An holistic approach to introducing geoscience into schools: The Israeli model – from practice to theory

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1 INTRODUCTION

Earth-science education in Israel is in a process of revival. In 1985 a decision in principle was taken by the Ministry of Education to recognise Earth-science (mainly geology) as an independent optional discipline within the Israeli education system. Later, geology was included among the several scientific disciplines which were financed for curriculum development by the Amos de-Shalit Israeli Center for Science Education. In 1988 the Ministry of Education nominated a co-ordinator and a steering committee to develop the high school Earth-science curriculum structure and syllabus.

In 1989 the Ministry of Education published an Earth-science curriculum for high schools. The curriculum, which was designed by a professional committee of academics and teachers, includes two levels – geology as a minor topic (3 units) and geology for majors (5 units). This was achieved as a result of the persistent efforts of a small group led by Prof. E. Mazor of the Weizmann Institute. The activities of this group included the development of learning and teaching materials, research, in-service training programmes for teachers and suggestions for the teaching methods and strategies which might be appropriate for Earth-science teaching.

Teaching Earth-science as an independent discipline in high schools began in 1991. The Earth-science teachers are all Earth-sciences graduates, and in 1992 a pre-service Earth-science teacher training programme was started in the Hebrew University of Jerusalem. At present (1994), Earth-science as an independent discipline, exists only at the high school level. In the lower levels, e.g. kindergarten, elementary and junior high school, Earth-science topics are included within other disciplines such as biology, chemistry, physics and geography and recently in a new STS (Science-Technology-Society) programme for the primary school. Although the curriculum of these disciplines includes Earth-science topics, their teaching is very limited (Table 1).

The introduction of Earth-science to the high school level is a goal in itself and at the same time is a means of penetrating the lower grades as well. Since 1990, curriculum materials for all ages have been developed, from the kindergarten through

Table 1. Earth-Science teaching (ES) in Israeli curricula – as of 1993.

Year/grade	Discipline	Earth Sciences (ES) curriculum	Teach. hours	Teachers' ES background	Extent of teach. ES	Present and near-future programs
18 yr	Geology	Introduction Advanced	270 hrs 450 hrs	ES graduates ES graduates	Limited Limited	Teachers' training program was firstly opened in 1992. New curriculum materials have been developed.
High school	Biology Physics Chemistry Environment	No specific course, but ES subjects and concepts are included in the curriculum	Few	Very limited in ES, but broad in science	Very limited	An interdisciplinary course in geophysics is now under development & implementation. More interdisciplinary courses are planned.
15 yr	Geography	Introductory; Geotop project	90 hrs 90 hrs	Limited in ES, very limited in science	Limited Limited	New curriculum materials have been developed. In-service teachers' training has been conducted
Junior high school 12 yr.	Sciences	No specific course, but ES subjects and concepts are included in the curriculum	Few	Very limited in ES, but likely in science	Very limited	New curriculum materials have been developed.
	Geography	Introductory course	30 hrs	Limited in ES, very limited in science	Limited	In-service teachers' training has been conducted
Primary school 6 yr	STS (Science Technology Society)	2 Units are included: Earth materials and Earth treasures	20 hrs 20 hrs	Limited in ES and in science	In progress	New curriculum materials have been developed.
	Geography	No specific course, but ES subjects and concepts are included in the curriculum	Few	Limited in ES, very limited in science	Very limited	In-service teachers' training has been conducted
Kindergarten 4 yr	Science	A new program has been developed and implemented	30 hrs	Limited in ES, very limited in science	In progress	A national implementation scheme is under development

the elementary and junior-high to the high schools. In-service education and training has been developed which deals with Earth-science subjects.

Although the process of introducing the Earth-sciences within Israeli curricula is in its first stages, it seems that this account of our experience might be useful for stimulating the efforts of Earth-science communities in other countries who also struggle to introduce Earth-science studies to the educational system.

Several aspects of the Israeli experience were presented during the conference. The purpose of this paper is to combine our presentations together in order to present a coherent and clear picture. This framework stresses the need for an holistic approach in order to put Earth-science education into the place which it deserves in schools. To be successful, this requires simultaneous efforts in many areas and with many formal and informal institutions of the educational system: the policy makers in the Ministry of Education and the geological academic establishment (Fig. 1); the science education establishment; the outdoor education centres; conservation bodies; the head teachers and teachers; the science media.

