Producing the thinking soil scientist

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Abstract
There is an increasing expectation that graduates in the discipline of soil science not only have a good grounding in existing knowledge, but the technical abilities and generic skills that enable them to use interdisciplinary approaches to solve real world problems. In doing so graduates have to be able to interact with members of the community at all levels and understand the social, economic and cultural elements that affect the adoption of the solutions they will provide. To develop graduates with such a holistic approach would require students, teachers and industry engaging with each other at appropriate times during the education process. To achieve this, and presented here for the first time, the evolution of a Teaching-Research-Industry-Learning (TRIL) educational framework is described and supported by educational theories. When illustrated using some of the current teaching and learning activities (e.g. practical classes or problem-based learning) used by soil science educators in Universities the theoretical framework may not be as foreign as it first appears. To evaluate the usefulness of TRIL five Australian Universities are working with agencies, accrediting bodies and industry to determine its use for producing a national soil science curriculum answering the need for work-ready graduates.

Key Words
Work ready, soil education, national curriculum.

Introduction
Today's graduates need to be adept problem solvers, use interdisciplinary approaches and be technically proficient. For example, Bouma (1997) states that modern approaches to indentifying and solving key issues in agriculture requires representation from a broad spectrum of the community, including agricultural scientists, government agents, environmental groups, producers and consumers. The development of graduates with a holistic approach requires greater synergy between students, teachers and industry. Surveys of students often indicate that teaching approaches tend to be traditional and teacher led. Many disciplines are also remote from industry such that, even with the best intentions, the development of work-ready graduates is lacking with problem-solving abilities being a common deficiency (AC Nielsen Research Services 2000). The Australian Vice-Chancellors have recognised the value of industry involvement in higher education for the development of work-ready graduates and have advocated a national internship scheme for all students (Universities Australia 2008). A recent Australian Learning and Teaching Council (ALTC) report on work-integrated learning has shown the growing trend in industry involvement in higher education and the benefits to students, universities and employers (Patrick *et al.* 2008).

As noted by Smiles *et al*. (2000) much of this is relevant to the discipline of soil science. Quoting John Philip when reflecting on his degree from Melbourne University 'all things are understood and that all a young engineer needs to know is what handbook to use' with the further point that 'a suppression of curiosity and the removal of the intellectual challenge made the course utterly boring and its products brain-dead'. Inspired by this quote Smiles *et al*. (2000) believes the challenge for soil science education is to stimulate curiosity and innovation while providing the students with a good grounding in existing knowledge. This also requires that students recognise the need for a holistic approach to solve real problems, but maintain their objectivity in their technical advice. They must be understandable when they interact with society and bureaucracy and understand that the application of soil science to problems has social, economic and cultural elements that affect its adoption by the end-user. To achieve this, a soil science educational framework needs to be developed that facilitates the interaction between the students, teachers and relevant industry parties.

The teaching-research-industry-learning (TRIL) framework
To satisfy the need for producing the thinking soil scientist to meet the challenges of the modern world, the TRIL framework needs to be considered. This framework illustrated in Figure 1 shows that learning by students and academics in a university is a complex interrelationship of teaching, research and association with industry.

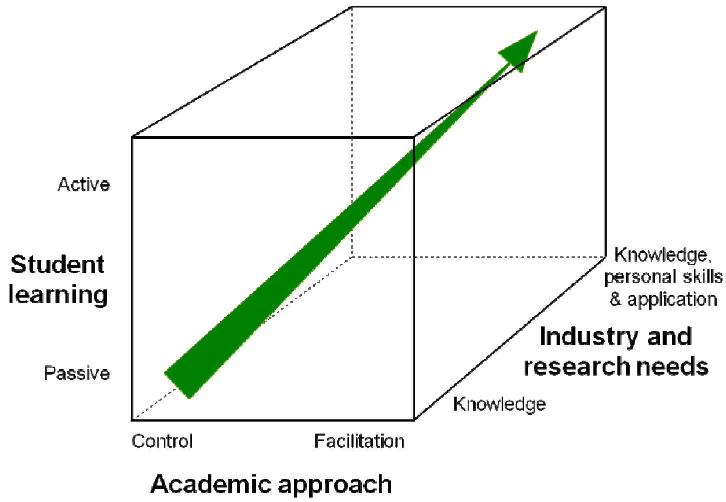

Figure 2. A further view of the Teaching-Research-Industry-Learning (TRIL) framework.

Learning is affected by the interaction between research and teaching and also by the impact industry has on them. Another view of the TRIL framework is given in Figure 2 and is concerned with the student, academic and industry with three axes that represent a continuum: student learning on a scale from passive to active; the academic teaching approach on a scale from controlling to facilitating; and the needs of industry, ranging from basic knowledge alone to knowledge, the application of knowledge, and the personal skills required to effectively perform in industry. The top right rear corner of the cube is where students are autonomous and independent learners enabled through academic facilitation to meet the needs of graduates for industry.

