New horizons for profiling soil science in schools

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Abstract
A key objective of this soil science education initiative is to enable teaching and learning experiences related to soil science to become embedded in school curricula. This initiative is composed of a targeted curriculum resource (SPICE Soil Science) and the Monitoring Soil Science Project. The program includes a teaching resource that directly relates to science curricula using the context of soil, supporting procedural material for teachers, allocation of soil scientists as school mentors, a dedicated website and a reference suite of soil analyses for each school. The keys to the sustainability of the project are the soil-related science curricula, support for teachers, and the website. The project provides an opportunity for school children, their teachers and parents to engage in activities that raise awareness of soil, first as a habitat for small animals and microbes and later as a significant global resource. It opens windows to the public about the importance of soil and creates a novel learning environment that is relevant to chemistry, physics, biology, geography and the earth sciences. It creates an awareness of 'dirt'.

Key Words
Education, soil plot, mentoring, soil analysis, soil fauna, science communication.

Introduction
The SPICE program is developing a soil science teaching resource. It specifically targets science curricula outcomes using soil fauna to illustrate the concepts - *interdependence of living things* and *sustainability of life and wise resource use*. The Monitoring Soil Science Project complements this teaching resource and seeks to establish innovative student-scientist partnerships through ongoing soil-based research. Students are trained in scientific methodologies, including sampling strategies, which they will use to collect a series of biological, chemical and physical soil science data. They upload their results onto a shared online database. The project introduces students to the importance of soils in the environment and to topical issues such as the climate change debate and environmental monitoring, in addition to developing scientific research skills including data collection and analysis.

The project seeks to engage and connect students and teachers in ongoing research in soil science. Student-scientist partnerships enable students to participate in genuine and realistic science activities. Monitoring soil fauna provides an engaging introductory step into soil science awareness as well as a springboard to discuss broader issues, such as the diversity of landscapes and climate change. Students follow scientific protocols to collect valid and reliable data, distinguish between the physical, chemical and biological aspects of the soil ecosystem, and interpret patterns and trends in these data. They can also compare their results with those of students from other schools, and develop their own soil science research project. In addition, students involved in programs of actual scientific value are possibly more likely to continue studying science-based courses in their later school years, and onwards (Woolnough 2000; van Eijck and Roth 2009). With this in mind, a pilot project was established in 2009 to trial and evaluate the Monitoring Soil Science Project in collaboration with SPICE Soil Science materials with six high schools in Western Australia (WA).

Embedding soil science teaching into the school curriculum
The SPICE program creates learning resources for teachers in collaboration with the Department of Education, Western Australia and The University of Western Australia; it supports teachers in providing innovative science experiences for students. Experiences with a wide range of curriculum development projects have shown that for a new initiative to become sustainable, strong links have to be forged to the core curriculum within schools. A SPICE learning sequence is being developed that uses a soil science context to support Years 8, 9 and 10 syllabus content related to: (i) *Investigating*: the planning, conducting, processing and evaluating of data, (ii) *Earth and Beyond*: the sustainability of life, and wise resource use, and (iii) *Life and Living*: the interdependence of living things, within Western Australia. Through the provision of engaging, challenging and innovative learning materials that initially focus upon soil fauna, all students are encouraged to become involved in soil science. The Monitoring Soil Science Project further enables students

to participate in a student-scientist partnership that enhances and extends their learning.Much of the subject matter associated with the Monitoring Soil Science Project is novel and new to science teachers and so a key strategy of the project has been to develop a structure that builds confidence through practical support. This has ranged from detailed professional learning, through comprehensive background and procedural documents to the provision of a mentor with soil science expertise.

Additional benefits of the project include a realistic context for students to study the interdependence of living things coupled with the opportunity to demonstrate scientific investigation skills driven by their own research aims, thereby enabling them to achieve essential learning outcomes. This process empowers students by encouraging them to take responsibility for their learning and allows them to develop scientific knowledge within a context that has been influenced by their own decisions.

