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Identifying learning outcomes for a Canadian pedology field school: Addressing the gap between new graduates’ skills and the needs of the current job market

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ABSTRACT

To address concerns among members of the Canadian Society of Soil Science (CSSS) regarding the discipline’s capacity to train new soil professionals, specifically in pedology and field skills, members of the CSSS’s soil education and pedology committees have proposed to develop a pedology field school. To aid in the selection of learning outcomes that are relevant to professional practice, an online survey was sent to Canadian soil professionals within private industry and governmental organizations. Professional feedback was also requested regarding the creation of a web-based national soil education resource, and the certification of soil pedological skills. According to the survey results, the quality of new graduates’ pedology and field skills was perceived as poor. Certain soil field skills and knowledge were thought to be either completely absent from the current Canadian curriculum (e.g. spatial variability of soil processes), or not well mastered by graduates (e.g. interpreting soil survey reports). Important learning outcomes were identified, such as: interpreting soil survey information, soil mapping, and soil-landscape classification with soil description/classification and soil genesis content needed as a refresher. Taking into consideration existing regional field schools, we recommend that the CSSS co-creates, where needed, and coordinate, where they already exist, regional pedology field schools throughout Canada. We also propose that CSSS develop a national pedology certification, and a web-based soil education resource. Also, further study is necessary to shed light on the contribution of non-disciplinary graduates to the professional practice and the impact this has on the perception of soil education in Canada.

Key words: field school, pedology, soil science, skills and knowledge, profession, education, postsecondary
INTRODUCTION

Soil science is a unique discipline characterized by the interactions between fundamental research and its applications (Bouma, 2001) or, as John Philip put it “[…] the content of soil science is uneasily placed between natural science on the one hand, and the world of professional practice on the other” (Philip, 1991). The discipline of soil science has undergone significant transformations since the major scientific discoveries of the early 20th century, followed by a decline in funding, lower student enrollment, and attrition of university departments in the 1990s and 2000s (Basher, 1997; Mermut and Eswaran, 2001; Baveye et al., 2006) to, more recently, a renewed demand for soil science expertise and information (Hartemink and McBratney, 2008; Hartemink et al., 2014).

The documented reduction in disciplinary capacity has been keenly felt in the sub-discipline of pedology. Pedology, with its focus on description, genesis, classification and mapping of soils, requires extensive field skills and is of great importance to the professional practice of soil science. Recently, members of the Canadian Society of Soil Science (CSSS)’s pedology committee acknowledged a growing concern regarding the nation-wide loss of academic capacity in pedology that has occurred over the last two to three decades. As pedologists retire they are not replaced, particularly in universities, research institutes, and governmental organizations. This loss has been exacerbated by an increase in demand for graduates with pedology knowledge and field skills. Some members of the committee representing industry professionals indicated that they were usually the only people on their teams that could carry out soil descriptions and understand the principles of soil formation, while members from academia indicated that they were often the only instructors in their unit that could teach pedology (Masse, 2017). In parallel, the closure of the soil survey units within the Federal government in the late 1990s and throughout the 2000s have deprived students of opportunities,
outside of the academic settings, to learn pedology in the field (Anderson and Smith, 2011). Arising from these discussions was a call to the CSSS to develop a pedology field school to be offered in addition to current field courses. The CSSS’s pedology committee members who work for government organizations also indicated that there is a need to instill rigor in the professional practice regarding soils field skills and knowledge through certification (Masse, 2017)

