High school student's research project in Earth Sciences as a pedagogic tool (Israel)

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Introduction

To educate our 21st century citizens, who live in a world in which knowledge doubles every two years, one of the main objectives of school must be the development of independent learners. This goal may be achieved by developing literacy skills in different learning environments, and especially investigative skills. This pedagogic truth should take a central place in the science curricula (New Zealand Ministry of Education 1993; Mayer 2002). The scientific investigative process during high school education should be continuous, with several sequential stages leading to the development of high levels of students' scientific thinking (Draper 1993; Hulland & Munby 1994; Orion & Hofstein 1994). Investigating at all levels provides challenges and creates positive attitudes (Novak & Gowin 1984; Kim 1999). Investigation skills may be improved by integrating a range of tasks into the curricula.

Following our 20 years of experience as Earth Science educators in Israel, we conclude that Earth Science education has great potential to address the above objective. In junior high schools, the Israeli Earth Science curriculum includes studying the Earth systems: *Matter on Earth* (*The rock cycle*), *Our blue planet* (*The water cycle*) and *The Earth systems* (*The carbon cycle*). The senior high schools' first level contains *Earth materials and processes* and connects to the rock and the water cycles (*Micro geology*). The curriculum continues with *plate tectonics* (*Macro geology*) and concludes with the *geological history of Israel* and *applications of Earth Sciences* (as *The application stage*) (Orion & Hofstein 1996; Orion 2002; Israel Ministry of Education 2004). The highest level of learning is a "selected unit", in which teachers and students can choose between different topics such as: The carbon cycle, Landscape evolution in deserts, or Oceanography.

Earth Science teaching at all levels encourages using multi-learning environments (classroom, lab, computer, media and outdoors). Special emphasis in the Israeli curricula is given to outdoor learning as a central environment integrated with the other learning environments (Orion & Hofstein 1994, 1996). This approach provides direct experience with phenomena and material and improves scientific skills (Orion 1989, 1996). Israeli Earth Science educators have developed various learning and teaching strategies for supporting the independent learner. The highest level is achieved by the students' Independent Research Project (IRP), which has proved to be a pedagogic tool with major impact on learning and teaching.

In this article we present the main aims and ideas of the Earth Sciences IRP, its stages and its main benefits for students and teachers.

Stages of development of the independent learner in Earth Sciences

In addition to studying a conventional core curriculum in Earth Sciences, the independent learner conducts several projects that affect the dynamic advance in the curriculum (Fig. 1). Most of these projects are connected to field trips and laboratory work, combining indoor and outdoor learning (Israel Ministry of Education 2004). Early in the learning process, students use classroom, lab, computer and media, and have their first experience with outdoor learning. Different experiments in the lab and observations during field trips in the local environment lead to better understanding and concretisation. The observations and conclusions are written up as simple reports of the activities.

The students then progress from short and simple outdoor and research observations to field trips that are 2–4 days long. In this stage of learning students are exposed to the "wide laboratory of nature", to different processes and various geological environments (Orion & Hofstein 1996; Orion 2003). Field learning is enhanced by field equipment (booklets, maps, definitions, mini-posters) and by indoor learning (Orion 1989). This learning requires implementing tasks that are the main part of the student's Earth Science portfolio. This portfolio includes laboratory and field trip reports. Through writing and editing these, students achieve their basic investigative literacy. Positive assessments of this portfolio and the final exams are worth four credits for the Israeli Matriculation Certificate (IMC) (Israel Ministry of Education 2004). (To complete IMC, at least 27 credits from all subjects including required subjects such as Hebrew, English, Math and elective subjects such as Earth Sciences must be gained).

