ENGAGING EMPLOYERS, GRADUATES AND STUDENTS TO INFORM THE FUTURE CURRICULUM NEEDS OF SOIL SCIENCE

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ABSTRACT
This paper reports on the findings of a project to investigate the future needs of a soil science curriculum to produce work-ready graduates. Soil scientists are expected to deal with increasingly complex problems and graduates are required to not only have well developed soil science knowledge and skills, but can also work between and across other disciplines communicate their findings appropriately. Survey results obtained from current students, graduates and employers of soil science indicated some areas of discipline knowledge that need to be addressed, as well as more emphasis on developing critical thinking and problem solving skills. Employers also expressed the desire to not only provide advice on curriculum change but a willingness to be involved in the learning environment. Using problem based learning as the scaffold an example of how industry maybe engaged is provided. Issues are raised around the need to align the graduate outcomes for soil science with Threshold Learning Outcomes for Science and Agriculture and the need for a core-body of knowledge (CBoK) that characterise graduates with soil science knowledge. As a result of widespread stakeholder consultations during the project a set of soil science teaching principles was developed (Field, Koppi, Jarrett, Abbott, Cattle, Grant, McBratney, Menzies, & Weatherly, 2011).

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INTRODUCTION
This paper reports on an ALTC funded project concerned with the knowledge, skills and capabilities needed to produce work-ready graduates with soil science knowledge which is relevant to the future needs of Australia. This is informed using feedback from current soil science students and graduates, and employers requiring soil science expertise. The paper also describes an approach that can be used to incorporate industry into the 'classroom' to further develop students' problem solving skills.

Soil is identified as being integral to many of the problems facing ecological and societal systems, including the challenges of: food, water & energy security, loss of biodiversity, and climate change abatement (Hartemink & McBratney, 2008; Flannery, 2010; Janzen, Fixen, Franzluebbers, Hattey, Izaurralde, Ketterings, Lobb, & Schlesinger, 2011; Koch, McBratney, Adams, Field, D., Lal, Abbott, Angers, Baldock, Barbier, Binkley, Bird, Bouma, Chenu, Crawford, Flora, Goulding, Grunwald, Hempel, Jastrow, Lehmann, Lorenz, Minasny, Morgan, O'Donnell, Parton, Rice, Wall, Whitehead, Young, & Zimmermann, 2013). This recognition means that those who identify as soil scientists or having soil science expertise will need to engage with a variety of people to identify what the problems are, and in doing so, work towards providing solutions to these ever increasing complex environmental problems. Not only do they need to have high levels of knowledge, skills and capabilities in soil science but they will have to be able to work between and across other disciplines to address these pressing issues. As pointed out by Bouma (2010) solving complex contemporary problems will not solely rely on the objective (*science*) answers of right or wrong, but also the relativistic (*societal and political*) answers that consider decisions as 'better' or 'worse'. Therefore, future graduates need to be able to engage with scientists from their own and other disciplines, policy experts, and users of relevant soil information (Wesslock, 2006).

To respond to this the soil science community undertook a process to review the needs of a future soil science curriculum. Curriculum change can be approached by reflecting on the feedback from stakeholders and the experiences of those who teach, as well as, from those who are learning (Jarvis *et al*., 2012). Knowing the role society is now expecting of soil science, feedback from employers, graduates, current students and academics were identified as representatives of the soil science community and their involvement should prove useful in evaluating curriculum change as required. With this in mind a 2-year project was established with the aim to develop a soil science curriculum that will produce work-ready graduates with the interdisciplinary knowledge, skills and capabilities relevant to the needs of Australia (Field, Koppi, Jarrett, McBratney, Abbott, Grant, Kopittke, Menzies, & Weatherly, 2012).