Hence, the overall objective of this study was to collect feedback from government and industry soil science professionals to guide the development of a pedology field school. Specifically, the views and opinions of soils professionals were collected on the following topics: (1) overall quality of soil science education in Canada; (2) pedology and field skills of new graduates needed for the professional practice of soil science; (3) current quality of training in pedology and field skills that new graduates possess; (4) structural form of the field school intended to be developed by the CSSS; and, (5) certification of pedological skills and knowledge, and need for a national pedology education web-infrastructure. Understanding the skills and knowledge that are relevant to professional practice, coupled with identification of those skills and knowledge that graduates are lacking, identifies the knowledge gap between the academic training and that needed by professional practice. In turn, understanding this gap would allow development of effective learning outcomes for a pedology field school. To our knowledge, this is the first time soil science professionals in Canada have been asked to participate in a national survey on learning outcomes for course development.
MATERIALS AND METHODS

To address the interests of government and industry soil science professionals regarding job-readiness of recent graduates, and to provide guidance on the basic structure and learning outcomes for the design of the pedology field school, an online-survey was designed and conducted with the professional assistance of the Social Science Research Laboratories (SSRL) of the University of Saskatchewan and delivered using the Voxco online survey platform (Group Voxco, Montreal, QC, Canada). The survey consisted of 14 questions that inquired about the respondents’ place of employment, the type of soil science knowledge and skills required for their work, and if there was a need for further training or resources for individuals practicing pedology skills and knowledge. Six out of 14 questions proposed multiple choices answers, three questions proposed yes/no answers, and five questions used a Likert scale-type (i.e., a rating scale from 1 to 5) answers. The respondents could also provide additional comments on 11 of the 14 questions asked. The complete list of survey questions can be found in the Supplementary Materials (Supplementary Material A).

The survey was sent to 104 active soil science professionals across Canada. These individuals were identified by co-authors of this study as those that currently supervise, employ, have hired and/or work directly with staff members who are responsible for soil survey and related field soil assessments. The respondents were invited to complete the survey via e-mail invitation sent by the SSRL. The initial invitation was sent on March 26, 2018, with subsequent reminders sent on April 10 and 25, 2018; and the survey closed on May 9, 2018. The survey took approximately 15-20 minutes to complete. Respondents were also invited to forward the survey link to other colleagues they considered suitable and should be included. Given this format of distribution, a response rate cannot be calculated. Each respondent was informed that consent was
assumed if the respondent completed the survey; however, participants also had the right to withdraw at any point before completion of the survey. The survey, including method for contacting potential participants and handling of results, was examined by the Behavioural Research Ethics Board of the University of Saskatchewan and given an exemption from ethics review.

Descriptive statistics were used to present an overview of the answers provided by the respondents. Then, item cluster analysis (ICLUST) using the R package psych (1.8.4) was performed to identified areas of interest from the respondents based on how each respondent answered the Likert scale-types questions, i.e. questions on a) the reasons for obtaining additional field training in soil science; b) the importance of different soil knowledge or skills to the current job market; and, c) the perceived quality of soil knowledge or skills of the graduates hired in their organization (Revelle, 2018). ICLUST is a hierarchical item-clustering procedure that uses reliability coefficients Cronbach’s α (eq.1) and Revelle’s β (eq. 2) conjointly to decide when to stop clustering (Cooksey and Soutar, 2006; Zinbarg et al., 2005).

\[
\alpha = \frac{N \cdot \bar{c}}{\nu + (N - 1) \cdot \bar{c}} \quad \text{(eq.1)}
\]

where: \( \alpha \) is the Cronbach’s α, \( N \) is the number of items, \( \bar{c} \) is the average inter-item covariance, and \( \nu \) equals the average variance. Cronbach’s alpha takes values from 0 to 1, with values >0.7 being considered as an indication of internal consistency in the response dataset.

\[
\beta = \frac{(n + m)^2 (\min \sigma_{ij})}{\sigma_i^2} \quad \text{(eq. 2)}
\]
where: \( \beta \) is the Revelle’s beta coefficient, \( n \) is the number of items in the first subscale, \( m \) is the number of items in the second subscale, \( \min \sigma_{ij} \) is the minimum of all possible averages of between-half item covariances, and \( \sigma_t^2 \) the variance of the total scale. The \( \beta \) coefficient takes values from 0-1, where 1 is 100% of the variance associated with a general first factor (Cooksey and Soutar, 2006). It is considered in support of, but also a better indicator than Cronbach’s alpha.

