A Short-term and Long-term Study of a Science Investigation Project in Geology, Used by Non-science High School Students

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ABSTRACT *A geological investigation project named 'Geotop' was introduced into the high school geography curriculum of Israel as a vehicle to enhance geology and science education within this non-science population. The evaluation research which followed the project from 1987 included assessment of the students' achievements and attitudes towards the project. In 1992 an attitude questionnaire was posted to the home addresses of students who participated in the programme during its 5 years of implementation. The findings indicate that the students hold high positive attitudes in the affective and cognitive domains of the programme. They view the programme as a very meaningful and enjoyable learning experience. Most of the students use the geological knowledge and the thinking tools they acquired in their daily life, thus enhancing their understanding of their natural environment. For some of them this experience influenced their current and future choices of academic subjects.*

Introduction

Science projects involving individual investigation tasks are quite well-known learning activities for high school students, mainly for gifted students but also for regular science classes (Tytler, 1992). A science project for biology high school Israeli students named 'Biotope' (regarding an ecological niche) has been run since 1977 (Bakshi & Lazarowitz, 1982). Following the biology project experience, a geology science project was developed as a compulsory part of the new Israeli high school earth science curriculum (Orion, 1989). The students conduct the projects as their fifth and last matriculation unit. 'Geotop' is defined as a mini-research project, which takes place in the field or laboratory or both. The educational objectives of the programme are:

1. The application of knowledge and skills learned in the classroom, laboratory and field.
2. Learning and exercising scientific investigation processes, for example, identifying a research question, observation and data collection, data analysis and writing a scientific report.
3. The development of individual learning skills.
4. Enhancing students' intellectual curiosity.

5. The development of a positive attitude to geology 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 ability to work independently;
- *hands on experience:* the project includes investigation of real geological phenomena in their natural environment;
- *expert supervision:* each project is supervised by a postgraduate geological researcher who is characterised by scientific curiosity and enthusiasm and willingness to contribute to the education of young students; and
- *co-operative learning:* students conduct their investigations in pairs. They are encouraged to discuss their results but they have to analyse the data and write their reports individually.

In parallel to the development of the geological project for earth science majors, a similar version was modified for high school geography students. It is this latter version which is described hereafter. The geography curriculum in Israel includes a small portion of geology, but both the students and the teachers have non-science backgrounds. The 'Geotop' project was introduced into the geography curriculum as a vehicle to enhance and strengthen the 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 a more positive light.

Conducting science projects among the student population as defined above might sound a rather ambitious task. Nevertheless, it can be done and it has been tried out in Israel since 1988. This article outlines the scheme of this project and its short-term and long-term effects on students and teachers.

The Purposes of the Study

The purposes of the study presented here were:

(a) to carry out formative and summative evaluation of the implementation of the programme;
(b) to develop assessment tools and criteria to evaluate students' performance and achievements;
(c) to discover the short-term effects of the programme on students and teachers;
(d) to assess the long-term effects of the programme on students and teachers; and
(e) to compare gender achievements and attitudes to the individual field investigation project.

A Description of the Geology Science Project (Geotop) for Non-science Geography Majors

Characteristics

The 'Geotop' system for the non-science students consists of four components: the programme organisers' team, the geography students, geography teachers and the field investigation project leaders.

The programme organisers' team, which consists of a few geological educators, has four main functions:

- the development of the 'Geotop' programme, i.e. its philosophy, operational system and assessment methods;
- the training of the field leaders in development and the implementation of their field investigation projects;
- the training of the geography teachers to analyse field data, how to write a scientific report and how to assess students' reports; and
- the conducting of the formative and summative evaluation of the whole project.

The field investigation leaders are mainly postgraduate geology students. They supervise the students during all stages of the project: field investigation, data analysis and the writing of the scientific report. Their assessment of students' performance is included in the student's final score.

The geography teachers are involved in the students' selection, assisting in the writing stage and assessing their reports. The students are eleventh or twelfth grade (age 16–17) geography majors who choose to participate in the project as the fifth unit of their geography matriculation programme. This programme is not compulsory and they can leave it whenever they like and take another course instead.

Since the geography students enter the 'Geotop' project with limited geological knowledge and investigative skills, it is unreasonable to expect them to follow the whole programme and process of the scientific research. The characteristics of this science project for non-science students are as follows:

1. An individual student investigation project of a geological phenomenon, closely supervised by a geologist (generally a postgraduate student).
2. The student chooses his/her topic of investigation from a detailed guide book which he/she receives before entering the project.
3. The student assignments include field observations, data collection, data presentation, data analysis and drawing conclusions based on the field observations.
4. The students have no prior information about expected findings and conclusions.
5. The project is mainly based on field-work and a modest degree of reading of the geological literature.
6. The time span of the field investigation is about five 1 day meetings. The student should submit his/her final report about 6 weeks after finishing the field investigation.
7. The student's final report should include the research description, data presentation, discussion and conclusions.
8. The student's final score is based on the assessment of three components: the student's performance during the individual investigation, the quality of the final report, and his/her understanding as expressed through an oral examination.

