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A Holistic Approach for Science Education For All

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This article suggests that a genuine reform endeavor towards the "Science for All" paradigm should adopt a holistic approach. There are several countries around the world that adopted the "Science for All" paradigm at the beginning of the 21st century. However, while looking closely at the amount of change that took place in schools following the new paradigm, it seems that like previous reforms, there is a gap between the rhetoric and the actual change. A series of studies indicate that Earth systems science approach is much effective than the traditional "science for all" approach. While implementing it correctly, it succeeds to attract students from both groups – the high achievers group and the much bigger group of students to whom the traditional science programs were frequently inaccessible. Both groups found the Earth System approach attractive and interesting and both gained a significant amount of knowledge and understanding. However, the earth systems approach alone will not be enough and in order to attract most of the students and in addition such programs should be based on a holistic approach that should also include the following characteristics: (1) Learning in an authentic and relevant context as much as possible. (2) Organizing the learning in a sequence that shifts gradually from the concrete to the abstract. (3) Adjusting the learning for variant abilities learners. (4) Integrating the outdoor environment as an integral and central component of the learning process. (5) Focusing on both the cognitive and the emotional aspects of learning.

Keywords: Reforms in Science Education, Science For All, Earth Systems Education, Long-Term Study.

INTRODUCTION

In 1990, the American Association for the Advancement of Science published the policy paper Science for all Americans (AAAS, 1990). This document was a part of the Project 2061, which calls for major reforms in relation to the goals and strategies required for teaching and learning science in schools. The new "Science for All" paradigm perceives the main goal of science education as preparation for the nation's new citizens and its implementation has grown rapidly during the last 15 years in several countries around the world. The most important aspect of this new paradigm was a change in the purpose of science education - from preparing future scientists towards the education of the future citizens. However, while looking closely at the amount of change that took place in schools following the new paradigm, it seems that like previous reforms, there is a gap between the rhetoric and the actual change in the classes. Orion (2003) reported a long-term study that followed the "Science for All" reform process in Israel from its beginning onwards from the 'storm eye'. It includes about 10 years of a qualitative and quantitative data collection, which covered broad components and processes of the reform system: science teachers, principals, superintendents, students, curriculum developers, the academic science education establishment, the ministry of education establishment, in-service training programs and pre-service teachers and programs. The findings indicate that some meaningful changes could be identified as well as effective models to lead and support them. However, in general, no meaningful change concerning the goals of

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the new curriculum was found. It is suggested that the three main groups that are responsible for the minor success of the "Science for All" reform so far are the science teachers, the science education leadership and the Ministry of education bureaucrats and politicians. It is also suggested that such outcomes are not unique to Israel. There are several reasons for the constant failure of educational reforms. A major reason in this case was the academic leadership of the implementation of the reform. Most of the leaders were grown and based their career on the previous paradigm and they themselves failed to undergo a genuine paradigm shift or do not agree with the new paradigm. They grew up in the traditional paradigm that views the main importance of science education lays in its contribution to a nation's strength in terms of economy and military through the study of only three scientific disciplines physics, chemistry and biology. However, the traditional approach fails to deal with or actually refuses to deal with a very crucial field – the environment. During the last few years we were able to watch in a live TV the tsunami in the Indian Ocean, Hurricane Katherine in USA, volcanoes and earthquakes in many places in the world. In addition, the media deals very frequently with topic such as the global warming, pollution of our atmosphere and hydrosphere and the availability of fossil fuel. There is no doubt that the understanding of these earth sciences environmental phenomena is crucial for our future citizens no less than the subjects that a traditional science education curriculum deals with. Therefore, earth and environmental sciences topics should be included in the core and to dominant any "Science for All" curriculum. However the profile of the earth sciences in school science curricula all over the world is ranged between low to negligible, even in countries like Turkey where millions of people live along a very active fault line.