Guttman's \( \lambda_6 \) was also employed to assess the reliability of the clusters (eq. 3):
\[
\lambda_6 = 1 - \frac{\sum_{j=1}^{n} e_j^2}{s_t^2}
\]

where: \( \lambda_6 \) = Guttman’s lambda 6, \( e_j^2 \) is the variance of the errors of estimate of item j from its linear multiple regression on the remaining \( n-1 \) items, and \( s_t^2 \) is the total variance (Guttman, 1945; Revelle, 2018). Guttman’s \( \lambda_6 \) considers the amount of variance in each item that can be accounted for by the linear regression of all of the other items. In datasets with few responders and a large number of responses the coefficient may overestimate reliability; however, it may be indicative of reliability of results when taken together with other indicators. Statistical analyses were conducted using R version 3.4.0 (R Core Team, 2017).

**RESULTS**

**Characteristics of the Respondents**

Thirty-seven respondents completed the survey. One respondent only provided two comments. His/her qualitative data were analyzed, but missing responses from that respondent were not included in the statistical analyses. Most respondents indicated that they worked within the private sector (50%, \( n=18 \)) or for a provincial government (39%, \( n=14 \)). The remaining
(12%, n=4) were split evenly between the federal government and non-governmental organizations. Originally, 54% of the invitations to participate in this survey were sent to industry professionals, 42% to government, and 4% to non-governmental professionals. This indicates that the response from each sector was proportional to the invitations sent. Moreover, we did not receive any responses from respondents that felt they were not one of the target sectors (i.e., no “others”).

Most respondents worked in ecology and environmental assessment (22%, n = 8) or crop production and agronomy (17%, n = 6), followed by soil characterization and mapping (14%, n = 5), restoration and remediation (11%, n = 4), land management (8%, n = 3), and land use planning (5%, n = 2). Of the remainder, respondents were evenly split between engineering (n = 1), forestry (n = 1), and mining (n = 1). Five respondents reported working in other specializations, such as agriculture, beneficial residuals management, land conservation, professional regulation, and land reclamation. Overall, respondents’ specializations were quite diverse, with a strong preponderance of applied disciplines.

Nearly all respondents (97%, n=35) were in a career position that requires pedology knowledge and skills, and 83% (n = 30) also reported that their knowledge extends to soil field skills, including sampling, soil profile characterization, soil classification and soil mapping. The majority of respondents were responsible for an employee who required pedology knowledge or field skills, either as a supervisor (64%, n = 23) or when hiring new employees (47 %, n = 17). A minority of respondents were not involved in supervising or hiring employees who needed these skills (28%, n = 10). Thus, we can be confident that the majority of respondents could speak with credibility on learning outcomes and design of a field school in pedology.
Perceived Quality of Soil Education

Overall, respondents did not report favourably on the current state of soil science education in Canada (Fig. 1), since the majority stated that graduates with whom they worked require additional training (94%, n = 33), either through a refresher course (34%, n = 12) or more intensive training in soil science knowledge and field skills (60%, n = 21). Only two respondents stated that current Canadian soil science education is adequate (Fig. 1). None of the respondents stated that soil science training was irrelevant for recent graduates or that gaps in training were small enough that they could be eliminated through on-the-job training.

When expanding on their response with a comment, some respondents stated that soil science education in Canada is adequate, but that it depended on the post-secondary institution. Additionally, Canadian courses may provide adequate teaching in some soil science areas but be lacking in others. Other respondents suggested that soil science education is ultimately lacking, as new graduates are not receiving comprehensive training in all necessary skills, usually due to lack of access to soil science-specific education. Participants also stated that they perceived the quality of education to be declining over the years. Pedology was identified as an area of weakness by several respondents. Additionally, it was stated that soil science education needs to be better aligned with the current job market (Table 1).