The next assignment is the "Geotop". This is a geological investigation project that comprises 3–4 days of field trips in a defined area, and is mostly done in pairs. This project applies knowledge and skills learned in the field, laboratory and library. It accesses scientific investigation processes by identifying research questions, observations, data collecting, and data analysis, and writing a scientific

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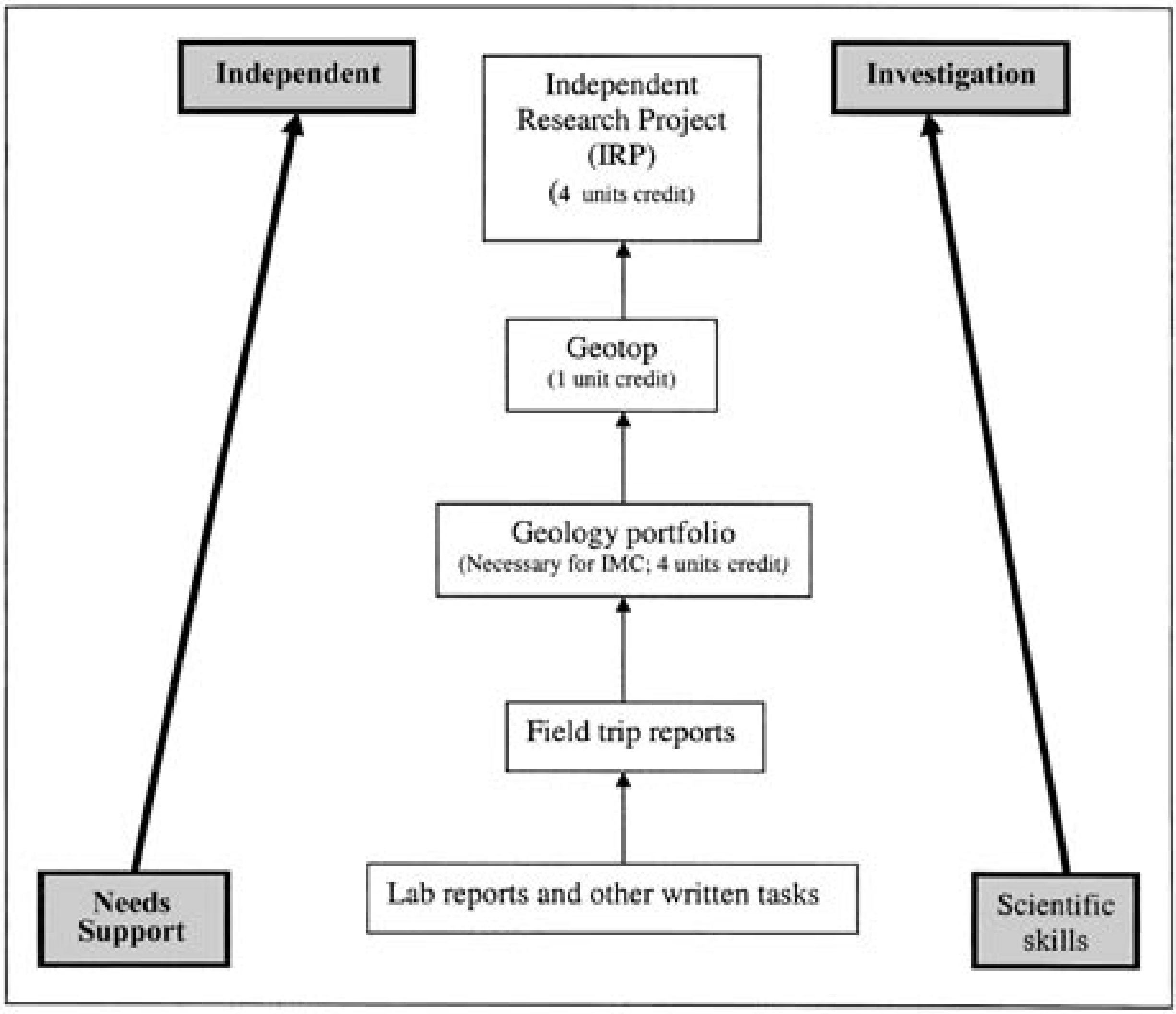


Fig. 1 Sequential stages lead to developing of high levels of students' independent learning.