Lovelock (1991) notes that the Earth is composed of several inter-related systems. He argues that only by developing a multi-dimensional perspective can one understand the global picture. In this light, he proposes that environmental research should be carried out with a multi-disciplinary holistic approach, as opposed to the reductionist approach, where each scientist specializes in a narrow field that does not relate to the entire picture. Mayer (1995) claims that the main constraint which prevents introducing a more holistic approach within the science curricula is the reductionist philosophy. This philosophy which rates the sciences according to a hierarchy of "importance", places physics at the top, and provided the basis for science education's main goal in schools, which was the preparation of a new generation of scientists. He contends that the "hard" science approach illustrates the severe limitations of the reductionist science for studying processes, as they occur in the real world. He therefore suggests to adopt an earth systems education framework for the development of integrated science curricula. Specifically, he refers to any physical, chemical, or biological processes that can and should be taught in the context from which the particular process was taken from in the earth systems.

Thus, the first step in the long process of implementing genuine "Science for All" curricula should include a paradigm shift of the academic leadership of science education. This shift requires the movement from a narrow perception of science education towards a more holistic perception in terms of social purpose of science education, scientific contents and educational approach. For example, a movement from teaching science as a tool to prepare the future scientists of a society towards the preparing the future citizens of a society; a movement from a disciplinary-centered towards a multidisciplinary approach; a movement from a narrow minded perception of science that includes only physics, chemistry and biology towards a broader perception which also includes the earth and environmental sciences; a movement from a classroom-based education towards the integration of multi learning environments including the lab, outdoors and computer; a movement from a perception that is mainly derived from the scientific world towards an authentic based perception that is derived from the real world.

It is suggested that any genuine reform endeavor towards the "Science for All" paradigm should adopt a holistic approach. In this paper I will concentrate on three components of such a reform: (1) A holistic framework for the science curricula. (2) A holistic learning environments (outdoors, lab, computer and classroom) component. (3) A holistic cognition-emotions learning component.

THE HOLISTIC FRAMEWORK COMPONENT

Orion & Fortner (2003) have argued that the earth systems approach is ideal as a holistic framework for science curricula. The starting point is the four earth systems that combine our natural world: geosphere, hydrosphere, atmosphere and biosphere. The study of cycles organizes earth systems education: the rock cycle, the water cycle, the food chain, and the carbon cycle. The study of these cycles emphasizes relationships among subsystems through the transfer of matter and energy based on the laws of conservation. Such natural cycles should be discussed within the context of their influence on people's daily lives, rather than being isolated to scientific disciplines. The earth systems approach also connects the natural world with technology: Technology transforms the raw materials that originate from earth systems. In contrast with traditional teaching approaches of science, the earth systems approach does not sequence the curriculum using topics from physics or chemistry. Instead, this approach organizes study in terms of systems and cycles as experienced in peoples' lives. It does utilize physics and chemistry as tools for understanding science at a deeper and more abstract level in this context.

The main educational goal of this environmental-based science education approach is the development of environmental insight. This insight includes the development of the following two principles: (a) We live in a cycling world that is built upon a series of sub-systems (geosphere, hydrosphere, biosphere, and atmosphere) which interact through an exchange of energy and materials; and (b) Understanding that people are a part of nature, and thus must act in harmony with its "laws" of cycling.

THE HOLISTIC LEARNING ENVIRONMENTS COMPONENT

One of the unique characteristics of the Earth systems is that it places the outdoor learning environment at the same level of significance with the indoor learning environments (classroom, lab and computer).