How 'Geotop' is Organised and Administered

The cycle of operational activities of the programme organisers' team covers the whole year. At the beginning of each school year, a detailed guide book entitled 'The Geotop Guide' is published and sent to all geography teachers who teach geology as a part of their curriculum. 'The Geotop Guide' details the philosophical and practical issues concerning the programme and the investigation projects offered. About 20 different projects guided by about 10 postgraduate geology researchers are offered each year. Four examples of these investigation projects are presented in Table I.

During the first month of the year the teachers present the programme to their students and encourage them to read 'The Geotop' Guide. The students who decide to participate have to rank three favourite projects. The teachers collect their students' selections and send them to the programme organisers. The teachers are encouraged not to be too critical in rejecting students who, according to their judgement, might not be able to cope with such independent learning. Instead, they are asked to rank their students on the registration form according to their capability. The ranking procedure enables the programme organisers to reject the lower-ranked students in cases of over-registration. This procedure also motivates students to prove that their lower ranking was wrong. The programme organisers sort out the students' lists and send each field leader a lists of their students' names, addresses, telephone numbers and their teachers' details.

The field leaders have to complete the field investigation meetings not later than 2 months after receiving their list of students, and the students have to submit their final report within 6 weeks after completing the field-work. In this stage of the programme the programme organisers send to each teacher a list of potential external examiners whom he/she could contact to co-ordinate the date of the examination. Since most of the examiners are actually the field leaders of investigation projects, teachers can contact only those examiners who had not guided any of their students. The examiner receives the students' final reports at least a week before the oral examination. The examiners are trained to spot misconceptions which can be related to the students' limited geological background or due to inadequate explanation by the field leader. The oral examination is conducted as an open discussion about their work. The examiners are asked to create a pleasant, supportive atmosphere and to test students' understanding and to correct their misconceptions through friendly conversation rather than inquiry.

This system functions on a minimal budget. The Ministry of Education subsidises a half-time post on an annual basis and the examiners' payment and that of the field leaders is paid directly by the students or their schools.

Design and General Procedure

The assessment and evaluation of the project was based on four main approaches:

(a) The collection of qualitative data about the attitudes towards the project and suggestions for its improvement from all the programme participants, i.e. students, geography teachers and field investigation leaders.
(b) The assessment of the students' achievements—process and knowledge.
(c) An attitude questionnaire which was mailed with a stamped addressed envelope to the home addresses of students who participated in the programme over 5 years (1988–1992). A similar questionnaire was also sent to the geography teachers and the investigation leaders who were asked to assess their students' attitudes.
(d) The recording of the percentage of students who failed to accomplish their project each year and the investigation of the reasons for their failure.

TABLE I. Four examples of field investigations projects ('Geotop') for non-science students

Subject	Research question	Students' investigation tasks	Meetings	Place
1. Volcanic rocks	Reconstruction of the stages in the development of a paleo-volcano	Rock identification Geological mapping Drawing of geological cross-sections Determining relative ages according to the field relations of the rock units	Five 1 day field/ laboratory meetings	Mt Carmel in the northern part of Israel
2. Faults	Reconstruction of the paleo-stress field system of faults structures	Rock identification The making of columnar sections Geological mapping Identification of fault structures Determining relative ages according to the field relations of the rock units	A study camp of 3 days and two 1 day meetings	Macktesh-Ramon. The Negev desert of southern Israel
3. Environmental geology	The mode of origin and mining techniques for copper and manganese, at the present day and in the ancient Egyptian epoch	Rock identification The making of columnar sections The drawing of geological cross-sections The location of ore units Determining relative ages according to the field relations of the rock units The investigation of mining techniques	A study camp of 3 days and two 1 day meetings	Eilat-Gulf of Aqaba in the desert of southern Israel
4. Coastal geomorphology	The slope and composition and seasonal changes, of the beach and their relation to the erosion of the cliff surface at the back of the beach	Constructing topographic cross-section Analysis of grain-size distribution Comparing the data which has been collected in different seasons	Five 1 day field/ laboratory meetings	Jaffa beach, coastal plain of central Israel

Method

Sample

The study included 335 eleventh and twelfth grade (age 16–17) geography major students who completed their investigation project from 1988 to 1992 (Table II). The study population came from 15 different high schools, taught by 18 different geography teachers and guided by 13 different investigation field leaders. Half of the geography teachers have participated in the programme since it started and the others joined it later. Five of the field leaders dropped out of the programme after 1 year and the others had participated in it for more than 3 years.

In 1992 an attitude questionnaire was posted to the home addresses of 185 students who participated in the programme during 1988–91 (75% of this population). While conducting this research, the 1988–90 students had already graduated from their high school (1–4 years) and most of the 1991 students were in their last year of high school. A total of 81 questionnaires (44% of the posted population and 33% of the whole population) were returned. This return percentage is reasonable, especially in relation to the Israeli situation where adolescents serve for several years in the army. The same questionnaire was also administered to the 1992 class by their geography teachers after they finished their oral examinations: as a result 70 student (78%) of this population answered the questionnaire. The gender distribution of the study population as a whole is symmetric although there are asymmetric distributions in some of the years (Table II).