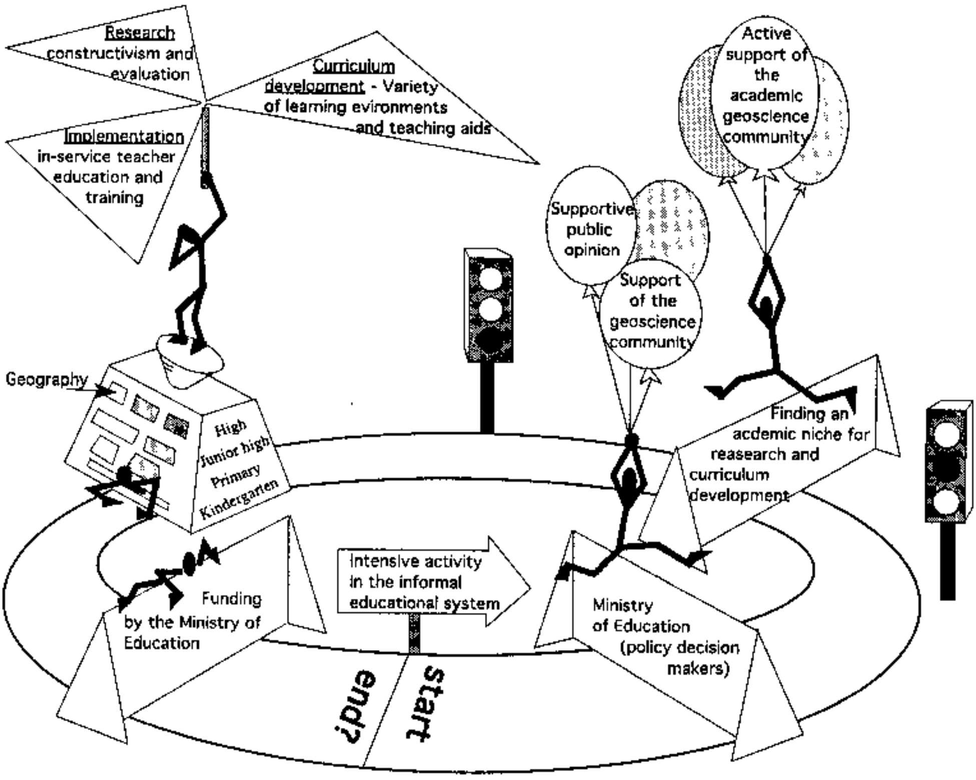

Figure 1. The 'hurdles race' involved in the introducing of Earth-sciences education into the Israeli educational system.

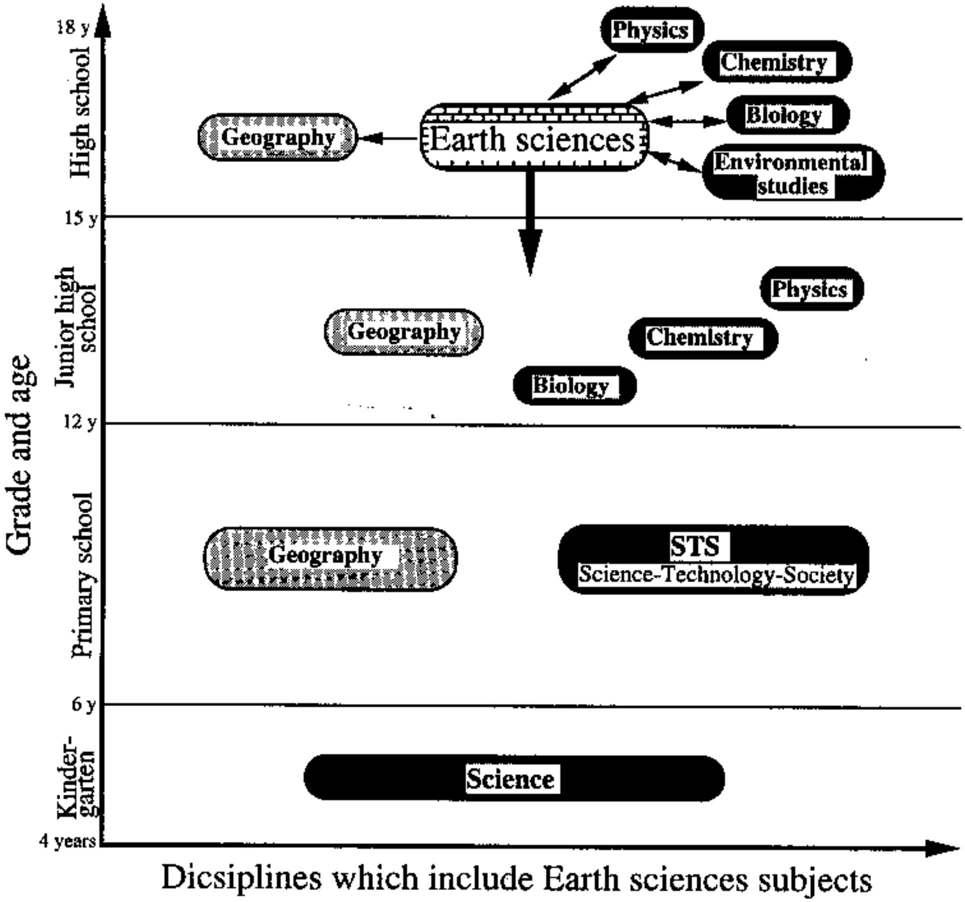

Figure 2. The places of the Earth Sciences in the Israeli curricula.

2 THE EDUCATIONAL POTENTIAL OF EARTH-SCIENCE STUDIES

In addition to the intrinsic scientific importance of the Earth-sciences, they possess a very high educational potential which can be exemplified in relation to the following characteristics:

The interdisciplinary nature of the Earth-sciences (Fig. 2).The Earth-sciences, by their very nature, are interdisciplinary subjects. Physical and chemical principles and biological processes and environment are used to explain geological phenomena. Therefore, the Earth-sciences can demonstrate the practical uses of physics and chemistry in our daily life. Earth-science has close relationships also with biological subjects such as evolution, and relates to interactions between rock-soil-flora-fauna.

Time and space dimensions. One of the characteristics of the Earth-sciences compared with the other scientific disciplines is the integration of concepts and processes related to time and space. A large time range, measured in millions and billions of years, and a huge spatial domain both above and below the Earth's surface are the routine objects of study.