There is little doubt that starting the learning process from the students own point of interest, or at least with their understanding of why they should learn a specific topic, might serve as a powerful tool for a meaningful learning process. Thus, it is suggested that the learning process should start with a "meaning construction" session, where students could discover what interested them about a particular subject. Depending on the subject and the school's location, this stage could be conducted in a relevant outdoor environment or in a versatile indoor space. In the former environment the function of the teacher is to mediate between the students and the concrete phenomena. In the indoor environment the teacher's role is to motivate students' interest by exposing them to phenomena that are related to the subject through the using of pictures, video films, computer software, Internet sites, and written texts. Orion (1993) suggested that the main role of the outdoor learning environment in the learning process is direct experience with concrete phenomena. The uniqueness of the outdoor learning environment is not in the concrete experiences themselves (which could also be given in the classroom), but the type of experiences. The main potential of such concrete experiences is that it deals with phenomena and processes, which cannot be cultivated indoors. The outdoors is a very complicated learning environment, since it includes a large number of stimuli, which can easily distract students from meaningful learning. Thus, the first task of teachers and curriculum developers is to identify and classify phenomena, processes, skills and concepts which can only be learned in a concrete fashion outdoors, and those that can be learned in a concrete fashion indoors. In addition, it is important to identify those abstract concepts to which the outdoor contributes little in student understanding, In such cases, more sophisticated indoor tools (such as pictures, films, slides and computer software) must be substituted to provide a fuller explanation.

The guiding principle of this model is a gradual progression from the concrete levels of the curriculum towards its more abstract components. This model can be used for designing a whole curriculum, a course, or a small set of learning activities. Following the "meaning construction" stage, which can be conducted both outdoors and indoors, the first phase of a specific learning spiral starts in the indoor learning environment. The length of time of this phase is varied; it is whole dependent on the specific learning sequence. The main aim of this phase is to prepare the students for their outdoor learning activities. The preparation phase deals with reducing the "novelty space" of an outdoor setting (Orion & Hofstein, 1994). The novelty space consists of three factors: cognitive, geographical and psychological. The cognitive novelty depends on the concepts and skills that students are asked to deal with throughout the outdoor learning experience. The geographical novelty reflects the acquaintance of the students with the outdoor physical area. The psychological novelty is the gap between the students' expectations and the reality that they face during the outdoor learning event.

The novelty space concept has a very clear implication for planning and conducting outdoor learning experiences. It defines the specific preparation required for an educational field trip. Preparation, which deals with the three novelty factors, can reduce the novelty space to a minimum, thus, facilitating meaningful learning during the field trip. The cognitive novelty can be directly reduced by several concrete activities, for example, working with the materials that the students will meet in the field, as well as simulation of processes through laboratory experiments. The geographic and psychological novelties can also be reduced indirectly in the classroom, first by slides, films and working with maps, and second by detailed information about the event: purpose, learning method, number of learning stations, length of time, expected weather conditions, expected difficulties along the route, etc.

The next phase in this cycle is the outdoor learning activity; it was placed early in the learning process, since it mainly focused on concrete interaction between the students and the environment. The outdoor learning experience, together with the preparatory unit, can constitute an independent module, which might serve as a concrete bridge towards more abstracts learning levels. Thus, an outdoor learning experience should be planned as an integral part of the curriculum rather than as an isolated activity. It should be based on curriculum materials, which lead the students to interact with the phenomenon and not with the teacher. Hands-on interaction should lead the students towards two main educational objectives: a) construction of understanding and b) inquiry concerning questions related to the studied phenomenon. The teacher's role is to act as a moderator between the students and the concrete phenomena. Some of the students' questions can be answered on the spot, but only those, which might be answered according to the evidence uncovered in the specific outdoor site. Otherwise, time and resources, including the students' attention is wasted on activities that might be done elsewhere. Lectures, discussions and long summaries should be postponed until the next phase, which is better conducted in an indoor environment.

THE HOLISTIC COGNITION-EMOTIONS LEARNING COMPONENT.

The earth systems approach emphasizes simultaneously on the development of thinking skills and on the students' affective development (emotional intelligence). For this purpose, it focuses on the development of thinking processes and connections between the students and their physical (natural and non-natural) environment. The environment offers students an opportunity to deal with scientific issues through their senses, thereby creating emotional experiences and insights that are not culture-dependent. The sense of accomplishment that students experience is likely to serve as a springboard for the enhancement of their scholastic motivation and for the improvement in their learning skills. The relationship with the immediate environment begins with authentic questions that are related to the students themselves and enhances their awareness and insight regarding their environment. Later, the students experience their environment through activities that are based on intake of stimuli of all the senses.