A set of soil tests provided by a scientific laboratory for each school will be used as a baseline for ongoing investigation related to soil and land, and establishes potential links to other areas of science and technology. The permanent 'soil plot' underpins investigations above and below ground, and the accumulation of data creates additional avenues for investigation by students, including sharing of knowledge among students as they progress from year to year. The interactive website gives students a global window to soil science with support of their local soil science mentors.

Pilot for the monitoring soil science project in 2009

During the 2009 trial period, six schools tested the suitability of the written materials and practical equipment prepared for them to start the Monitoring Soil Science Project. Two accessible areas of land (plots 4m x 4m) were selected at each school as permanent sites for monitoring. A soil scientist was allocated to participating schools by the WA Branch of the Australian Society of Soil Science Inc. (ASSSI) as a mentor for the project.

Initially, each school monitored their soil plots for the abundance of mites and springtails and several soil tests such as soil pH and electrical conductivity, bulk density, soil moisture content and organic matter content. The project included an initial discussion among the students about how and where the soil samples should be taken. The location of the soil plots depend on the characteristics of the site and a discussion of options is an important first step in the process. Students can log-in and upload their data onto the Monitoring Soil Science Project website which automatically presents their information in a graphical form within their log-in area. The cumulative data for all accredited schools are visible on the internet without a log-in requirement.

Students are encouraged to pursue their own investigations alongside the project, and this is expected to expand as the project develops. The desired project outcomes are that students will be able to (i) participate in science activities that are not artificial, (ii) follow scientific protocols to collect valid and reliable data, (iii) distinguish between the physical, chemical and biological aspects of the soil ecosystem, (iv) interpret patterns and trends in these data, and compare their results with students at other schools who will have different soil types and land management practices, and (v) develop their own soil science project.

The pilot schools included extremely remote, rural and city schools with a range of science facilities. This gave a breadth of experience from which to evaluate the resources provided. Based on the evaluation of the pilot project in 2009, changes are being made for wider implementation. The next phase includes more schools from a wider geographical area, supported by their local soil science mentor. Accredited schools can participate via the online access section of the website and upload their data.

Getting the monitoring soil science project started

As a preliminary step in developing the instructions for teachers, the methodology for sampling soil was investigated by a group of senior high school students who were participating in a workshop at The University of Western Australia as part of the Primary Industry Centre for Science Education (PISCE) program. The PICSE program was established at the University of Tasmania and seeks to establish a national model of collaboration among universities, their regional communities and local primary industries to attract students into tertiary science and increase the number of skilled professionals in science-based primary industries and research institutions.

The students at the PICSE workshop were assigned the task of determining how they would sample soil for mites and springtails within a defined area of the university campus. Limited instructions were given to the students; they worked in groups to problem solve the task of defining the 'soil plot' location and sampling methodology. It was interesting to watch how the four groups tackled the concept of the 'soil plot' in different ways. This open-ended investigation proved to be a useful starting point for the Monitoring Soil Science Project, before the students were supplied with the standard instruction protocol required for consistent data collection. The students concluded that it was essential to have a specific explanation of (i) data quality, (ii) data variability, (iii) sampling strategies and (iv) statistical analysis, in the resource package for teachers. Background information was also requested about soil physics, soil chemistry, soil biology, pedology, soil mineralogy, use of geographical information systems technology and soil management.

After trialling the concept of establishing and sampling the 'soil plot', the students concluded that:

1. Clear instructions needed to be given to teachers about the potential variability of sites with a recommendation that the first activity could deal primarily with sampling strategies and assessing site variability.
2. Instead of selecting one large plot (as first intended), smaller plots should be selected to include different soil environments within the study area.
3. Details of the kit for soil sampling, soil animal extraction and analysis methodology should be simple and easily obtained.
4. Very clear information about the sampling implements and method of sampling need to be included (e.g. sampling depth and suggestions about what to do with leaf litter or mulch).
5. Additional notes about the site should be made including presence of plants and soil quality.
6. Clear instructions about the volume of samples are necessary and a standardized volume should be used because of differences in bulk density (which could be measured as well).
7. Sampling high traffic areas (e.g. walkways) should be avoided.
8. Contrasting sites should be selected to maximize the chance of differences in soil fauna, and correlate differences with soil factors (e.g. soil carbon).