Formative Evaluation

The implementation of the programme was followed each year by a naturalistic evaluation study which collected data about many aspects of the programme, such as student selection criteria, registration procedures, the quality of each of the investigation projects and its field leader, the geography teachers' contribution and the assessment system. The evaluation follows the programme over the whole year as follows:

1. During the field investigation stage, the programme organisers are regularly informed through formal and informal interviews and conversations with the field leaders, teachers and students. At the end of the examination stage, individuals and groups of students are interviewed through a random selection procedure.
2. Following the oral examinations and the final reports, each examiner indicates misconceptions related to a specific project scheme or style of guidance. At the end of the school year, the programme organisers conduct a one-day meeting with all the field leaders and geography teachers who participated in the programme. Each participant summarises the programme from his/her angle and indicates the difficulties and problems as well as positive features which emerged during the year. All these issues are discussed and ways for improvement are suggested.
3. During the summer holiday the evaluation findings of the past year are summarised and the modifications deemed appropriate are published in the next 'Geotop Guide'. . . . and another cycle begins.

The Assessment Tools

The students' achievement scores are determined (as for every matriculation score in Israel) equally by external and internal scores. The 'Geotop' external score consists

TABLE II. The number of non-science participants in the 'Geotop' project during 1988 92 and the study population addressed by the questionnaires

Year	Number of participants	Number of posted questionnaires	Number of returned questionnaires			Returns from posted population (%)	Returns from whole population (%)
			Total	Males (%)	Females (%)		
1988	40	30	11	4 (35)	7 (65)	36	28
1989	55	27	16	8 (50)	8 (50)	60	30
1990	60	50	24	13 (54)	11 (46)	48	40
1991	85	75	30	21 (70)	9 (30)	40	35
1992	90	90	70	29 (42)	41 (58)	78	78
Total	330	272	151			56	46

equally of the students' assessed final report and oral examination. The internal score is equally determined by the field leaders' assessment of students' performance and the geography teachers' assessment of the students' final reports.

To minimise subjective assessment, the following criteria were developed (a detailed description of the criteria is presented in Table III):

(a) *The criteria for assessing students' final reports are as follows:* structure; quality; extent and complexity; form and style; independence.
(b) *The criteria for assessing the oral examination are as follows:* proficiency; presentation; understanding; logical thinking; general knowledge and understanding; involvement.
(c) *The criteria for the assessment of the field investigation are as follows:* level of independency; problem-solving ability; interest shown by the student; motivation and persistence; the quality of the field investigation; the quality of the student's data presentation and analysis.

The validity of the assessment criteria was tested by two methods: (a) expert judgement by five scientists, five science educators, eight geography teachers and seven field investigation leaders; and (b) testing the same student by two different examiners and comparing their scores. The test was conducted in 15 different cases and an average difference of scores of 7% over the three sets of criteria was found between the different examiners.

Attitude Instrument

The long-term study is based on a questionnaire which was developed for this study and has two parts: a 'closed' questionnaire including 18 Likert-type and two yes/no questions and an 'open' part where the students were asked to write down their summary of the programme and their suggestions for improvements. The first part asked the students for their views on various domains related to the programme such as, affective, cognitive, general contribution to learning, teaching, values, usefulness (yes/no questions) and a recommendation to a friend who might like to participate in the 'Geotop' project. For 17 items on the questionnaire, respondents used a 5-point scale: very high, high, moderate, low and very low. One item (Recommendation) used only a 3-point scale. In the introduction to the instrument the students were told that the purpose of this study is to improve the programme and they were asked to be constructively critical and to propose suggestions for improvement.

The instrument was validated through the expert judgement of 10 science educators and teachers. Since it was not developed as a scaled questionnaire, each question was analysed separately. Data analysis includes frequency distribution, means and standard deviations, *t*-test and analysis of variance (ANOVA) statistics. A similar attitude questionnaire was developed for the teachers and the field leaders, who were asked to estimate their students' views about the programme. The questions in that questionnaire were modified as: 'The enjoyment your students gained from their project was . . .' etc. The teachers' and the field leaders' questionnaires included 14 and 11 items respectively.

Results

Percentage of Projects Completed

The percentage of students who failed to hand in their projects may serve as an

TABLE III. The three components of the final score, their criteria and percentage of components