Scientific thinking. The Earth-sciences can be used as a paradigm for the inculcation of scientific process skills: observation, hypothesis-making, hypothesis-testing through observations, working up conclusions and starting a new investigative cycle. Since the Earth-sciences try to unravel processes which took place millions of years ago, the geologist has developed a particular way of thinking – retrospective thinking: drawing conclusions from clues and pieces of information which are combined together as a jig-saw to create a clear four-dimensional picture. This contribution to the students' cognitive abilities, together with the development of spatial visualisation skills, are almost unique to Earth-science education.

Integration of the outdoors and the laboratory in the learning process. Earth-science provides a natural framework and discipline through which it is possible to integrate formal teaching in the classroom with laboratory experiments and field observations.

From the kindergarten to the high-school. Earth-science topics can be developed at different levels of concretization or abstraction. By classifying the learning of Earth-science concepts from the 'concrete to abstract', Earth-science can be presented appropriately to students of all abilities from kindergarten to high-school.

Environmental education. The Earth-sciences have a major part to play in the environmental education of society. They give the students – as future citizens – the knowledge and the ability to reason about such subjects as the utilization and conservation of energy, water supply and material resources; they deepen the student's awareness of his/her physical surroundings and the make up of their homeland.

3 THE LOW STATUS OF EARTH-SCIENCE EDUCATION

The high educational potential of the Earth-sciences is little reflected in Israeli schools. The status of Earth-science education all over the world is quite low or non-existent (see George, 1972 and other articles in this volume). In order to improve this situation it is vital to attempt to understand the possible reasons for this world-wide phenomenon. Why, despite its great educational potential, does the Earth-science education have such a low profile? The position in Israel, described below, may be of general applicability.

In Israel, the immediate explanation for this situation is rooted in the fact that, until recently, Earth-science topics were only to be found in geography curricula. The geographers have been doing their best to teach the relevant concepts well, but their ability to do so proved to be limited. Without a deep scientific background and with only very limited geological understanding, they have shown that they could not successfully cope with such complex ideas. As a result, only a small percentage of the geography teachers include Earth-science topics in their teaching schemes. However, no-one should blame the geographers for this situation. The only group who should be invited to public trial is the geoscience community and especially its establishment who have been guilty of deserting the educational battle field. What are the sources or reasons for this? Is it a tendency to social reservation? Is it an hereditary fear of the church which has remained from the early days when scientists who dealt with Earth-science clashed with religious authorities? Is it a feeling of inferiority in relation to the traditionally high prestige of the other sciences? The discussion about these speculations is beyond the scope of this paper. The main point, however, is that only the geoscience community can initiate a meaningful effort to ensure that Earth-science education finds its appropriate and respectable place in schools.

4 THE ROLE OF THE PROFESSIONAL GEOSCIENCE COMMUNITY

The prominent role of the professional part of the geological community in the introduction of geoscience into the curricula is well exemplified through the Israeli experience. The decision of the Israeli Ministry of Education in 1985 to recognise Earth-science as an independent scientific discipline was granted only as a result of the initiative and efforts of a single scientist (Prof. Emmanual Mazor, a geologist-geochemist from the Weizmann Institute of Science). It was this man who later opened the doors of the Department of Science Teaching of the same Institute to Earth-science educators. The policy decision in 1990 of the universities to give Earth-science matriculation results an equal weight to those of other scientific disciplines when accepting new students, resulted from the efforts of an academic lobby for geological education. The decision of the Hebrew University of Jerusalem in 1992 to open a new programme for the educational training of Earth-science teachers was a direct result of the efforts of members of the Geology Department of the Hebrew University.

It is also very important to recognise that some of the main opponents of the geoscience education in schools were geologists. It took a few activists several years before they were able to count on the support of the geological establishment. The main arguments of the geologists who were against Earth-science education in schools related to three factors which are likely to be of world-wide applicability:

1. A professional aspect: 'There are enough geologists and we do not need any more'.

2. An academic aspect: 'We prefer students who know maths, physics and chemistry; therefore schools should only focus on teaching these subjects. We will teach them the Earth-science ourselves'.

3. A fear of the likely low level and poor quality of the Earth-science teaching in schools: 'Only a specialist knows enough Earth-science in order to teach it in schools'

All are very serious arguments which deserve thoughtful consideration and rebuttal. The two first arguments are derived from an egocentric view and the response to them is the same: the main objective of Earth-science education (as distinct from science education) in schools is to fulfil a birthright and to prepare future citizens. It is not to produce future geologists. In these science-society relationships, the geosciences have a central role to play as explained above, a role which has almost been ignored by the geoscience community till now.

The third argument deserves more careful and longer treatment, since we have to convince practising geologists that geoscience education and geoscience educators are an integral part of the Earth-science community. The role of Earth-science educators is to bridge between the science-scientists and society. The geoscience community has to be convinced that this is a genuine partnership and that science education channels are open to them: they are not only welcome but are expected to influence the educational process. This partnership is not easy to achieve since many traditional scientists hold conservative views about science education. They argue that traditional science education: 'was right for us when we were at school'. However, difficult as it might be, we must cultivate and enhance this partnership, since without it we lose a great deal of our moral and practical power and abilities. A long-term solution for this situation is to involve the Earth-science undergraduate students in the educational activities of science departments in schools. In due time some of these students might eventually become university staff members and then it will be much easier for them to break down artificial barriers.