For example, one of the schools that implemented such an earth systems "Science for All" program is situated near dunes. The first learning activity of the 7th grade classes was outdoors in the dunes, where they combined cognitive oriented tasks like observing geological and biological phenomena and asking questions with emotional oriented tasks like climbing the moderate slope of a dune and rolling down the steep slope. Following the first visit to the dunes the students were introduced to a realistic authentic question concerning the future of that dune area. At the time there was a debate among the citizens of this town whether to use this area for a new real-estate enterprise or to conserve the natural area for future generations.

The focus on the affective aspect of learning includes the response to the variance of students. For example, including activities that are based on the multiple intelligences approach (Gardner, 1992), the use of varied methods of assessment, mediated learning and development of motivation and emotional intelligence.

FROM THEORY INTO PRACTICE

The following are a few examples of an earth systems learning sequence that demonstrate the practical use of the above holistic principals. The first example is an Earth systems "Science for All" program that was developed for a junior high school in a town that is located in a dunes area. The learning sequence of this program starts in the 7th grade with an authentic and relevant question concerning the future of the dunes area that borders with the town. This question raises a need to know and understand the dunes area. This acquaintance focuses on the concrete visual geological and biological phenomena that exist there. Yet, soon enough the students find that an in-depth understanding of every concrete phenomenon leads them to raise questions concerning aspects that are not concrete at all. For example, when they study the quartz grains that build the dune, one of the questions is: "where did they come from?" This question opens a new learning cycle that includes also the studying of weathering of granite. Thus, in this context the students learn the chemistry that is needed in order to understand this process. While dealing with the process of the transportation of the quartz grain and the dune structure, the question that rises is what influences the direction of the wind. This question opens a new learning cycle which mainly deals with basic concepts in physics such as radiation, heat absorption, heat transformation, in the air, air pressure, etc.

The grainy structure characteristic of the dunes leads the students to the relationships between the geosphere and the hydrosphere. More specifically, it leads to the aquifer topic and from there to the question of what influence the quality of our drinking water and this of course opens a new learning cycle that goes deep to very basic concepts in chemistry. Following the understanding of the relationships between the geosphere and the hydrosphere the students ask about the interrelationships of these earth systems with biosphere. This aspect allows the students to study very basic concepts in biology and again to deal with other basic concepts in physics and chemistry that again were studied in the context of concrete biospheric phenomena.

The translation of the program's principles and key ideas are described in Table 1. It is important to emphasize that the earth systems "Science for All" program complies with the concepts in physics and chemistry that appear in the national curriculum and standards and in the same depth as the traditional

Tables 1. Principles of an earth systems-based program and their fulfillment

Principles	Actions
Learning in authentic and relevant contexts	The development of the learning units around environmental real-life issues. Using the outdoor as an integral and essential learning environment. Using the Earth systems approach as a platform for the "Science for All" curriculum. The learning revolves around authentic questions and authentic assignments.
The learning sequence moves gradually from the concrete to the abstract.	Each learning unit starts with hands-on activities in the lab and in the outdoors. Following the authentic questions that were raised and the understanding that was built students move to deal with more abstract concepts that could be built through concrete interactions with the natural phenomenon.
Adjustment of the learning for variance of learners	Each unit includes a variety of learning strategies and environments dealing with both cognitive and emotional aspects. Focusing on both the cognitive and emotional needs of the students. The program emphasizes the development of all seven intelligences defined by Gardner (1983, 1992).