The theoretical justification for the relationship presented in Figure 2 begins with the concept that there is a need for a deep approach to learning so that students can relate theory and knowledge from different sources to construct a coherent whole. This is best achieved when students are active participants in their learning (Ramsden 2003) rather than passive recipients. This active learning needs to be supported by a teaching approach that relinquishes exclusive control by the teacher in favour of facilitation (Salmon 2003). Commonly, this often involves teaching and learning activities where the students interact with each other as well as the teacher. In particular, the students also have more choice in learning topics and assessment (Chickeing and Gamson 1991; McCombs and Lauer 1997; Boyer 1998; Duffy and Kirkley 2004). The intention is to focus on what the student does and promote student responsibility (Biggs 1999). Through this interaction it is also hoped, in addition to knowledge, that as graduates the students have acquired 'generic skills' or 'generic attributes' (Barrie 2004 2007). With these skills the graduates should have qualities such as adaptability, resourcefulness and flexibility to enable success in the workplace (Curtis and McKenzie 2001). This is best achieved by a closer liaison between employers and higher education when teaching and has been advocated for the mutual benefit of students and industry (Conner 2005). Furthermore, Garraway (2006) has noted that employers need to be part of the curriculum development process.

Looking at the teaching and learning activities that are currently used by soil science educators in Universities the TRIL theoretical framework may not be as foreign as it first appears. This can be illustrated by the following examples, all of which are satisfactory and relevant teaching and learning approaches used in soil science. If we consider the top left front corner of the framework, representing a controlled-active-knowledge building environment, this more than likely would represent many laboratory classes that students of soil science participate in throughout their degree.

Examples of soil science laboratory classes can be found that shift the activities towards the top right front corner where the teacher relinquishes control. In one such class the students negotiated with the teacher the theme of their study (e.g. heavy metal contamination or mineralogical characterisation of the profile). They then collected their own soil samples, were presented with a generic methods book, and had to write their findings for publication in the Australian Journal of Soil Research. The work was then assessed using the guidelines used by reviewers for accepting the paper for publication (Field and Gräfe 2007). The role of the instructors was to act as advisors as the expectation was the students would identify the appropriate; methods to use, data processing and manuscript preparation.

The controlled-active-application represented on the top left back corner of Figure 2 would describe case-based learning (CBL) commonly used not only in soil science but science in general (Smiles *et al.* 2000). In such an environment often students are presented with a problem and working with each other and the teacher acquire the knowledge and skills necessary to develop a solution. The key issue here is that the teacher has identified the problem and knows the answer to the problem that the student will finally present. More recently, an approach described as problem-based learning (PBL) is being used in the senior years at institutions that teach soil science (e.g. at The University of Sydney). The difference being that the students are put in contact with industry and work through a process to identify the problems and negotiate, with each other, industry and the teacher, which of these they are going to work through. The students are also expected to design the process and manage the problem, which they record and may be used in the assessment. As the problems are real the solution is not always know from the beginning, and as noted by Smiles *et al*. (2000), the solution has to take into consideration other factors such as economic constraints and/or government policy implications. Approaches such as PBL shift the learning to the top right far corner which should facilitate the development of the thinking soil scientist.

Researching for a curriculum

An additional challenge is the falling enrolments in sectors of the globe and the uneven distribution of academic expertise in institutions affecting the delivery of graduates with the required soil science expertise. This, in addition to the diversity of the Australian climate and landscape, has resulted in a partnership being formed between The University of Sydney and the universities of Melbourne, Adelaide, Queensland and Western Australia that will test the viability of the SAI framework to promote curriculum development. The key aim of this partnership is to involve industry more in student learning; establish shared and cooperative methods between universities to alleviate declining academic expertise in any one institution, and within the framework described above to develop learning and teaching processes to produce graduates with the knowledge and skills to meet the broad challenges facing the agricultural and environmental sectors. For this to occur representatives from other universities will be included as the project develops and a reference group includes representatives from: the Australian Council of Deans, the Australian Soil Science Society, Certified Professional Soil Scientists accreditation body, and industry partners. By looking at current teaching practices and canvassing the opinions of students, university staff and industry participants over a number of iterative action-cycles it is hoped that an overarching national soil science curriculum will start to emerge to address the key aims outlined.

Conclusions

This paper has highlighted the need for graduates who are work-ready and prepared to solve complex real world problems. Current thinking is that this is achieved through a strong engagement of the student, academics and industry in common teaching and learning environments. To support this a Teaching-Research-Industry-Learning (TRIL) framework has evolved and can accommodate the current teaching and learning practices already used in soil science, but also should prove useful when developing and mapping a curriculum that requires the input from students, teachers and industry.

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