The geoscience community needs to appreciate that ultimately, budget cutting or growth are determined by politicians who are influenced by public opinion. Thus, if one is not involved in bettering society, one cannot expect to be understood and hence be supported by society. The educational channel is the best way to deliver the message that understanding geoscience concepts is of vital importance in our daily lives.

For the last ten years we have been trying to implement the philosophy of working together with the geoscience community. Our steering committee includes members from all the geology departments of universities and all geological societies. The development of the teaching-learning materials involves consultation with expert geoscientists. Earth-science undergraduate students are involved in educational activities in schools. Each year our group presents a poster or a lecture in the annual meeting of the Israeli Geological Society. It seems that these efforts have at last begun to bear fruit; Earth-science education in schools has come a long way from prominent opposition to vigorous support.

5 THE INTER-RELATIONSHIP BETWEEN THE FORMAL AND INFORMAL EDUCATIONAL SYSTEMS

Efforts to introduce the Earth-sciences into the educational system were anticipated by intensive activity in the informal education systems. Co-operation with bodies such as The Conservation Authority, The Society for the Protection of the Nature and the Israeli Open University was particularly successful and created a supportive public opinion with respect to teaching Earth-sciences as an independent discipline in the formal educational system.

At present these relationships are deepening and expanding. Curriculum materials which were developed for the formal system have been modified for the informal system and our group is utilising knowledge which generated in schools in training field leaders to teach Earth-sciences in the field.

6 INTRODUCING EARTH-SCIENCE TEACHING IN SCHOOLS

Introducing Earth-science teaching in schools is quite complicated and has been accomplished by a step-by-step process. The first stage required the breaking of several vicious circles, and the paving of a new road as described in the following events:

1. Achieving the status of an independent scientific discipline in the high school by edict of the Ministry of Education.

2. The nomination of a co-ordinator and a steering committee by the Ministry of Education.

3. The development of an Earth-science curriculum for the basic and advanced levels for matriculation (as exist for the other scientific disciplines).

4. Obtaining recognition from the universities of Earth-science matriculation scores in their student acceptance criteria of comparable weight to those of the other scientific disciplines.

5. Establishing an academic niche for research, curriculum development and implementation procedures.

6. Establishing a course of Earth-science teacher education and training.

These six events took place away from schools and largely on the desks of the policy makers in the Ministry of Education and in the universities. They were achieved only through the support of the geoscience community and public opinion. These achievements paved the road for the 'real' work of the second stage – the introduction of a new curriculum into an over-crowded and 'tired' education system. At this stage no lobby could help very much. This was the 'moment of truth', when only the quality of the curriculum materials and the carefully thought-out implementation strategies could persuade hard-headed principals, teachers and students that the Earth-sciences could successfully be taught and learned in their schools.

Firstly, the group had to decide the best level at which to enter the system. The Israeli education system is upwards-oriented. This means that high schools are very concerned with the chances of their students being accepted by the universities. In turn the junior high schools are very concerned with increasing the chances of their students being accepted by the best high schools. Therefore, in our case, starting to introduce Earth-science at the top at the high school level, was a tactical decision, which our group believed would enable Earth-science teaching to seep downwards to the lower grade levels as well. It is also important to emphasise that our main target is the larger population of the junior high and primary school students since at the high school level it is only possible to reach a very small portion of the student population. Although the process is still at its beginning, it is already noticeable that teachers and principals are now more open to encouraging the teaching of the Earth-sciences at the lower grades.

Our entry card to schools was the adaptation and application of the philosophy of the Department of Science Teaching of the Weizmann Institute, which is working within the research – curriculum development – implementation triangle. This strategy is very powerful since it facilitates control of all the components of science education. The development of curriculum materials begins with a study of student and teacher needs, preconceptions and abilities. The implementation is based on a pre-service and/or in-service education and training programme which is followed by a formative and summative evaluation study. Actually, the process of the modification of the curriculum materials never ends. The group continues to follow and support implementation in schools for a long time, even after the main development effort has ended. When trying to implement a new curriculum, there is no other alternative than to walk with the teachers hand in hand for a long way until they feel confident and competent to continue by themselves.

7 EARTH-SCIENCE EDUCATION IN THE ISRAELI HIGH SCHOOL (TO THE END OF 1993)

Earth-science as an independent scientific discipline has been taught at the high school level for only a few years, but Earth-science topics have been included in the geography syllabus for many years. Our efforts to establish Earth-science as an independent discipline are by no means only through geography. On the contrary, since Earth-science topics are also learned by geography students who are generally non-science-oriented, Earth-science is the only scientific discipline in schools which serves as a bridge to the non-science-oriented population. In relation to other scientific disciplines this is one of our advantages, which needs to be capitalised upon. In our case, each item of curriculum material which was developed for the Earth-science students and teachers was simultaneously modified for the geography curriculum as well.

The following is a brief description of the Earth-science curriculum and its contribution to other disciplines.

8 THE EARTH-SCIENCE CURRICULUM OF THE ISRAELI HIGH SCHOOL

The Earth-science curriculum for the high school includes two levels (Fig. 3): an introductory Earth-science unit as a minor topic (3 matriculation credit units) and an advanced programme – Earth-science for majors (5 matriculation credit units). The curriculum is modular, and the introductory course is a prerequisite for the advanced course.