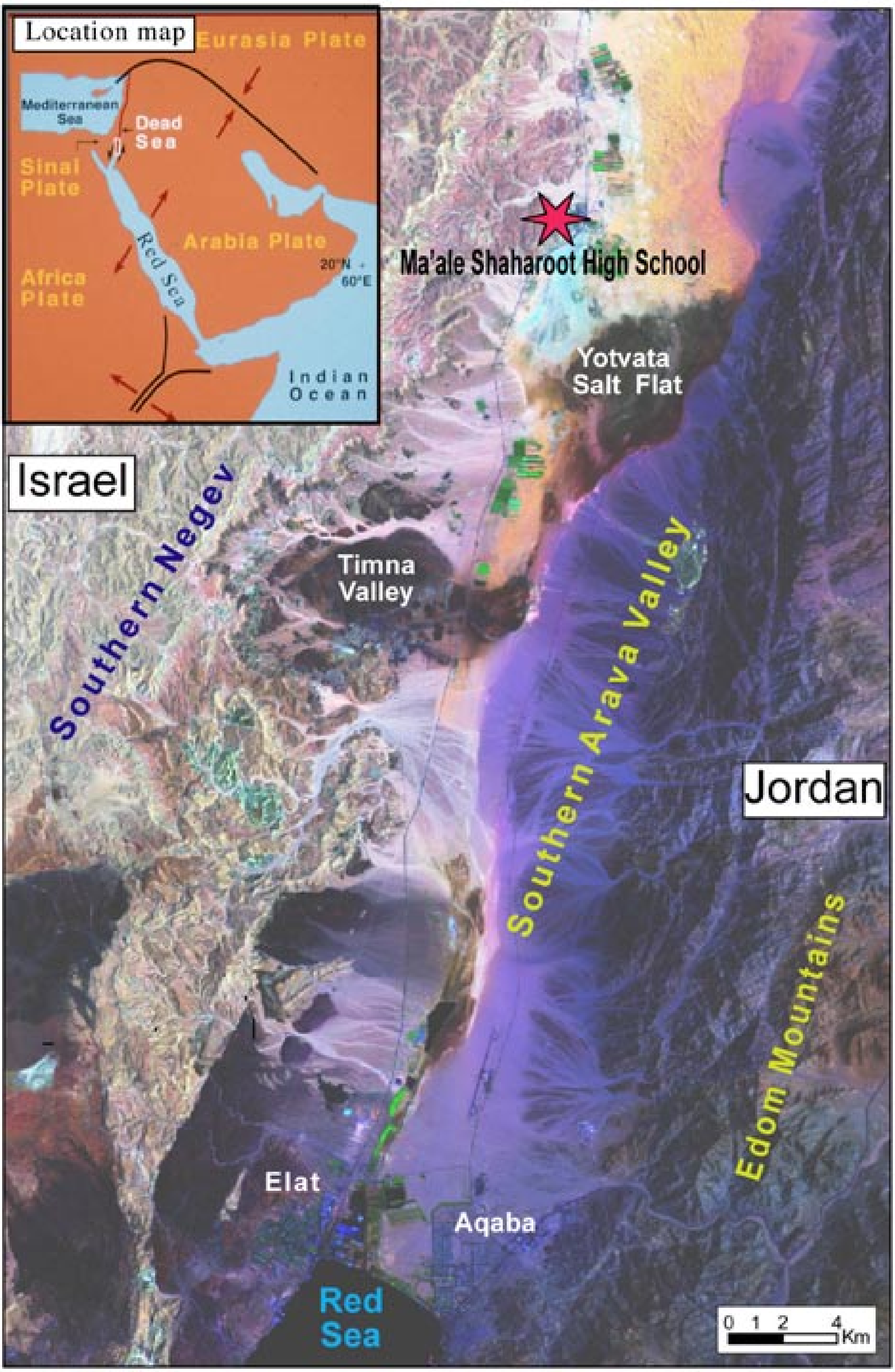
report (Orion 1994). Examples of Geotops can be: "The assemblage of fossils in Hazera Formation" or "Roundness of pebbles as a function of the transport distance, Timna Stream". The Geotop is worth an additional credit point as part of Earth Science IMC credits (Israel Ministry of Education 2004).