Soil science resources for teachers

A detailed concept design for the soil science teacher resources was developed in relation to the project outcomes. Background theoretical and factual information was researched, reviewed and amended following teacher feedback. Procedure sheets, worksheets and results sheets were drafted for the pilot project and reviewed by teachers during the pilot project. Amendments were made following teacher feedback. A soil science equipment kit was prepared for each school with the support of members of the Western Australian Branch of ASSSI. A set of soil science text books which included information relevant to Western Australia was provided to each school by ASSSI. A professional learning day for the teachers was held by the SPICE program prior to the commencement of the pilot project in schools.

The Monitoring Soil Science Project website is being developed with two levels of access: one for schools which have been accredited and granted log-in approval, and one for the general public, including schools which are not yet accredited. Accreditation of schools to participate in the project involves establishment of a formal agreement between a local soil scientist and the school, and approval via the website. Accreditation will enable schools to upload data collected by students and a defined set of reference soil analyses provided by an approved local soil-testing laboratory, with oversight by the soil science mentor. A variety of resources will be available to all schools via the website so that accreditation is not essential, but it will be encouraged so that soil scientists are formally linked with a school in a mentoring role within an international network. The schools are located on the website via Google Earth. The general access to the website will enable anyone to follow the instructions and explore their own soil in a global context.

Making sure the monitoring soil science project is viable and ongoing

Embedding access to knowledge of soil science in school curricula and supporting teachers in using information about soil in their science teaching is an ongoing goal of the Monitoring Soil Science Project. Sustainability of the project requires: (i) establishing a reference plot of land at the school (every school has some land!), (ii) providing an entry point for students to attract their attention (living organisms – soil fauna), (iii) instructions that are easy to follow and do not require complex materials or equipment, (iv) support for teachers and students from a nominated soil science mentor, (v) web access for data uploading and visualization, (vi) involvement of local soil-testing laboratories through provision of a set of reference soil

analyses for each school, (vii) availability of suggestions for further activities, and (viii) connection with other schools via the website. Accreditation of schools which participate is an important part of the project, and this involves a connection with soil scientists and soil science societies. The project is affiliated with the International Union of Soil Sciences (Division 4).

Responses to the monitoring soil science project

***Science teacher**: "The year 9 students felt really privileged and excited to be a part of a pilot project like this one. Most of them did not realise and were amazed at the number of organisms that were living in such a small sample of soil. They had an opportunity to carry out scientific procedures and also to use technical equipment which they had not used before. Soil is no longer 'boring'! Teaching the project was easy as all the procedures were provided and easy to follow."*

***Science teacher**: "Initially the students were unsure of what they would find. Once they had experienced seeing the mites and springtails their interest was generated. All sorts of ideas of how we should proceed in our investigation were suggested. We pursued one particular avenue: a comparison between managed and unmanaged land. There was lots of discussion of possible further work. It was an excellent opportunity to conduct open-ended investigative work, which helps students understand the nature of science and the scientific method."*

***Student participant**: 'Sir, soils aren't soils anymore ….. it's a proper ecosystem"*

***Soil science mentor**: "I worked with high-achieving students who had a passionate, committed and highly skilled teacher. The students were very engaged with the activities in the project and seemed to have a good background knowledge. Guided by their teacher, the project gave students a great opportunity for hands-on learning, and it was great to see many of them experience moments of personal discovery."*

Photo 1. Collecting soil samples.

Photo 2. Examining the soil fauna.

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