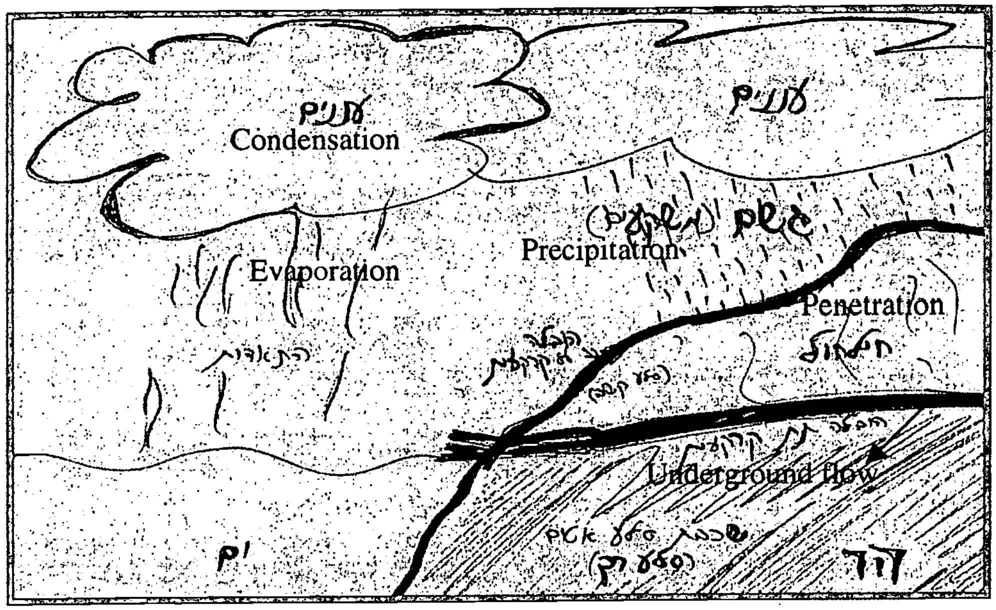

Figure 2: A drawing, which describes the underground water as underground river.

It was found that most of the students were not aware of the underground movement of water in earth. Amongst those who were aware of underground movement only 23% thought that rain which penetrate through rocks, may move horizantally under the ground to the sea and only 20% held a scientific model of underground water movement through porous rocks. Therefore, most of the students claimed that underground water can be found only in rainy areas (Table 2).

STUDENTS CONCEPTIONS OF THE WATER DISTRIBUTION ON EARTH

Most of the students possessed an incomplete picture of the water distribution on earth. For example, 78% claimed that the amount of available water in rocks is small and even smaller than the amount of water existing in rivers or lakes.

About 80% of the students did not connect between the relative size of the oceans and the amount of precipitation that fall on oceans. They claim that most of the global precipitations fall on land, eventhough 70% of the earth surface is made of oceans. As a results there drawings show that water evaporates only from the ocean and rain falls only on land (Figure 3).

Most of the students have magnified the human part in the water cycle. For example, many students drew the water cycle with the emphasis on human consumption (e.g. pipe and tap water, etc.). 45% of the students ranked the partial amount of tap water sewage water and water in human's bodys, high above their realistic values.

Table 2: Students preceptions as showed in a Likert–type questionnaire for Assessing Students' Knowledge (ASK).

Statements	Agreement	Uncertainty	Disagreement
1. The composition of a cloud, which has formed above the "Sea of Galilee" is different than a cloud that has formed above the "Dead Sea"	28	24.3	47.7
2. Most of the rain falls on the ocean and only small portion falls on lend.	18.2	24	57.8
3. Most of the underground water persist in the small porouses in the rock, similarly to a well-watered sponge	25.7	43.4	31
4. Under ground water is similar to underground lakes that are located in spaces in side the soil	49.5	26.6	23.9
5. Only when rocks are cracked can water penetrate them	28.8	23.1	48.2
6. The water that is leaching into the rocks flow to the sea under the surface	23	43.7	33.2
7. Most of the rain that falls on the ground is penetrating into the rocks and only small portion flow in streems and rivers.	24.8	27	48.2
8. Rocks don't influence the composition of water that leachate through them, since the hard rocks don't break down in water	46.9	29.7	23.5