As the process of learning through investigating progresses, the tasks become more abstract and the students become more independent (Fig. 1).

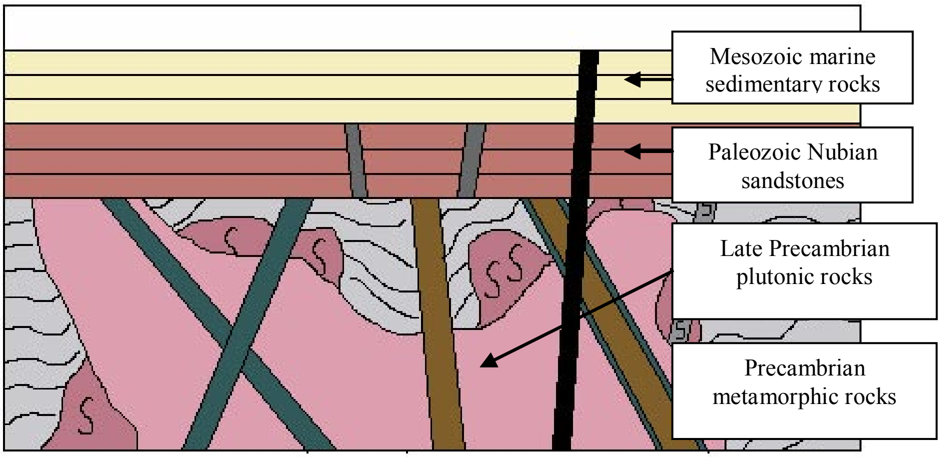
The Independent Research Project process

Successful execution of the stages may lead students to take part in the highest level assignment – the Independent Research Project (IRP). This is a dynamic project in which students have to deal with actual scientific materials. The IRP includes an in-depth study of a selected subject combining observations from different sources such as academic articles, the internet and library. There is also laboratory work and 10–15 days of outdoor independent learning. To achieve cyclic and systematic scientific thinking, students may need to do their IRP with investigations in different learning environments. The students become deeply involved in research and therefore the learning process becomes very significant, meaningful and positive. By preparing this project, students achieve high-level thinking skills of integration and discussion. Successful students pass all the main research stages: planning, focusing, collecting data from different environments, reading relevant references, collating, writing, preparing figures, editing, presenting and publishing. IRPs are supervised by postgraduate geological researchers who oversee the students during all stages of the project. Students are also assisted by their teachers at each stage. This project is done during 12 months in the last two years of school and the assessment is made by an academic expert. The IRP is worth four credits for the Israeli Matriculation Certificate (final report).

Some projects that were done during the last three years by Israeli high school students were: "Field relationship between different dykes and their host rocks, Southern Arava" (see Fig. 2), "The characterisations of sand along



A satellite map of Southern Israel (Including the main research areas)



Geological schematic cross-section of the different series of dykes that had been injected during the geological history (Geinosar 2004).

the Israeli West Coast" and "The Geology of Graben Yotam" (for more examples see Fig. 3). In some instances the students take part in a continuous research project that is conducted over a few years, as in the IRPs that were done through the topic, "The connections between water, soils and plants in the margins of Yotvata Salt Flat". The abstracts of the research projects were edited, translated (to English) and computerised onto a multi-language website (http://shaharoot.kfar-olami.org.il/salt-flat/indexE.htm).

The use of the website makes the students partners as both "contributors" and "consumers", and their research becomes available for students worldwide. New students can join this dynamic research and their data will become part of the geology, geomorphology, climatology, hydrology and biology data resource.

On the way to completing a successful IRP, students must contend with many challenges such as the demands of much additional work and time while continuing to study other subjects. For the project to be successful, the students' teachers and supervisors must provide support at all stages. The students' main guideline should be: *"We prefer what is necessary in order to obtain what is possible, and we rapidly discover that we achieve the impossible which recently seemed like a distant dream"* (old Chinese proverb).