Components of final score	Criteria	Description of the criteria	Each component (%)
(a) Final report	Structure	The report should include a title, abstract, description of the purposes, methods and schedule of the study; data presentation through appropriate presentation techniques such as maps, cross-sections, tables, graphs, drawings and pictures; discussion and conclusions; brief summary; references and properly presented bibliography.	25
	Quality	The purpose, methods and schedule of the study are to be clearly presented, the data are to be properly collected, analysed and clearly presented; there is a clear relation between the research objectives and the investigation methods; there needs to be a clear and logical relation between the findings and the conclusions; there needs to be a distinction between the essential and the ancillary.	30
	Extent and complexity	The subject should be neither too broad nor too narrow; the extent of profundity, the extent of intellectual efforts which have been made such as the complexity of the investigation project, the analysis of data, the literature review, extent of time, the extent of physical efforts made.	20
	Form and style	The report should be well presented, having a clear and flowing style, and be easy to follow, e.g. the chapters are to be clearly segmented, the pages, tables and figures are to be numbered; there should be a proper list of contents.	15
	Self-reliance	Individual thinking and originality should show through the data analyses; the extent of self-reliance in conducting the investigation should be considered.	10
(b) Oral examination	Proficiency	The student's familiarity with his or her work and his or her ability to give detailed description of its content e.g. the field investigation methods, findings and data analysis methods.	20
	Presentation	The student's ability to present his or her work in a focused and clear way.	20
	Understanding	The extent to which the student really understands the thinking behind his or her findings and conclusion. Did s/he just write down what s/he heard from the field leader or teacher?	20
	Logical thinking	The extent to which the student can use his or her findings to solve a similar problem from another setting which is presented to him or her during the examination.	20
	General knowledge and understanding	The student's ability to talk about general geological principles which are related to this piece of work.	10
	Involvement	This section tests the student's individual contribution to his or her work, his or her personal involvement and enthusiasm.	10
(c) Field leaders'	Level of *self-reliance* shown by the student during the field investigation. The students' *individual thinking* or problem-solving ability. Level of *interest* shown by the student during the project. Level of *motivation and persistence* shown by the student. The quality of the student's *field investigation*. The quality of the student's *data presentation and analysis*.		The total score is weighted equally upon the six criteria.

TABLE IV. The 'Geotop' failure percentage over the years 1988 92

Year	Number of beginners	Number of finishers	Failure (%)
1988	83	40	52
1989	105	55	48
1990	75	60	18
1991	96	85	12
1992	95	90	5
Total	454	330	27

indication of the suitability of the programme for the non-science population. Table IV shows a very high failure percentage (50%) during the two first years and then a sharp decrease down to 18% in the third year moving gradually to 5% in the fifth year of the implementation of the programme.

It was found that reasons for the students' decisions to drop the programme were related neither to their school achievements nor to the teachers' view of their abilities. Students with a reputation for moderate or low achievement successfully accomplished their projects (Table V) and in other cases high achievers decided to leave. Interviews with students and teachers over the years revealed three main reasons for students leaving the programme:

- *The insufficient information*, or even wrong information, students received from their teachers about the programme. '... We were told that it was going to be fun and students usually received high scores, ... I did not realise how much work and time we would have to give ... so, after the first meeting I decided to quit ...'.
- *Matters related to particular field leaders' quality of guidance.* Students made two different kinds of complaints about some field leaders' behaviour: (a) relating to their carrying out of responsibilities: '... he used to change the dates of the meeting ... and sometimes he forgot to inform me, ... and so the next time I decided not to come ...'; and (b) relating to the suggestion that the field leader was too demanding: '... He asked us to do everything ourselves and he was not helpful at all. ... what did he think, that we are his university students? ... I heard from my classmates that their field leaders are so helpful and dedicated ... so I decided to quit ...'.
- *Self-reliance problems.* Some students had difficulties in managing such independent experience. Since some of the students were highly regarded by their teachers for their abilities to summarise and memorise what was taught in the classroom, it may be suggested that these abilities do not guarantee self-reliance.

The significant decrease in failure over the years is probably a result of the improvements which took place following the evaluation study and the experience acquired by the field leaders and the teachers.

Students' Achievements

Table V presents the mean scores of the 'Geotop' of 1992 geography students together with their general geography grades which were given, at the end of the year, by their geography teachers. The results are very similar to results of previous years since 1988: an average score of 90 on a 100-point scale. Since the scores are compiled from different

TABLE V. The distribution of the mean scores of the 'Geotop' and geography final scores of the 1992 non-science students

		Geography students' 'Geotop' scores				Students' internal geography scores			
School	*n*	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
1	11	93·5	3·5	88	98	73·6	7·1	65	85
2	10	91·3	5·8	82	100	71·3	9·8	51	85
3	7	90·1	3·2	86	94	78·6	3·8	75	85
4	5	90·8	5·9	83	98	78·0	11·6	64	90
5	5	95·6	3·6	92	100	76·4	4·6	71	82
6	2	92·5	0·7	92	93	70·0	1·4	69	71
7	9	93·1	6·1	80	99	74·5	13·3	55	99
8	18	90·7	5·3	84	100	76·1	9·6	60	95
9	19	93·2	4·3	82	100	89·5	5·5	80	100
10	4	93·2	5·7	85	98	70·2	4·1	65	75
Total	90	92·3	4·9	80	100	77·9	10·3	51	100

SD = standard deviation.

evaluators and different sources, it might be concluded that these scores really do reflect the students' performances.

The significant difference between the students' 'Geotop' and geography internal scores is also replicated constantly over the years. One might suggest that this difference is mainly a matter of different test procedure. It is suggested, however, that while a student who has a reputation as a low achiever produces high quality work and a modest student achieves excellent results, it is more than just a different way of testing. This may also imply that the individual investigation programme succeeds in revealing the real potential of those students whose ability did not show up during the regular, traditional classroom studies.

There was no difference between male and female abilities to conduct independent field-based investigation.