The introductory programme

This programme, comprising 270 teaching hours, serves as an introduction to geology. It emphasises the geological systems of our planet, and also their interrelationships with the other components of the natural system and society. The teaching scheme is based on a gradual transition from the concrete to the abstract. Practical work in the laboratory and the field makes up the concrete parts of the learning. Fieldwork is an integral and essential component of the programme and it includes three one-day field trips and an additional three-day field camp. The one-day field trips are focused on the learning of basic concepts whilst the field camp is

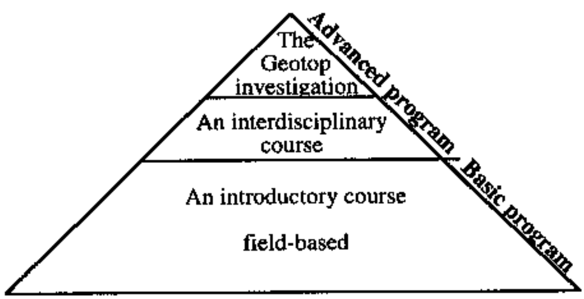

Figure 3. The structure of the high school Earth-science curriculum.

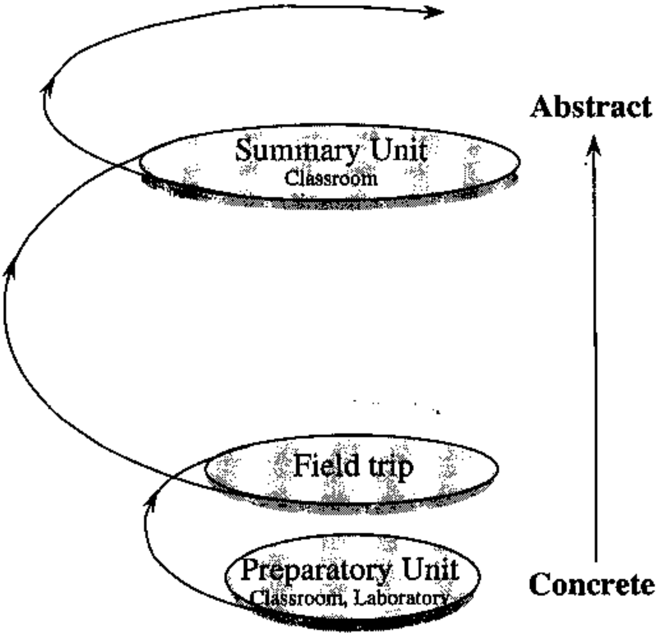

Figure 4. A spiral model for the integration of the field trip within the curriculum.

predominantly aimed at the development of field investigation skills. Each of the field trips is integrated with the curriculum in a learning spiral (Fig. 4), which ranges from the concrete to the abstract. This spiral includes the following three parts (Orion 1993):

a) *The preparatory unit.* This relatively short unit is based on concrete learning activities in preparation for the field trip. The purpose of this unit is to reduce the three novelty factors relating to the field trip as a learning environment: the cognitive, the geographical and the psychological. The cognitive novelty can be directly reduced by using several concrete activities: the identification of soils, hand specimens of rocks, minerals and fossils; observing the micro-structure of rocks through a microscope; conducting a simple laboratory practical to illustrate various geological processes. The geographic and psychological novelty factors can be reduced in the classroom, by providing detailed information about the event (e.g. its purposes, learning methods, the number of learning stations, the duration of the trip, the expected weather conditions) and by using slides and films and by working with maps.

b) *The field trip.* The field trip is the central unit of the programme and, together with the preparatory unit, serves as a concrete bridge towards more abstract learning levels. Three one-day field trips were developed in the southern part of Israel (Orion et. al. 1986) and another three in the central part of country. The last three field trips transect Israel from the Mediterranean Sea to the Dead Sea (Orion 1989a, b). The curriculum package that was developed for each field trip includes the following items:

– A preparatory unit, including a workshop and laboratory activities in order to prepare students for the field trip.

– A field-trip booklet which directs each student's work at each of the learning stations.

– A series of coloured mini-posters that help the teacher to explain some of the observations which can be made in many locations.

– A teacher's guide.

c) *The summary unit.* This unit includes more difficult parts of the curriculum. It includes complex concepts which demand a higher level of abstract thinking and a higher concentration level from the students. It involves the consideration of time and space dimensions, as well as the physical and chemical processes which take place out of sight deep in the Earth's crust.

An intensive evaluation study which followed the implementation phase revealed that students who participated in these field trips following this model, achieved a high level of learning in the field through active interaction with the environment. They gained a significant amount of knowledge and understanding and developed positive attitudes following their experience which they described as a very enjoyable learning event (Orion & Hofstein 1991).

In addition to the materials which were developed for the field and the laboratory, the curriculum package includes an Earth-materials kit, geogames, computer-based learning materials, slides and video films.

The final matriculation examination of the introductory programme is based on three equal assessment components which are assessed by an external examiner: a) an oral examination in the field to evaluate students' investigative skills and interpretative abilities; b) the submission of a portfolio including students' field and laboratory reports, and an Earth materials collection which they assembled and labelled during the fieldwork, and c) a standardised national written examination.