By Tom Geinosar, 12th grade student, Ma'ale Shaharoot High School, Israel, 2004.

Project outline

A 20 days of field trips including detailed mapping and geological cross-sections in seven sites in the Southern Negev (the southernmost part of Israel).

B Observations through microscope (rocks and thin sections).

C Gathering references from books and articles (in Hebrew and English) and interviewing an Israeli geologist who researches these dykes.

Brief overview of main conclusions

1. There is an interesting connection between the width of the dykes and their influence on the host rock.
2. The "contact area" is influenced mostly by the structure and minerals of the host rock.
3. It is suggested that the width of the xenoliths is connected to the host rock and to the temperature of the dyke during the injection.
4. In some groups of dykes, field observations of "fingers and channels" can prove horizontal injection.
5. Dyke lithology is related to tectonic history.

Age	Widespread lithology	Tectonic history
Precambrian	Schist dykes	Subduction zone
Late Precambrian	Rhyolite, Quartz Porphyry, Andesite (Ultramafic Dykes)	Creation of the Arabic-Nubian Massive
Jurassic and Early Cretaceous	Trachyte, basalt	Opening the Tethys Sea
Tertiary	Basalt (Mafic dykes)	Creating the Dead Sea Transform

Fig. 2 Field relationship between different dykes and the host rocks in Eilat area (and as a key for better understanding of the geological history of this area)

Geology

Ronen, G. 1995. Copper: Rocks and mining, Timna Valley
Zion, H. 1996. Characteristics of different formations of sandstones, Timna valley
Yaakobi, Y. 1997. Young geologic faults along the east margins of the Southern Arava Valley
Yaakobi T. 1999. Interesting outcrops of Cretaceous and Miocene volcanic intrusions and their geological history, Southern Arava Valley
Apshtein, N. 2001. Active faults beside the head of the Red Sea
Carmi, O. 2004. The geology of Graben Yotam, Elat Mt.
Geinosar, T. 2004. Field relationship between different dykes and the host rocks Southern Negev

Geomorphology

Zeevi, N. 1995. The landscape evolution of Timna Valley
Asila, Y. 2001. The characteristics of calcite sand grains in climbing and falling dunes, Southern Negev

Climatology and Hydrology

Reisel, M. 2001. The water regime during floods in Yotvata Salt-Flat catchments area
Domb, T. 2005. Differentiations of the rain amount during rain storms, Southern Arava

Geo-Biology and Pedology

Carmi, M. 2001. Soils characteristics in the west margins of Yotvata Salt Flat
Leshem, L. 2003. The factors that influence natural plant groups' spreading in an extreme arid zone, Timna Valley

Earth Sciences education

Moskovitch, I. 2001. Design of an apparatus to study wave movements and their influence on various coastlines
Menahem, N. 2001. Educational impacts of using the educational website: "Yotvata Salt Flat, Man and Environment" http://shaharoot.kfar-olami.org.il/salt-flat/index.html
Daniel, L. 2003. Roundness of pebbles from different origins as a function of transport distance – Measuring along the Timna Stream and designing pedagogic tools to present the function
Tal, I. 2004. Different degrees of scientific challenge in distance learning, and their educational impacts

Fig. 3 Subject of Earth Sciences students Independent Research Projects (1995–2005) (Ma'ale Shaharoot High School, Yotvata, Israel). (Published in Hebrew.)

The benefits

The implementation of IRPs lead to learning and teaching processes that provide some important benefits:
1. Effective development of meaningful learning skills.
2. Direct interaction with natural environments in different learning environments.
3. Provision of real academic challenge and improvement of thinking systems.
4. Creation of a positive attitude to learning and investigating.
5. Development of good personal relations between students and teachers.
6. Improvement of teachers' research skills and enjoyment of teaching through the student-teacher research partnership.