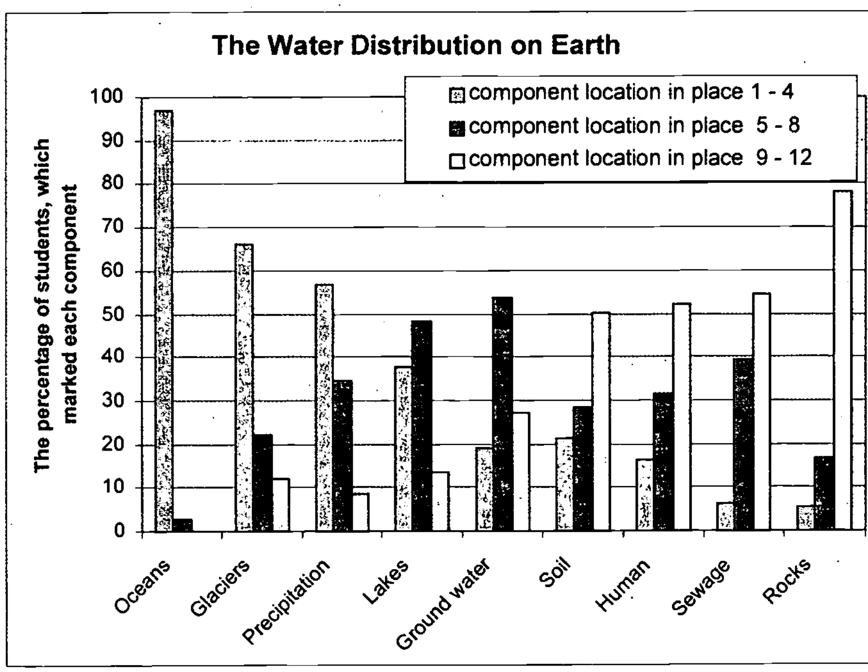

Figure 3: Students perceptions as showed in – A global magnitude Questionnaire (GMQ), In order to evaluate the students' conception regarding the water distribution on earth

UNDERSTANDING OF PHYSICAL AND CHEMICAL PROCESSES OF THE WATER CYCLE.

Understanding of processes such evaporation, condensation and dissolution is critical for the understanding of matter transportation within and between the earth subsystems.

Analysis of the questionnaire and interviews show that most of the students could explain evaporation process according to the particles model (as they studied in class).

However, they had difficulty in connecting this "physical" process with the natural phenomenon of evaporation within the water cycle. Students that in the interview could clearly explain the "particle model" could not use this model to explain water evaporation in nature. Since in most of the science lessons teachers tend to present evaporation in context of boiling water, students tend to claim that evaporation can only occur in hot water. As a result some students drew kettle in their water cycle drawings. 47.7% of the students did not agree with the statement that: *"The composition of a cloud, which has formed above the "Sea of Galilee"* is different than a cloud that has formed above the "Dead Sea". Analysis of the data implies that students perceive, the chemistry of the water solution as constant throughout the entire water cycle (Table 2).

UNDERSTANDING THE CYCLIC NATURE OF THE WATER CYCLE.

Cyclic thinking is the ability to perceive matter transformation within and among the earth systems, as a part of cyclic process. A process in which the overall amount of matter is being preserved. Cyclic perception includes the understanding that there is no start or end points within the cycle.

The analysis of the data indicates that more than 50% of the students claimed that the water cycle has a starting and end points (Table 3). *" There must be a starting point; the end point I don't know. The end point could be either the sea or groundwater..."*

A similar amount of students also agreed that *"the amount of water in the ocean is growing from day to day because rivers are continuously flowing into the ocean"*.

A positive correlation was also found between those students who included groundwater in their drawings and those who demonstrated cyclic thinking in their questionnaires.

Table 3: Students preceptions as showed in a A Cyclic Thinking Questionnaire (CTQ). A Likert–type questionnaire for assessing student's understanding the cyclic nature of the hydrosphere.

Statements	Agreement	Uncertainty	Disagreement
Ocean is the starting point of the water cycle and ground water is its end point.	17.7	27.7	54.6
The amount of water in the ocean is growing from day to day because rivers are continually flowing into the ocean".	26.3	29.6	44.2
The increase in waste that human produce causes to incease in earth mass (weight).	22.5	26.9	50.6
Massive mining (quarrying) of minerals causes to earth mass (weight) decrease.	10.9	34.5	54.5

UNDERSTANDING OF THE SYSTEMIC NATURE OF THE WATER CYCLE.

Systemic thinking is the ability to perceive the water cycle in the context of its inter-relationship with the other earth systems.