Student Interviews

The interviews, which were conducted at the end of each year, included about half of the students, representing all the investigation projects and schools included in that year. The general picture which is drawn from the interviews indicated that the students enjoyed the field investigation very much, but they had difficulties in writing the scientific reports. It seems that the writing difficulties had no negative influence on their attitude and, in perspective, they even felt satisfaction with their triumphing over their handicaps.

The reviewers' reports often mentioned the enthusiasm shown by students while talking about their experience. The students' positive observations generally included the following aspects:

- the enjoyment and fun of a field-study camp;
- the enjoyment of independent learning, particularly in contrast to experiences in the school learning environment;
- the thought that concrete learning is a very efficient learning method;
- the social virtues of getting to know students from other schools;

- the contribution of the field investigation leaders. Some of the students mentioned that they were carried away by their guide's enthusiasm and personality.

As already mentioned, some field leaders were criticised for being too demanding or irresponsible with respect to the meetings' schedule. The data collected by the organisers' team revealed that most of these field leaders decided to leave the project after 1 or 2 yeas because, as they explained to the organisers' team, they had found the use of such teaching methods unsuited for them.

Teachers' and Field Leaders' Reports

The field leaders' reports gave a very positive picture. The high motivation and enthusiasm of the students during their projects appeared in most of their reports and interviews; as one of them said: '. . . Although we work from early in the morning till dark, I had to force them to go to sleep at midnight, since they were so occupied with the work and analysis of the data they collected throughout the day'.

The geography teachers' reports indicated that the students brought their motivation and enthusiasm to the geography classes and in some cases they even influenced the attitudes and behaviour of their classmates who had not participated in the programme. Some students' parents also reported to teachers the positive changes in their children's behaviour following their investigation projects. Geography teachers emphasised difficulties students had in writing scientific reports since it was the first time they had attempted this. During this stage students used to complain about the difficulty of this assignment, yet after they had accomplished it they were very proud of themselves.

During the early years geography teachers reported their great difficulty in assisting their students in writing the final report and its assessment. They also found themselves in the position that, in some areas, their students were more up-to-date than they themselves. However, this situation forced them to update their knowledge and to improve their skills:

> . . . I have ten 'Geotop' geography students in my class who participate in five different projects. The knowledge they bring to the classroom is enormous. Sometimes I find myself in a situation when they correct me or talk about ideas which are new for me. So, I contact their investigation field leader and ask him what it is all about. Thus, in the next class I am better prepared.

After a few years of experience, all of the geography teachers agreed about gaining significant geology knowledge and understanding; they felt much more confident in assisting their students and in evaluating their reports. Some of them claimed that as a result their self-image as a professional teacher was improved.

The Long-term Attitude Study

The results presented in Table VI indicate that the students hold high positive attitudes in the affective and cognitive domains of the programme. They strongly agreed that their learning performance had improved and were very interested and enjoyed it, especially in relation to their other studies in high school. This enjoyable learning experience was implanted in their minds and they still carry it with them. Most of the students use the geological knowledge and the thinking tools they acquired in their daily life, thus enhancing their understanding of their natural environment. For some of them this experience influence their current and future choices of academic subjects.

TABLE VI. Attitudes of the study population to the individual field investigation programme ($n = 151$)

Categories and statements or questions	Frequencies (%)						
	Very high (5)	High (4)	Moderate (3)	Low (2)	Very low (1)	X	SD
Affective domain							
1. My enjoyment of the 'Geotop' project study was:	52	37	9	1	1	4·4	0·7
2. My interest in the 'Geotop' project study was:	61	36	3	—	—	4·6	0·5
3. My enjoyment of the 'Geotop' project study in comparison to the rest of my studies was:	58	32	9	1		5	0·7
4. My interest in the 'Geotop' project study in comparison to the rest of all my studies was:	37	47	15	—	1	4·2	0·7
Cognitive domain							
5. My understanding of my investigation subject was:	63	34	2	1	—	4·6	0·6
6. My present recollection of the details of my work is:	43	38	17	2	—	4·2	0·8
7. The knowledge and understanding I gained from my project in comparison to the rest of all my studies were:	22	51	26	1	—	3·9	0·7
8. The intellectual efforts I invested in the 'Geotop' in comparison to the rest of all my studies were:	6	27	55	10	2	3·2	0·8
General contribution to understanding and learning							
9. My extent of learning following the 'Geotop' was:	42	44	11	3	—	4·3	0·8
10. The contribution of 'Geotop' study to my general understanding of geology was:	40	44	14	2	—	4·2	0·8
11. The increase of my interest in learning geology following the project was:	31	34	27	5	3	3·9	1·0
12. The increase of my interest in learning geography following the project was:	21	30	33	10	6	3·5	1·1
Teaching domain							
13. The contribution of my field leader to my understanding of the investigation was:	56	26	14	2	2	4·3	0·9
14. The field leader contribution to my enjoyment of my investigation was:	44	32	18	4	2	4·1	1·0
15. The geography teacher's contribution to the success of my investigation was:	31	37	18	8	6	3·8	1·1