Not all students complete the full investigative process. Those who do succeed have climbed to the top of the "learning pyramid", and for them independent learning becomes a powerful strategy. These IRP are also part of the curriculum in biology, social studies and many other subjects. Both students and teachers are able to identify the contribution of the project to their development. The educational process becomes *"Not just the filling of the pail but rather the lighting of the fire"* (W.B. Yeats 1865–1939). As one of the students said: "My IRP is the most meaningful and enjoyable thing that I remember from school after 5 years. It was a very exciting, challenging and interesting experience!"

Conclusions and a personal view

The development of investigation literacy in the context of science consists of several sequential stages arranged in a hierarchical pyramid structure. The IRP becomes the highest level of learning. To be successful in creating a deep, meaningful and enjoyable research project in a selected subject, students must pass all the stages. The skills they develop at each stage serve as the basis for the development of the next higher-order stage. The IRP will be remembered by the student as their main positive, challenging and significant experience.

New Zealand, including its continental shelf, is more remote than any other inhabited landmass on Earth, and is one of the best countries for displaying a number of active geologic processes. Tectonic uplift, volcanic, geothermal, glacial, fluvial, aeolian and coastal processes produce a remarkable diversity of landscapes (Suggate et al. 1978; Coates 2002). These processes and landscapes create endless possibilities for research topics in Earth Sciences.

All these geological processes can be addressed by students in the *Planet Earth and beyond* strand of the NZ Science Curriculum (New Zealand Ministry of Education 2004). The option to prepare and submit an IRP is offered in the New Zealand Science Curriculum and has been implemented in those schools offering science at year 12 and 13 (Alan Munro and Glenn Vallender pers. comms.).

We hope that our experience in Israeli education will be useful in other countries, including New Zealand. Cooperative learning through IRP and other scientific investigation projects between educators of Earth Sciences from both countries may support learning processes and in-depth pedagogic connections. We hope this paper will pave the way for cooperation and reciprocal enrichment.

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Comment – Relevance of the student research project in Israel to New Zealand Science

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Introduction

Since 1999, New Zealand has introduced a method of assessing the skills of science by the use of achievement standards related to investigative skills, namely science 1.1 (AS 90186), science 2.1 (AS 90312) and science 3.1 (AS 90XXX). The theme followed by these standards is to improve the investigative skills of students over each year. In science 1.1 the teacher directs the investigation, in 2.1 the teacher supervises the investigation but by level 3 the teacher guides the investigation and the students carry out the complete investigation themselves.

Level 3.1 science

In 1995, science became a subject to year 13 in its own right along with all the other sciences, biology, chemistry, and physics. As part of the subject, great importance was placed on investigative skills and critical literacy skills. Over the last 10 years these skills and their assessment have been refined. Students are now able to carry out detailed investigations in their chosen aspect of science. In Earth Science some examples are, "Sediment carrying capacity of the Matai Stream in Nelson, under flood conditions", "Do acidic rocks in the Nongataha Quarry in Rotorua follow Bowens Reaction series", and "Stalactite formation in the Orepuki goldfield in Southland". In New Zealand, year 13 science investigations can be done in any area of science.

Comparison between research projects in New Zealand and Israel

I have had the privilege of talking to both Hanan Ginat and Nir Orion about the work being done in Israel with student research projects in Earth Science. Israel has been offering students high-level research projects related to investigative skills since 1989 and is further down the track than we are. New Zealand's level 3 assessment schedules have only been re-written this year. We can learn from the Israel experience and use the best of their research to help develop our own assessment of investigative skills. What we have seen done in Israel would be at level 8 of the New Zealand curriculum and could be a future pathway for New Zealand in all the sciences.

Relationship of the Israeli Experience to the Curriculum review

This year the science curriculum has started a review process and has produced draft achievement aims and objectives for the new integration strand. The four aims are:

- understanding about science
- investigating
- critical literacy
- action competence.

What has been produced in Israel meets these aims. What New Zealand has done so far with science to year 13 has started to address these aims. A look at the Israel experience could help New Zealand in the future.

Reviewed by Allan Munro, Glenn Vallender,
Dr Daphne Lee