METHODS

This project involved core participants form the Universities of Sydney (lead), Adelaide, Melbourne, Queensland, and Western Australia. Part of the research was conducted using data collected via surveys of current students, graduates and academics of soil science as well as their employers (Ethics-12584). The surveying of current soil science undergraduates of the five participating universities asked about the learning and teaching of soil science in relation to their experiences and expectations. Informed by Fowler (2002), the design of the survey included open-responses in most questions to avoid constraining student responses and was delivered on-line. There were 107 responses (24 % response rate) with over 300 comments made. Graduates with soil science knowledge were asked if their education in soil science prepared them for their current employment, which was delivered online generating 205 responses. The response rate could not be determined as this survey was distributed through the alumni offices of each participating institution and their adherence to confidentiality meant the number of surveys distributed was not provided. Fifty-two employers (37 % response rate) from around Australia responded to their paper-based survey. While a range of questions was asked of graduates and soil science employers, for the purposes of this paper, the discipline knowledge, preparedness of graduates, and critical thinking abilities are most relevant.

In the graduates and employers surveys the questions used a Likert scale ranging from '*not at all important*' (scored as 1) to '*very important*' (scored as 5) and, each question queried what were their '*needs*' as opposed to what they actually '*got*'. An attribute, skill or knowledge was identified as a concern if their median rating for 'need' was a 5 and there was a significant difference between this and what the employers or graduates perceived they actually 'got'. The magnitude of the difference between these two criteria enabled the importance of the attributes, skills and knowledge to be ranked. For all surveys a thematic approach, as informed by Boyatzis (1998) and Bogdan and Biklen (2002), was used to analyse the qualitative responses made. The detailed responses to the surveys and relevant rankings identified from employer and graduate responses can be found in a report submitted to the Office and Learning and Teaching by Field *et al*. (2012). For this paper the significant concerns raised by students, graduates and employers using both the qualitative and quantitative responses have been combined and presented here in Table (1).

The survey data was also used in a series of forums which where framed using a sequential action learning-model approach, guided by Kelly, Reid, and Valentine (2006). This involved participants coming together   This approach was chosen as it recognises that the teaching of soil science involves a community of: soil science teachers (with their own personal experiences of teaching), students (with their own preferences for ways of learning), and the valuable input that can be provided by soil science graduates, employers of soil scientists, other stakeholders, and the use of the education literature (Field *et al*., 2011). The design of each forum used a combination of prior consultation on topic tabled at each forum, bring participants together to meet, provision of information to set the context, plenty of time for small mixed-group workshop activities, topics led by team members with expert input only when required (Schön, 1987; Brookfield, 1995; Canadian Literacy and Learning Network, 2011). The first forum involved academic staff reflecting on their teaching practices, experiences, and the feedback provided by the student surveys, as a way to inspire change (Jarrett, Field, & Koppi, 2011). The second forum required participants to further reflect on the teaching and learning practices in response to feedback obtained from graduates and employers. While the third forum focused on opportunities to develop common units of study between the institutions involved.

RESULTS AND DISCUSSION

It is not surprising that discipline knowledge was identified by employers, graduates and current students as being key to preparing them for the workplace (Table 1). Employers and graduates did note that the level of knowledge was a concern, and in particular they noted that application of their discipline knowledge to provide solutions to environmental issues was important. Employers also identified that an understanding of how soil science knowledge is useful in systems approaches, and that soil chemistry knowledge could also be improved. This focus on environmental issues demonstrates that soil science has moved from predominately servicing agriculture to addressing environmental concerns (Havlin, Dalster, Chapman, Ferris, Thompson, & Smith, 2010; Hartemink, 2012).