TABLE VI.—*continued*

Categories and statements or questions	Frequencies (%)						
	Very high (5)	High (4)	Moderate (3)	Low (2)	Very low (1)	X	SD
Values domain							
16. The increase of my acquaintance with my country following the 'Geotop' study was:	13	32	34	16	5	3·3	1·0
17. The 'Geotop' study strengthened my connection to my country:	12	16	34	19	19	2·8	1·2
Practical long-term effects (includes only 1988–91 students)							
	Yes	No					
18. Have you been using the knowledge you gained from your 'Geotop' project since? (if yes, please specify).	60	40					
19. Has the 'Geotop' project effected your current interest in your studies? (if yes, please specify).	35	65					
Recommendations							
	Strongly recommend (3)	Recommend (2)	Not recommend (1)	X	SD		
20. What advice would you give a student who might ask you if he/she should participate in 'Geotop' project?	75	24	1	2·7	0·5		

SD = standard deviation.

Although the interviews with teachers and students indicated difficulties at the writing stage, with the perspective of time, most of the students perceived the programme to be of moderate difficulty. The results support the geography teachers' reports about the significant contribution of the programme to classroom learning. It seems that since 'Geotop' became part of the geography curriculum the students transferred some of their positive attitude to geography as well, even though there is little similarity in Israel between these two disciplines at school or at the academic level. The key role of the field leaders, both in the cognitive and affective aspects of the programme, is also supported by students' attitudes. The contribution of the geography teachers was found to be less significant, as expected, but even so it seems that many teachers had supported their students well. In relation to attitudes in the values domain, which is actually a side effect of the programme, the findings are also encouraging. Following the programme, about 80% of the students are better acquainted with their country and about 60% felt more involved with their environment. Some 60% of the students used the knowledge they gained in the programme in their daily life. Most of them wrote that while walking around the country, they were able to identify and understand geological phenomena and liked to explain them to others. About a third claimed that they would like to study geology or physical geography in the university and a few of them had already registered (most of the students have been serving in the army in 1992). Their high satisfaction with the programme is clearly expressed by the frequency distribution of their recommendations.

Table VII shows that the programme has long-term effects on the students and the development of positive attitudes, mentioned above, remains constantly high over the years. An analysis of variance (one-way ANOVA) was conducted for three groups: 1988-89 students, 1990 students and 1991 students. A significant statistical difference among the groups was found only for one statement, 'the field leaders' contribution to understanding' (No. 13, Table VI). It was found that for the more recent groups, the field leader had influenced them more positively. This finding might reflect improvements in the procedures followed in setting up the field investigation project, replacing of unsuitable field leaders and the quality of guidance offered over the years.

The respondents of 1988–91 represent only about one-third of the whole population of these years and this might raise a question about possible sampling bias. In order to test this a *t*-test analysis was conducted between two groups: the 1988–91 student group and the 1992 student group, which represents about 80% of the whole 1992 'Geotop' student population. Among the 20 items analysed, only in three cases were significant differences found (Table VIII): in students' memory of the work they had carried out, the usefulness of the project in their daily life, and the degree of contribution of the geography teachers. The differences in the two first items could be expected. The higher positive attitudes to the geography teachers' contribution probably reflects the teachers' improvement over the years.

The data analysis of the geography teachers'/field leaders' views about their students' views of the programme, which is presented in Table IX, is another source of validation of the students' attitudes. It is impossible to look for statistical differences between these two unequal groups but the overall picture which is revealed in Table VIII, Table IX and the teachers' and the field leaders' reports can given solid support to the validity of the long-term findings concerning the study population.

A *t*-test analysis indicated that there were almost no gender differences concerning the attitude outcomes of the programme. Only two significant statistical differences were found: (a) female attitudes were significantly positive concerning the geography teachers'

TABLE VII. Long-term attitudes of students 1–4 years after the project and 4 years after leaving high-school