The advanced programme

Only students who were successful in the introductory course can take the advanced programme which includes two units:

a) *The interdisciplinary unit.* This course emphasises the interdisciplinary nature of the Earth-sciences. In this unit teachers are encouraged to teach an interdisciplinary topic such as geophysics, geochemistry, geo-biology, geo-environment, geo-economy or even multi-disciplinary courses which attempt to look at planet Earth as an integrated system.

b) *The 'Geotop' investigation project.* This project is conducted as the fifth and last matriculation unit. Its name – 'Geotop' – refers to the top unit of high school geoscience studies. 'Geotop' is a mini-research project which takes place in the field or laboratory or both. The educational objectives of this programme are:

1. The implementation of knowledge and skills learned in the classroom, laboratory and field.
2. The development of individual learning skills.
3. Learning and practising scientific investigation processes. These include indentification of research questions, observing, collecting and analysing data and writing a scientific report.
4. Enhancement of students' intellectual curiosity.
5. The development of a positive attitude to Earth-science as a scientific discipline.

In order to achieve these objectives the 'Geotop' project is based on the following learning strategies:

Individual learning. The project reflects students' individual interests and abilities to work independently.

Hands on experience. The project includes the investigation of real geological phenomena in the natural environment.

Expert supervision. Each project is supervised by a postgraduate geological researcher who is carefully selected for his/her scientific curiosity, enthusiasm and willingness to contribute to the education of young students.

Co-operative learning. Students conduct their investigations in pairs. They are encouraged to discuss their results, but the data analysis and the preparation of the final report are conducted individually.

9 STRENGTHENING THE EARTH-SCIENCE COMPONENT OF THE GEOGRAPHY CURRICULUM

In order to strengthen Earth-science teaching in the geography curriculum, two sets of curriculum strategies relating to the geological field trips and the 'Geotop' were modified so as to suit the abilities and needs of the geography teachers and students.

The geological field trips. More than 1000 students have participated in at least one geological field trip each year for the last six years. The curriculum materials which were developed for each field trip and the provision of an in-service education and training course enabled some geography teachers to teach on the field trips themselves, whilst others preferred to rely on an Earth-science teacher for assistance.

The 'Geotop' investigation project. In parallel with the development of the project for geology majors, a similar version was modified for high school geography students. The 'Geotop' project was introduced into the geography curriculum as a vehicle to enhance and strengthen geology teaching within the geography curriculum, as well as to give those students, many of whom had suffered failure and frustration in their former science studies, another (and maybe last) opportunity to experience science in more positive light.

The 'Geotop' organisation for the non-science students consists of four components: the team of programme organisers, the geography students, the geography teachers and the field investigation project leaders (mainly postgraduate geology students).

In the last four years, about 100 students each year have successfully participated in the project. Most of the projects involve field investigations which are located at about 15 locations scattered all over Israel. Each field investigation project leader supervises a group of 5-10 students drawn from different schools. The project generally involves the participants attending 3 meetings as follows: The first meeting (6 hrs) is dedicated to gaining basic knowledge, understanding and skills concerning the problem under investigation. Secondly and later the students go out for a 3-day field camp. In the last meeting (6 hrs), the investigation leader assists the students in summarising their results and directs them how to write a scientific report. The students have to write their scientific report within one month and at this stage they have the assistance of their own geography teacher. The student reports are assessed by an external examiner who later tests the students' understanding through oral discussion. The students' final grade is a combination of the scores of the external examiner, the investigation leader and the geography teacher.

A study which has evaluated the project over several years (Orion 1994) constantly reveals that student achievement is very high and much higher than their normal geography scores. In 1992 an attitude questionnaire was posted to the home addresses of all the students who participated in the programme during the last five years and the responses have been recently tabulated.

All the different sources of the evaluation research combine together to give a very encouraging picture of the 'Geotop' programme. These findings indicate that the students hold positive attitudes towards the effective and cognitive domains of the programme. They strongly agreed that their learning performance had improved. They were very interested in the project and had enjoyed it, especially compared with their other studies in high school. Most of the students use the geological knowledge and the thinking tools they have acquired in their daily life, thus greatly enhancing their understanding of their natural environment. For some of them, the experience influenced their current and future choices of academic study. An additional very important finding was that after a few years experience, all the geography teachers agreed that they had gained significant geological knowledge and understanding; they all felt much more confident about assisting their students and evaluating their reports.

10 CURRENT EDUCATIONAL EFFORTS AT THE HIGH SCHOOL LEVEL

In addition to our group's efforts to strengthen what has already been achieved, it is trying to expand to those areas where Earth-science education holds an educational advantage in relation to other scientific disciplines.

The development of interdisciplinary programmes. Three such programmes: environmental geology, geochemistry and geophysics are in the early stages of development. Their planning has been achieved through collaboration of the Earth-science co-ordinator with the co-ordinators of these disciplines in the Ministry of Education. These developments are designed to serve the students of all the different scientific disciplines. The development of these multi-disciplinary programmes will be carried out by graduate students as part of their thesis research and will be based on the research – development – implementation strategy previously described.

Recently a committee of the Ministry of Education has been appointed to plan a new and integrated science curriculum ('Science for all') for non-science-oriented students. The group suggested that Earth-science should form the backbone of such a curriculum. However, the group is still at the stage of waging a political struggle even to include Earth-science as an integral part of this curriculum.