Table 2. A comparison of the science knowledge and skills between the students who studied the traditional science program and those who studied science by the Earth systems approach

	Traditional program		Earth systems based program			
	M	SD	M	SD	*t*	*P*
Whole test	0.59	0.15	0.69	0.1	4.4	0.0001
Multiple choice part	0.57	0.2	0.67	0.15	3.3	0.001
Graphs analysis part	0.45	0.3	0.66	0.25	4.4	0.0001

program. However, it places them in a different order within the learning sequence in comparison to the traditional study program.

THE EFFECTIVENESS OF THE EARTH SYSTEMS "SCIENCE FOR ALL" APPROACH

There are several studies that indicate the effectiveness of Erath systems approach in development of both general scientific literacy and thinking skills (Orion & Fortner, 2003; Dodick & Orion, 2003; Kali, Orion & Alon, 2003; Ben-zvi-Assaraf & Orion, 2005). In a more recent study we compared between two groups of junior high school students from the same age and school who taught by same teachers according to their the scores of a national science knowledge exam. One group studied the science curricula according to the earth systems approach and the other one according to the traditional approach. Since the "traditional" group did not study any earth sciences topics or principals the calculation of the exam's scores included only those questions that were related to physics, chemistry and biology. Table 2 presents the comparison of the outcomes of the two groups. It reveals a significant difference between the achievements of the two groups. The advantage of Earth systems approach group in a general science test is very clear in both parts of the test, but much clearer in terms of the scientific skills of data analysis and graphs reading.

PROFESSIONAL DEVELOPMENT VERSUS PROFESSIONAL CHANGE

There are two limiting factors that should be overcome in order to move towards the Earth systems science education approach. The first and the most difficult to overcome is the science education establishment, which is usually combined of disciplinary oriented scientist science educators and educational bureaucrats. While overcoming or bypassing the first limiting factor there is a second limiting factor to overcome - the science teachers.

The teaching strategies of the Earth systems based science program are quite different from the traditional way of teaching science (Table 3). For many traditional science teachers all over the world, the implementation of the new "science for all" programs in general and the Earth systems approach in particular is not just a professional development. The meaning of professional development is that the subject of the development, in our case science teachers, have a very solid basis of their profession and from this professional core they can grow and expand. However, in order that teachers will move from the right column of Table 3 to its left column, even in relation to some of the six parameters, they have to change their goals, contents, ways and philosophy of teaching. Moreover, the shift presented in Table 3 is valid for any genuine "Science for All" teaching, however the Earth systems teaching demands on top of it two additional new aspects for teachers: (a) Teaching earth sciences subjects, which many science teachers in many countries have no scientific background in this area and (b) the using of the outdoor learning environment, which is also ignored by most of the traditional science teachers.

Thus, the shift from a traditional science teacher towards Earth systems teacher is not just a development rather it is a major reform or even a revolution – a professional change.

For the last 10 years we conducted several studies that explored strategies and models that might lead teachers towards teaching earth systems "Science for All" programs (Orion, 2003; Orion, Ben-Menacham & Shur, 2007). Our findings suggest that the in-school INST model is much effective in conducting professional change while it includes the following components:

1. At the first stage the teachers have to experience the new methods and contents as learners. Positive experiences as learners will help both to be convinced of the effectiveness of the new paradigm and later to deal with their students' learning difficulties on the basis of their difficulties that they experienced as learners.
2. The school's management should be an integral part of the INST and to take the commitment for facilitating the implementation of the new reform.
3. The first teaching experiences of the new methods of contents should be done with a close support of the INST experts.
4. The INST leaders should be equipped with psychological knowledge and skills to deal with reservation and oppositions, which are the result of a change fear.

Our findings also suggest that even the most powerful and effective INST alone cannot guarantee a long-term sustainable reform. Unfortunately, education in many countries is controlled by economic and political decisions and not by pedagogical decisions. Thus, in order to lead the teachers to such a paradigm shift a lot of resources should be invested during a long period of at least ten years. However, in addition to the unwilling of the policy makers to allocate the needed resources, a genuine conceptual change cycle is much longer than a political cycle (the time from election to election). Therefore, the process never comes close to maturation. It is suggested that the heart of the problem is the science education leadership. This leadership has the responsibility to educate the teachers and to convince the Ministry of Education to invest the needed resources. Thus, the failure of the science education reforms is primarily the failure of the science education leadership.