Analysis of the data indicates that students tend to diminish the influence of the geosphere on the other water cycle components. 48% of the students do not identify a connection between springs and the water cycle and 34% cannot identify such relationships with the rocks. Only 20% of the students understood the connection between the composition of the water solution and the rock which they pass through, *"Rocks don't influence the composition of water that penetrate them"*.

The interviews revealed that students perceive the interaction between the rock and the groundwater as a physical or mechanical processes.

Q – " How does water influence the rocks?"

S – " The water can make or expand cracks in the rocks".

Q – " Is there any possibility that rocks can influence the ground water?

S – "I do not think so!"

SUMMARY OF THE RESULTS

The followings are the main findings of the predevelopment study:

1. Most of the students possessed an incomplete picture of the water cycle.
2. Most of the students perceive the underground water as a static body.
4. The students showed difficulties to identify relationships amongst the various components of the water cycle.

5. Most of the students have difficulties to perceive interrelationships between the water cycle and other earth systems, mainly the geosphere.
6 The students showed difficulties to transfer basic knowledge in physics and chemistry in order to explain relavant processes that occur within the water cycle.
7. Most of the students have difficulties in perceiving matter transformation within and between the earth systems, as a part of cyclic process in which the overall amount of material is preserved.

DISCUSSION:

The main goal of the Blue Planet program is the development of environmental insight, in order to provide students with skills so they can translate environmental problems, such as water pollution, into a more coherent understanding of the environment. Yet, it appears that while entering junior high school, most of the students possess a partial and fragmental understanding of the water cycle, as well as many alternative frameworks. Moreover, most of the students have difficulties in understanding the systemic and cyclic mechanisms of the water cycle and its relationship with mankind.

As previously mentioned, earlier studies had already indicated that junior and high school students hold many alternative frameworks concerning the water cycle (Bar, 1989; Bar & Travis, 1991; Brody ,1993; Fetherstonhaugh and Bezzi,1992). Thus, the development of any curriculum in this area should emphasize the including of learning strategies to enhance conceptual changes. Today, while science education is deeply related to the constructivist approach, there are dozens of articles and books that deal with student–oriented education and strategies such as the cognitive conflict that might create a personal conceptual change (e.g., Brody, 1994; Strike and Posner, 1985; Trowbridge and Bybee, 1996).

Our findings indicate that students do not relate their school learning of the water cycle to their daily experience. This finding is quite surprising since there is no doubt that the water cycle is mostly relevant to our daily life, espacially in a semi arid area. It is suggested that this finding indicates that dealing with a relevant subject is probably not enough for making it relevant in the students' eyes. In order to do so the whole learning process should be conducted in a way that the students will see the relevancy of the learning from the first step throughout the whole curriculum. Thus, it is suggested that instead of dealing with the water cycle in light of its physical and chemical processes, it should be learnt in it environmental–social context. It is important to note that we do not suggest to omit the physical and chemical processes out of the curriculum, but only to change the order of learning. First to create the relevancy and interest among the students and later to teach the more abstract part of the scientific curiculum while it was needed to solve a specific authentic problem. This strategy is very similar, of course, to the well documented approach known as STS (e.g., Bybee, 1987, 1993; Hofstein et al., 1988; Orion, 1998).