	Frequencies (%)																											
	4 years after ($n = 11$)							3 years after ($n = 16$)							2 years after ($n = 24$)							1 year after ($n = 30$)						
Item	(5)	(4)	(3)	(2)	(1)	X	SD	(5)	(4)	(3)	(2)	(1)	X	SD	(5)	(4)	(3)	(2)	(1)	X	SD	(5)	(4)	(3)	(2)	(1)	X	SD
Affective domain																												
1	55	45	—	—	—	4·5	0·5	44	50	6	—	—	4·3	0·6	58	42	—	—	—	4·6	0·5	50	36	14			4·4	0·7
2	73	27	—			4·7	0·5	63	37	—	—	—	4·6	0·5	63	33	4			4·6	0·6	55	41	4	—	—	4·5	0·6
3	82	18		—	—	4·8	0·4	50	38	12	—	—	4·4	0·7	63	29	8	—	—	4·5	0·7	55	36	9	—	—	4·5	0·7
4	45	55	—	—	—	4·5	0·5	19	69	12			4·1	0·6	63	25	12	—	—	4·5	0·7	27	64	5	—	4	4·1	0·9
Cognitive domain																												
5	82	18	—	—	—	4·8	0·4	63	37		—	—	4·6	0·5	83	13	4	—	—	4·8	0·5	45	50		5		4·4	0·7
6	27	18	45	10		3·6	1·0	31	31	38	—	—	3·9	0·9	34	58	4	4		4·2	0·7	18	50	32	—	—	3·9	0·7
7	27	45	18	10	—	3·9	0·9	13	56	31	—	—	3·8	0·7	33	29	38	—	—	4·0	0·9	32	55	9	4	—	4·1	0·8
8	—	55	45	—	—	3·5	0·5	13	12	75	—	—	3·4	0·7	8	29	38	21	4	3·2	1·0	5	32	50	9	4	3·2	0·9
General contribution to understanding and learning																												
9	27	55	18	—	—	4·1	0·7	37	44	19	—	—	4·2	0·7	54	38	—	8	—	4·4	0·9	18	59	14	9		3·9	0·8
10	36	36	10	18	—	3·9	1·1	44	44	12	—	—	4·3	0·7	54	34	8	4		4·4	0·8	32	45	23	—	—	4·1	0·7
11	36	18	27	10	9	3·6	1·4	38	44	12	6	—	4·1	0·9	50	17	21	8	4	4·0	1·2	14	27	41	9	9	3·3	1·1
12	54	10	18	18	—	4·0	1·3	31	50	7	6	6	3·9	1·1	17	25	46	12	—	3·5	0·9	18	27	36	5	14	3·3	1·2
Teaching domain																												
13	36	27	27	10		3·9	1·0	38	31	13	6	12	3·8	1·4	50	42	8	—	—	4·4	0·7	68	23	9	—	—	4·6	0·7
14	37	27	18	18		3·8	1·1	31	25	25	6	13	3·6	1·4	46	37	17			4·3	0·8	55	32	13	—	—	4·4	0·7
15	27	27	28	18	—	3·6	1·1	37	25	25	13	—	3·9	1·1	8	50	29	8	4	3·5	0·9	46	9	9	9	27	3·4	1·8
16	18	54	10	9	9	3·6	1·2	13	44	31	12	—	3·6	0·9	8	21	42	25	4	3·0	1·0	14	45	27	14		3·6	0·9
17	18	37	18	9	18	3·2	1·4	6	25	38	25	6	3·0	1·0	13	17	39	22	9	3·0	1·1	9	14	27	18	32	2·5	1·3

Values domain												
	Yes		No	Ycs		No	Yes		No	Yes		No
18	45		55	63		37	63		37	64		36
19	36		64	19		81	42		58	36		64
Recommendations												
	(3)	(2)	(1)	(3)	(2)	(1)	(3)	(2)	(1)	(3)	(2)	(1)
20	100	—	—	81	19	—	75	21	4	59	41	—

SD = standard deviation.

TABLE VIII. Statistically significant differences between 1988–91 group ($n = 81$) and 1992 group ($n = 70$)

Statements	1989–91 group		1992 group			
	X	SD	X	SD	t	P
6. My present recollection of the details of my work is:	4·0	0·7	4·5	0·6	4·7	0·0001
15. The geography teacher's contribution to the success in my investigation project was:	3·6	1·3	4·0	0·9	2·6	0·01
18. Have you been using the knowledge you gained from your 'Geotop' project since? (Yes/No question—2-point scale)	0·6	0·5	0·2	0·4	4·6	0·0001

SD = standard deviation.

contribution ($t = 2·2$, $p = 0·03$); and (b) male attitudes were significantly positive concerning the knowledge and understanding they gained relative to the rest of their studies ($t = 2·3$, $p = 0·02$).

All the different sources of the evaluation (students, teachers, field leaders), the different methods of evaluation (quantitative and qualitative), the different outcomes (attitudes and achievements) and the time perspective (short-term and long-term) consistently support each other, combining together to give a very encouraging picture of the 'Geotop' programme. These findings indicate that the programme achieved its objectives in many aspects of the Israeli educational system with respect to: students, classes, teachers, physical geography, geology and science.

Discussion

The findings suggest that 'Geotop' is a powerful educational programme and evidently the 'Geotop' participants had experienced meaningful learning. This supports Ausubel's theory (Ausubel, 1968) which has already identified individual learning as a powerful strategy for achieving meaningful learning (Novak, 1977). In this study, the road to 'meaningful learning' undoubtedly crossed the interest–motivation junction. This might explain why moderate to low achievers from a non-science background suddenly found the power, abilities and commitment needed to produce such a quality performance resulting in high achievement in conducting an individual science investigation project. This explanation is based on Dewey's (1938), Kilpatrick's (1951) and Wilson's (1971) ideas about autonomous learning, which could be achieved through educational practices which are both student-centred and interest-based.