Table 3. A comparison between the traditional science teaching and the ES teaching

Traditional science teaching	Earth systems teaching
The main purpose is to prepare the future scientists of a society	The main purpose is to prepare the future citizens of a society
Disciplinary-centered teaching	Multidisciplinary teaching
A teacher-centered teaching	A child-centered teaching
Content-based teaching	Integration of skills within contents
The teacher is a source for knowledge/information	The teacher is a mediator for knowledge
"Chalk and talk" based teaching	Inquiry based teaching
School-based learning	Multi learning environments: Classroom, lab, outdoors and computer.
Teaching that is derived from the scientific world	Authentic based teaching that is derived from the real world
Traditional assessment	Alternative assessment

MYTHS THAT SUSTAIN THE DOMINANCE OF THE TRADITIONAL PARADIGM

The philosophy that establishes the dominance of the traditional paradigm of science education for generations is widely accepted among scientists and science educators all over the world. However, some foundations of this philosophy are not well supported. The followings are four examples of such myths.

Myth 1: Studying science from the earth and environmental sciences (the so-called "soft" sciences) perspectives will be on the expense of the "real" sciences - physics and the less "hard" science – chemistry.

Our 15 years study indicates that studying science from the Earth systems perspective was not on the expense of the other sciences. On the contrary, it raised students' interest in studying all the sciences and increased their learning achievements in physics and chemistry. Moreover, it elevated their learning achievements in these areas to a level which is higher than the level they reached while studying the sciences that are physics-chemistry oriented and do not include any earth sciences component.

Myth 2: If students will go outside the class for field trips then when will they really study?

Our 20 years study in this area indicates that integrating the outdoor learning environment was not a waste of precious teaching hours, on the contrary, both students and teachers found it as one of the major contributors for the students' high achievements.

Myth 3: Focusing on the preparation of students towards national and international test will increase their achievements.

Our 5 years study shows that students who studied science in the traditional approach and then were prepared for the national science test for a period of about six weeks had significantly lower achievements than those students who were not prepared for the test and studied science through the earth systems approach.

Myth 4: Practicing science teachers are incapable of making changes in the way they teach.

Our 10 years study in this area indicates that although it is very difficult to change teachers' habits and perceptions of science teaching, it is a possible task even for seniors with 20 years of teaching experience). We found that such teachers changed their science content focus and taught earth sciences subjects that were completely new to them. They began to teach in the outdoors learning environment. They changed their ways of teaching and changed their views on the purpose of science teaching. Such professional change was achieved through long term in-service training programs conducting in the schools with close support and assistance that included both professional and emotional backing.

SUMMARY

Our studies indicate that Earth systems science approach is much effective than the traditional "science for all" approach. While implementing it correctly, it succeeds to attract and advance students to whom the traditional science programs were frequently inaccessible. However, the success of the students, who usually do not find school in general and science learning in particular interesting, did not happen on the expense of those students who are considered high achievers. Both groups found the ESS program attractive and interesting and both gained a significant amount of knowledge and understanding.

There is no doubt that the traditional science programs are very useful for the selection of that 1%-5% of the population that could be the future physicists. Our studies suggest that an earth systems science program might serve as a much powerful platform for any science program that claims to be "for all". Yet, the earth systems approach alone will not be enough and in addition such programs should also include the following characteristics:

- Learning in an authentic and relevant context as much as possible.
- Organizing the learning in a sequence that shifts gradually from the concrete to the abstract.
- Adjusting the learning for variant abilities learners.
- Integrating the outdoor environment as an integral and central component of the learning process.
- Focusing on both the cognitive and the emotional aspects of learning.

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