The use of fieldwork and laboratories as teaching environments was identified as being essential learning environments in preparing graduates for the workplace. This is a critical observation as evidence is needed to justify fieldwork teaching in an environment when costs savings in teaching are often promoted. Critical thinking and problem solving were consistently identified where improvements could be made by all groups surveyed. Students stated that courses should always have a component of critical thinking while employers and graduates ranked having the ability to identify the problem from a mass of detail is a high priority and this also needs to be combined with improved communication skills (Table 1). At the forums employers made it clear that writing skills in particular need attention. This issue is not the technicalities of writing, i.e. spelling and grammar, but that graduates focused only on the conclusions, neglecting the need to properly describe the problem and how the problem was to be analysed which are basic requirements of clients. Team work was also raised as a concern and employers did note that although this should be part of the teaching at University that this will be further developed when graduates spend time in the workplace. The need for good discipline knowledge, critical thinking, problem solving, and good communication skills for soil science graduates is also supported internationally, as reported by Jarvis, Collett, Wingenbach, Heilman, and Fowler (2012).

These concerns were reviewed at the second project forum which resulted in the development and publication of a set of soil science teaching principles (Field *et al*., 2011). These principles reflect the nature of soil and the practices of soil scientists. In particular, the principles emphasize the need to engage students in authentic real-world problems, and be able to integrate their knowledge of soil science in different situations. Soil related problems are part of a system and there is a need for graduates to also recognise the social and economic dimensions when suggesting solutions to problems being presented. Bouma and McBratney (2013) suggests that adopting teaching practices based on these principles of problem-solving and recognition of interdisciplinarity in soil science curricula will make a significant contribution to preparing graduates to effectively engage with complex contemporary problems where the solutions are now not about ‘wrong’ or ‘right’ but a choice between ‘better’ of ‘worse’.

Although the development of on-going common units of study across the participating institutions needs to still be realised the teaching and learning aspirations described in the teaching principles and the desire to engage industry in the teaching soil science inspired the development of the *Teaching-Research-Industry-Learning* nexus as described in Field, Koppi, and McBratney (2010). As well as recognising the usual teaching practices of lectures, laboratories, fieldwork and the opportunity of research, this nexus emphasizes the use of problem based learning as a framework to engage industry into the learning environment. This is illustrated by a capstone soil science unit of study at The University of Sydney. In this problem-based unit students work on authentic real-world problems and its success relies on the involvement of industry and the community, i.e. as clients. Student teams must negotiate, work with, and report to the client. To date industry and the community have engaged students in a number of problems sourced from agricultural and environmental areas situated in both rural and urban environments. As evidence of the real-world nature of the problems some of the reports produced by students have actually been used by the client of the scenario. This learning approach also requires students to consider problems as transdisciplinary. Table (2) is an example of a list of questions that was raised when students considered the impact of changes in soil organic carbon in the Hunter Wine Growing region requested by the Private Irrigation District (PID). It is evident, as we move down through the questions, the need to engage other discipline knowledge increases as does the complexity regarding possible solutions, moving towards decisions of ‘better’ or ‘worse’. The change in the communities that would be interested would need to be considered when reporting the solutions. Although employers acknowledge that the knowledge, skills and capabilities required to achieve this will develop with the on-going experiences in the workplace they do see the benefit of introducing students to these experiences, thus their continued willingness to give their time for this teaching activity.

Table 1: Major concerns from employers (Emp.) and graduates (Grad.) responses to qualitative (quant., *Likert ratings*) and qualitative data (qual., *written comments*), as well as, corresponding findings from the student surveys. The (✓) indicates where there was a

discrepancy identified by the groups surveyed between what they 'need' and what they 'got' (derived from Field *et al.*, 2012)

Issue	Emp. quant.	Emp. qual.	Grad. quant.	Grad qual.	
Discipline Knowledge	✓	✓	✓	✓	Discipline knowledge was the most common reason cited when students were asked how their courses prepared them for employment
Data interpretation/scientific method	✓	✓			
Applying knowledge and skills, e.g. field measurements & sampling/laboratory techniques	✓	✓		✓	Students want more laboratory and fieldwork or complain that it's missing from their courses. These were overwhelmingly seen as the most effective learning activities
Written communication skills: technical reports, communicating to non-discipline experts.	✓	✓	✓	✓	
Critical thinking and problem solving	✓	✓	✓	✓	Most students agreed that courses should involve problem-solving and critical thinking. Currently these activities comprise relatively small proportions of the time.
Keeping up to date with relevant developments	✓		✓	✓	
Contact with professionals in industry/work place		✓		✓	Over one third of students recognized that courses involved input from industry
Interpersonal skills: team-working and relating to clients	✓		✓		Apart from field and laboratory work, activities are relatively solitary.