Special visualisation. Spatial abilities or skills are required in many important fields such as natural sciences, geometry, engineering and architecture. However, a large part of the population displays considerable difficulties in dealing with spatial tasks. This cognitive ability has been extensively investigated for many years, mainly in relation to mathematics education. Although geology students are required to make intensive use of this cognitive ability, mainly in crystallography, structural geology and geological mapping, many of them also display difficulties whilst solving spatial tasks. Very little research has been carried out previously in this area in relation to Earth-science education (but see Chadwick 1977).

In a study of high school and university students, using two standard spatial visualisation tests, a significant improvement was found in the students' spatial visualisation ability following an introductory course in geology (Orion et. al. 1994).

In order to improve the achievements of high school students who were learning concepts and acquiring spatial skills in structural geology, a computer-based learning unit has been developed. The development was preceded by pre-development research based on interviews and open-ended questionnaires to explore student thinking processes in solving spatial tasks in structural geology. The computer-based learning unit is being developed on the basis of the findings of this study and is to be followed by formative and summative evaluation (Kali 1994).

Retrospective thinking. The teaching of the Earth-sciences contributes to the students' cognitive development in a unique way related to the ability to think retrospectively. Generally, whilst studying science, students are frequently asked to 'predict' the behaviour of a chemical compound, the velocity of a machine, the period over which acceleration takes place etc. While studying Earth-science, the students are asked frequently to begin with the results of former behaviours and processes and then, like a detective, to look for clues which will allow them to reconstruct the processes that caused the phenomena and to order events chronologically. Since retrospective thinking is dominant in geological studies and almost no research has been conducted in this field, cognitive research in this area is very desirable. The main objective of such research is to gain more insight into these thinking patterns, and to translate what we learn into teaching and learning strategies. A pilot study has already started.

11 AN EARTH-SCIENCE PROGRAMME FOR THE KINDERGARTEN

The provision of a programme of study at this level is preceding one for the Junior-high and the primary levels, since the group has found that principals and teachers at this level are much more open to innovation than their counterparts at the higher levels. At the kindergarten level (ages 4-6) there is only minimal emphasis on covering the syllabus and gaining high academic achievement and the teachers can still pursue the education of each child *per se*. The development of the Earth-science programme for the kindergarten came as response to the decision of the Ministry of Education to specify a science unit for the kindergarten curriculum. The main objective of the programme is to develop simple scientific skills through hands-on activities with concrete natural Earth materials (like rocks and soils). This is to be associated with the development of an awareness of the importance of these materials in our daily lives and, hopefully, positive attitudes to the environment.

Through the investigation of rocks, children develop basic skills such as observation, classification and identification. Later, through simple experiments, children become involved in more advanced skills such as measuring, presenting data, inferring, questioning and controlling variables. During their observations the children work with hammers and very dilute hydrochloric acid (6%). During these activities they use goggles, gloves and aprons and it is amazing to see how quickly they developed a strong concern for safety. The programme deals with six common rocks: sandstone, clay, rock salt, limestone, flint and gypsum rock. Whilst exploring the nature of each of these rocks, the children work in small groups in four activity centres: the investigation corner, the experimentation corner, the craft corner and the story corner. Following the investigation of the rocks the children go outdoors to locate these rocks in their daily surroundings in both the natural and the man-made environment.

The *investigatory* activities include exploring the characteristics of the rock through hands-on tests and by observation under a magnifying glass. The experimentation includes simple controlled experiments, for example putting two identical rock specimens into two containers, one filled with water and the other empty. Later on they evaporate the water. The children have to observe the processes which take place and 'write' the results which they observe on a special sheet. Since they do not yet know how to write, a written sign language was developed which allowed them to draw their results. This simple experiment exemplifies the concepts of a reversible and an irreversible process.

The *craft corner* includes a variety of activities such as preparing pictures with sand, moulding, sculpturing, making a mosaic and preparing and drawing with paints made from natural raw materials.

In the *story corner* the teacher tells folklore stories about the origin of the rocks. For example, one activity utilizes flint and opens the door for learning about the use of this rock by prehistoric societies and from this topic the children move on to deal with the importance of rocks in our industrial civilization. It is important to emphasise that the programme involves only rocks which are common in Israel and in each region the teachers give special emphasis to the rocks which are most common in their local region.

In 1994 a group of about 60 kindergarten teachers participated in an experimental in-service implementation course. The course included 8 one-day meetings. The development and implementation of this programme was jointly conducted with Tamar Liviatan who is an experienced kindergarten teacher. It was based on Prof. Mazor's original programme – 'Our friends the rocks'.

None of the teachers had any experience in teaching the Earth-sciences, and most of them had minimal previous knowledge of this subject. As a result, they displayed, in the beginning, considerable apprehension and diffidence about their ability to deal with these topics. Their attitudes were dramatically changed after a short time, as a result of the basic knowledge and understanding which they acquired throughout, the curriculum materials which were provided and the particular format of the INSET. In each of the INSET meetings, the teachers were provided with materials and information for managing a series of sequenced pupil-centred activities prior to the next INSET meeting. Their main encouragement came from the children's responses to the programme. Very soon the teachers understood that the value of the programme is not restricted to teaching geology but is about the development of a wide variety of skills, basic knowledge and values about our environment generally.