The findings support Tytler's (1992) conclusion that students' research projects should not be limited only to talented or gifted students: '. . . interest and motivation rather than intellect are the key ingredients in pursuing a piece of research and a model to a successful conclusion . . .' (Tytler, 1992, p. 409). Although the 'Geotop' findings might indicate that almost every high school student is capable of conducting an individual investigation project, it is not suggested that everyone should do so. Since the 'Geotop' programme was not compulsory, the first and maybe most important commitment students display is in their choosing to participate in the programme. Autonomous learning or individual learning which leads to meaningful learning should start within the

TABLE IX. Teachers' and field leaders' views about their students' views of the programme ($n = 20$)

Categories	Frequencies (%)						
	Very high (5)	High (4)	Moderate (3)	Low (2)	Very low (1)	X	SD
Affective domain							
1. Students enjoyment of the 'Geotop'	80	20	—			4·7	0·5
2. Students interest in the 'Geotop'	46	54	—	—	--	4·5	0·5
3. Enjoyment in comparison to the rest of all of their studies	81	19	—	—	—	4·8	0·4
4. Interest in comparison to the rest of all of their studies	64	36	—	—	—	4·4	0·5
Cognitive domain							
5. Understanding of the investigation	38	62	—	—	—	4·6	0·6
7. Knowledge and understanding in comparison to the rest of their studies*	18	64	18	—	—	4·0	0·6
8. Intellectual efforts in comparison to the rest of all of their studies	9	55	36		—	3·7	0·6
General contribution to understanding and learning							
9. Learning following 'Geotop'*	23	77			—	4·2	0·4
10. Contribution to the understanding of geology	54	46	—			4·5	0·5
11. Increased interest in geology following the project	27	64	9	—	—	4·2	0·6
12. Increased interest in geography following the project*		75	25	—	—	3·7	0·5
Teaching domain							
13. The field leaders' contribution to their understanding of the project	69	31	—	—	—	4·7	0·5
14. The field leaders' contribution to their enjoyment of the project	38	62	—	—	—	4·4	0·5
15. The geography teacher's contribution to the success of the project	—	33	56		11	3·1	0·9

Note: *Items included only teachers' responses; SD = standard deviation.

individual and can be derived only from his/her interest. The educational system should create a greenhouse environment for the flowering and growth of the initial interest and motivation of all students and later help to support individuals to nurse their interest and motivation.

Although there is growing awareness of the potential of individual investigation projects, e.g. in the secondary education (General Certificate of Secondary Education) of England and Wales, they are still not very common in schools. It is unreasonable to expect that teachers, even the best of them, will find the time, energy and knowledge to supervise individual projects of a whole class. It is suggested that in order to extend the use of individual investigation programmes as an integral part of the curriculum, they should be developed just as any other curriculum development task would be but with even more care given to the implementation process.

The 'Geotop' example might serve as a model for the development and implementation mechanism for such programmes. It is suggested that the adjustment of the 'Geotop' model for large student populations would mainly require an extension of the role of the central organisation and the teams of field leaders or, more likely, the establishment of a few regional teams. This suggestion gives rise to a legitimate question about the cost of such programmes which might be a challenge to their continued existence. To answer this question one should calculate cost in relation to its effect. Accepting the impressive outcomes of 'Geotop' as an indication of the potential educational effect of such programmes should make the costs appear quite trivial. Schools all over the world contain many bored and unmotivated students, identified by their teachers as 'wasting their potential or talent'. Most of them appear to have lost their interest and motivation somewhere during their earlier years in school. It is the responsibility of the education system to find the ways and resources needed to awaken those students so that they fulfil their potential. Our growing awareness of the needs of the less able as well as the gifted students should not lead us to leave this silent majority behind.

Summary

Individual science investigation projects can be successfully run with non-science students and teachers. It is suggested that a successful model for such a programme should be based on development–implementation–evaluation interrelationships which require external support by qualified field leaders and a central co-ordination team. The study supports the idea that by giving students autonomy together with the necessary teaching support and encouragement, meaningful cognitive, affective and values outcomes can be expected.

This study also emphasises the potential of earth sciences to act as an educational bridge between the science and non-science oriented student population. Similar projects might also be developed in relation to other disciplines such as, history, archaeology, economics, and even disciplines of the fine arts such as sculpture, photography and painting.

It is suggested that the novelty and interdisciplinary characteristics of the earth sciences and the 'Geotop' model could be used to develop investigation projects in relation to other science student populations concerned with chemistry and physics. Such ventures would enable those students to apply some of their theoretical background knowledge to solving real earth science problems.

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REFERENCES

AUSUBEL, D.P. (1968) *Educational Psychology: a cognitive view* (New York, Holt, Rinehart & Winston, Inc.).

BAKSHI, S.T. & LAZAROWITZ, R. (1982) A model for interdisciplinary ecology project in secondary schools, *Environmental Education and Information*, 2, pp. 203–213.

DEWEY, J. (1938) *Experience and Education* (New York, Macmillan).

KILPATRICK, W.H. (1951) *Philosophy of Education* (New York, Macmillan).

NOVAK, J.D. (1977) An alternative to Piagetian psychology for science and mathematics education, *Science Education*, 61, pp. 435–477.

ORION, N. (1989) Field trips in the Israeli high school geology curriculum, *Earth Science Teaching*, 14, pp. 25–28.

TYTLER, R. (1992) Independent research projects in school science: case studies of autonomous behaviour, *International Journal of Science Education*, 14, pp. 393–411.

WILSON, P.S. (1971) *Interest and Discipline in Education* (London, Routledge & Kegan Paul).