Our findings underline the ignorance that exists among students concerning the role of the geosphere in the water cycle. In the "Science for all" era, while the main purpose of science education is defined as the education of our future citizens, such lack of knowledge cannot be accepted by any society. This strong statement was written since most of the environmental topics such as river pollution, quality of drinking water, and contamination of ground water, are commonly derived, at least in part, from society's ignorance of the role of the geosphere within the earth systems. Thus, any curriculum that deals with the water cycle should emphasize the learning of processes that occur in the geospheric system such as the interrelationships between the type of rocks and the existence of underground water and the interrelationships between the type of rocks and the water quality. However, the high frequency of alternative frameworks found by this study and their broad appearance is not only the result of inappropriate teaching, but also a reflection of the complexity of the hydrology concepts mentioned above. This complexity is derived from the level of abstraction that is needed for understanding hidden processes that take place under the ground. Thus, a curriculum that involves the water cycle should emphasize activities to concretize the hidden underground part of the cycle. One way of concretization of the underground system is the use of 3D models, where students can confront their alternative conception through instructed and constructed activities and self–investigations. While working with such models, students could gain the opportunity to translate environmental phenomena to the higher level of relationships amongst components of the water cycle. However, models and simulations can give only a partial solution to the concretization of abstract processes. Moreover, they always lead some students to develop new misconceptions about the natural phenomena that they try to demonstrate. Thus, there is no ideal substitute for the real world than the real world itself. Therefore, any curriculum that deals with natural phenomena should use the outdoor learning environment as much as possible. Orion & Hofstein (1994) have suggested that the main role of the outdoor learning environment within the learning process is a direct experience with concrete phenomena and materials. It is suggested that Orion's (1993) model for conducting an outdoor learning as an integral part of the whole learning process can serve as a useful tool for emphasizing the role of the geosphere in the water cycle. This model may help the students to connect and integrate learning materials, such as knowledge that was acquired in the lab and classroom with components of the earth systems as they appear in nature. Moreover, questions that may be raised in the authentic situation as the result of the encounter and interaction with the real world might serve as a powerful motivator tool to delve into the learning of abstract concepts and complex interrelationship later in the classroom. Even if some students are familiar with some of the water cycle components in nature, they still face some difficulty in the perception of the global systems. The direct encounter with locations and processes might enable student to create a concrete local water cycle, which might later enlarged into the more abstract, global cycle.

In contrast to the poor acquaintance of students with the geosphere components of the water cycle, most of the 8th and 9th grades students stated that evaporation is one a familiar and understandable process that was learn in 7th grade. Nevertheless, similarly to studies of Bar (1989) and Bar & Travis (1991) this study indicates that most of those students express difficulties in understanding the process of evaporation in the natural context and tend to claim that evaporation can occur in hot water only. Johnson (1998a) and Johnson (1998b) suggested that the basis for understanding the water change of state by students should be the understanding of the "particle model" which emphasized the particle nature of substance. All the students in this study had spent a lot of time and efforts to study the "particle model" of matter, but yet most of them could not use it to explain water evaporation. Our findings suggest that even those students did understand the particles model of matter, they still had difficulty to transfer it in order to explain a real world situation. Consequently, the claim that the first subject in the junior high school science learning should be the particles model, since this is the ultimate gate to understand science does not fit to the "Science for all" era. Alternitivaley, it is suggested that studying the particles model in the context of learning of natural phenomena, in a context of authentic and relevant situation might be more useful for most of the students. Thus, the studying of the water cycle could serve as a poerful platform studying the particles model, rather than being taught as a separate or disconnected physical and chemical processes.

Our findings concerning students' difficulties in perceiving the hydrosphere as a coherent system may suggest that this cognitive ability depends on both scientific knowledge and high order thinking skills. It is suggested that the perception of the water cycle as coherent system involves the operation of two high order thinking skills, namely cyclic thinking and systemic thinking.

Our analysis suggests that students perceive the "water–cycle" as a set of unrelated pieces of knowledge. They understand various hydro–bio–geological processes, but lack the dynamic, cyclic and systemic perceptions of the system. One of the methods for dealing with students' tendency to compartmentalize knowledge is the use of knowledge integration activities (Linn, 2000; Kali, Orion & Eylon, 2000b). Kali et al (2000b), reported a meaningful improvement of students towards the higher part of the systems–thinking continuum concerning their perceptions of the rock–cycle. This improvement was a result of knowledge integration activities. Such activities included a type of concept network drawing, in which the component of the rock cycle was represented. After studying each process (inquiry activities), students were requested to add arrows to represent the process that they have just learnt. Finally, students` work represented the dynamics of material transformation in the rock cycle. It is suggested that similar knowledge–integration activities could be also use for the construction of the water cycle as a dynamic cyclic system.

Implications

Following the findings and the discusion presented above it was decided that the new curriculum "The blue planet" that have been developed for 8th grade science students will include the following components:

1. Using constructivistic methods to alter the students misconceptions of the water cycle.
2. Presenting a coherent depiction of the various processes at each stage of the water cycle.
3 Presenting a systemic approach of environmental problems, namely relating the water cycle to the various parts of the earth system.
5. Focus on skills, rather than on content.
6 In order to allow the students to acquire Systemic thinking, summary activities such as concept map were designed.
7. Adapting an holistic learning environments approach including the outdoor learning environemt as an integral part of the program.
8. Presenting the water cycle in a Science Technology and Society (STS) format.
9. Using computers to access global data bases so that the students will better understand that the water cycle is a worldwide phenomenon.
10. Presenting the multi–disciplinary nature of science.

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