Table 2: Aligning the types of questions with the characteristics of 'Mode 1' and 'Mode 2' types of knowledge as defined in Nowotny, Scott, and Gibbons (2002).

A Range of Consulting Questions	Knowledge	Types of engagement
1) What quantity of soil organic carbon (SOC) is required to benefit crop production 2) What management practices will maintain or increase SOC	'Mode 1'	*Context*: Academic *Who*: discipline experts *Character*: monodisciplinary, or (interdisciplinary) *Ouput*: publication 'h-index'
3) How has the change in management practices in the PID affected SOC quantities 4) How do we use SOC as a soil quality indicator that will be seen as beneficial by the PID 5) How can the SOC be used as carbon offsets by the PID in a carbon trading scheme	'Mode 2'	*Context*: Real-world *Who*: Discipline experts Stakeholders Policy *Character*: transdisciplinary *Ouput*: novel procedures societal effectiveness

CONCLUSIONS AND FUTURE WORK

Feedback from students, graduates and employers surveys and discussions in forums have identified some concerns in knowledge, skills and capabilities that need to be addressed in future soil science curriculums to produce work-ready graduates. The ability to apply soil science knowledge across disciplines and to environmental systems and, to develop the critical thinking and problem solving were identified by all groups surveyed. A set of teaching principles has been develop and published to address these changes and as a framework to map the different teaching practices and encourage fieldwork and problem-based learning environments. Where possible this problem-based learning should involve participation of industry and community groups and focus on authentic real-world problems.

During the project a number of over-arching learning outcomes where developed and published (Field *et al*., 2011). With the advent of the Threshold Learning Outcomes (TLO's) initiative there may be a need to determine how the soil science graduate outcomes align and contribute to the TLO's produced for Bachelor of Science (Jones & Yates, 2011) and the future the TLO's being developed for Agriculture (Acuna, Lane, Kelder, & Hannan, 2012), at a course and institutional levels (Table 3). As with the problem-based learning questions, a key characteristic of the graduate outcomes is the recognition of engaging with other disciplines, recognise the contextual nature of problems, and ability to work with and communicate with the broader community, which is illustrated as you move through the graduate outcomes from 1 to 4 (Table 3). These soil science graduate outcomes guide the unit of study described earlier.

Table 3: Soil science graduate outcomes (Field *et al*., 2011) aligned with the TLO's for Science (Jones *et al*., 2011).

Soil Science Graduate Outcomes	Threshold Learning Outcomes, for Science
1) Identification, understanding and application of the unique features of Soil Science	align with 1.1 & 1.2
2) The role, context and relationships of Soil Science to other disciplines and society as part of interrelated systems	align with 2.1 &2.2
3) Identify problems and designing relevant contextual solutions	align with 3.1, 3.2, 3.3, & 3.4
4) The ability to coordinate and function within and between relevant groups and effectively communicate results.	align with 4.1
5) Manage self for personal development and lifelong learning	align with 5.1, 5.2, & 5.3

Finally, in the later forums the question of needing a core body of knowledge (CBoK) for soil science was flagged. Since there is no degree in soil science and that it is taught in many courses such as in Agriculture, Earth Science, and Environmental Sciences, participants queried if there is a need to develop a CBoK to guarantee a minimum standard of knowledge of graduates. They also asked if a CBoK is developed what will be the framework around this to ensure that this CBoK is reviewed regularly keeping it up-to-date and relevant to produce work-ready competent graduates with soil science expertise.

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