The subsequent evaluation provided very encouraging findings. The teachers displayed a great deal of enthusiasm and were grateful for the programme. They maintained that the programme's outcomes exceeded their expectations. They stressed the following outcomes which went farther than just Earth-science or science education:

Language enrichment. The children learned and internalised many new words.

Socialisation. The activities, which were mainly conducted in small groups, led to very positive social interactions amongst the children.

Enjoyment. The children enjoyed the programme very much. Some of this was derived from the freedom and the legitimacy of breaking and crumbling natural materials and getting dirty.

Inter-relation with the arts. Many teachers connected the craft activities using earth materials to 'similar' works of great artists such as Leonardo Da-Vinci, Henry Moore and famous Israeli artists. Some teachers even used the rocks in music lessons and the children learned both to listen and to produce different tunes from different rocks.

Parental involvement. All the teachers emphasised the positive parental involvement in the programme, which was much higher than usual. Parents donated their own specimens and books for consideration and use by the class. Some of them told the teachers that they were asked by their children to go out together to look for hand specimens in the natural environment in order to stock the rock display.

Following these findings the Ministry of Education decided to expand the programme to a national basis.

12 EARTH-SCIENCE EDUCATION IN PRIMARY AND JUNIOR HIGH SCHOOLS

The junior high and the primary school levels are our group's favoured target, but they are more difficult to enter. The main obstacle relates to the same vicious circle which arises from including Earth-science education in the geography curriculum and not in the science curriculum. The breaking of this circle should involve firstly, political efforts to include Earth-science in the science curriculum, and secondly educating geography teachers in Earth-science and providing them with suitable curriculum materials.

The working hypothesis of our group is that the 'three-dimensional stress field' (consisting of the political pressure, the downward forces exerted by the high school level and the upward forces provided by the kindergarten level) will allow an increase of Earth-science education in these grades to an appropriate degree. A positive sign in this direction can already be seen, as a new Science-Technology-Society (STS) curriculum has been developed for the primary level and this includes several Earth-science contributions. In addition a new and integrated science curriculum for junior-high schools is now in its first stages of planning and our group is trying to ensure that the Earth-science component will not be neglected. In the meantime, the group has already begun to prepare curriculum materials for the primary levels. Here again, we started at the 'concrete' end of the Earth-science spectrum. The development of 'The EArth Materials (TEAM) Kit of Israel' (displayed at the conference) has been completed and is available for teachers and students. The kit includes specimens of common rocks, soils and minerals (Table 2), identification tools and identification cards.

Table 2. The specimens which are included in the Israeli Earth materials kit.

Rocks			Minerals	Soils
Sedimentary	Igneous	Metamorphic		
Sandstone	Granite	Schist	Calcite	Terra Rossa
Marl	Basalt	Gneiss	Gypsum	Rendsina
Clay			Halite	Loam
Limestone			Malachite	Loess
Chalk			Barite	Basaltic soil
Chert			Quartz	Sandy soil
Phosphorite			Feldspar	
Asphalt			Biotite	
Gypsum			Garnet	
Rock-Salt				
Dolostone				

The purposes of the kit are:

– To develop investigational scientific skills.

– To acquaint pupils with common natural materials of the Earth's crust and particularly those from Israel.

– To facilitate the learning of basic geological concepts.

– To serve as a concrete introduction to many Earth-science topics which are taught in biology, chemistry, Earth-science and geography curricula.

A set of geological games and a Prolog 'expert-system' computer software unit, both aimed at the investigation and identification of rocks, soils and minerals, were also developed so as to complement the hands-on activities. The geogames were developed jointly with Hanan Ginat who is both an Earth-science teacher and a practising geologist (Orion & Ginat 1991). As the names suggest, the geogames are an educational modification of popular card games (Rummy-rocks, Memory geogame and Rock-quartets). Their purpose is the rehearsing and memorizing of rock characteristics in an enjoyable and effective way.

13 SUMMARY AND CONCLUSIONS

The process of introducing the Earth-science (largely geology so far) into Israeli curricula is still in its first stages. However, we can already suggest from the basis of our group's experiences, that an effective way to introduce a new curriculum should include simultaneous efforts in many facets of the educational system: in the formal and the informal parts and amongst the policy decision makers in the Ministry of Education and the academic establishment. In our case, starting at the top with the high school and then seeping downwards to the lower levels has proved to be the most effective way to enter the formal educational system. Three factors have had a crucial effect on our success so far:

a) Intensive activity in the informal educational system, which anticipated our efforts in the formal system, creating a supportive public opinion for Earth-sciences at all levels of the formal educational system;

b) The active support of all the branches of the geological community; and

c) A philosophy of working within a research – curriculum development – INSET implementation triangle.

The last factor proved to be the most effective entrance card to the educational system. It enabled our group to convince teachers and principals that the Earth-sciences can be successfully taught and learned at all levels of the educational system.

It is very important to mention that the low world-wide profile of Earth-science education has a negative influence on the ability of our group and other groups in and other countries in introducing the geosciences into schools. An outcome of the Israeli experience is to suggest that a world-wide network of Earth-science educators and academic and industrial leaders should be established. This movement should ideally be presented to the international public by a scientist, preferably Earth-science, of a world-wide reputation (Carl Sagan or Stephen Gould, for example) or a distinguished media figure (Sir David Attenborough, for example), who could influence other well-known scientists, governments and Earth materials-suppliers to contribute to Earth-science education in both schools and the informal education system.

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