None of the respondents stated that their new hires were exceptional in any of the knowledge or skill areas even if that category was available to them (Fig. 2). Nonetheless, the majority of respondents agreed that new graduates possess either “good” or “excellent” knowledge and skills in principles of soil genesis and development (55%, n = 18), soil profile characterization (53%, n = 17), Canadian system of soil classification (50%, n = 16), role of soils in land reclamation (47%, n = 15), and interpreting soil analysis reports (42%, n = 14).
Numerous respondents indicated that new hires performed poorly on several other soil knowledge and skill areas including the role of soils in environmental assessment (39%, \( n = 12 \)), role of soils in ecosite classification (43%, \( n = 13 \)), soil survey and mapping (47%, \( n = 15 \)), hydric soil identification (55%, \( n = 18 \)), and non-Canadian soil classification systems (62%, \( n = 20 \)) (Fig. 2).

Participants were also given the option to provide an assessment of the level of preparedness new graduates had for soil knowledge and skills that were not originally mentioned in the survey (Table 2). All suggestions, shown in Table 2, were made by an individual respondent, with no area suggested by multiple respondents. For example, new graduates were considered to have a good understanding of soil chemistry, while their understanding of GIS and assessing soils in regard to sustainable agriculture were rated as satisfactory. On the other hand, it was thought that new graduates had a poor understanding of topics such as spatial variability of soil processes and landforms, surficial geology and geomorphology, predictive mapping, contaminant behaviour, the significance of soil biology and the role of soils in risk assessment. None of the respondent claimed that new graduates had an excellent or an exceptional understanding of their suggested skills (Table 2).

**Important Soil Science Knowledge and Skills Needed by New Graduates**

Respondents were asked to rank a number of skills and knowledge, identified by the research team, based on their perceived importance for the current job-market and their ranking (from most to least important) was as follows: (1) Soil profile characterization; (2) Interpretation of soil survey reports; (3) Interpretation of soil analysis; (4) Explanation of soils’ roles in environmental assessment; (5) Knowledge of the Canadian system of soil classification; (6) Knowledge of soil genesis and development; and (7) Knowledge of landform classification (Fig.
3). On the other hand, respondents viewed the following knowledge and skill areas as the least important for new graduates: (1) Knowledge of soils’ roles in ecosite classification; (2) Identification of hydric soil; and, (3) Knowledge of non-Canadian soil classification systems (Fig. 3). Respondents also had an option to suggest additional, potentially useful knowledge and skills to new graduates (Table 3). The suggestions included both theoretical and applied subjects specific to soil science such as soil chemistry, spatial variability of soil processes, surficial geology and geomorphology, significance of soil biology, GIS, predictive mapping, soil handling during construction, and general personal skills like driving on gravel roads, inter-personal skills and more (Table 3). All suggestions, shown in Table 3, were made by an individual respondent, and none of the skills were suggested by multiple respondents.

Overall, respondents stated that the most important reasons for new graduates to obtain additional training were the need (1) to gain hands-on experience; (2) to augment previous training from an allied discipline; (3) to better supervise and train other junior staff; (4) to augment classroom or lab-focused training in soil science; and, (5) to be a better policy developer. They stated that obtaining a professional designation and general interest or curiosity were less important reasons to engage in additional training (Fig. 4).

**Interest and Suggestions for Field Training**

Overall, respondents indicated that a pedology field school would be useful and beneficial to them and their colleagues. The following comment summarizes that sentiment “I think a soil survey and soil utilization field school is an excellent idea. I constantly view information, or participate in on-line offerings, the Soil Science Society of America makes available. I could be ignorant when it comes to such offerings in Canada, but I think I have had a good look around at what’s available; certainly would welcome any training opportunities. The Canadian Society of
Soil Science could move soil management within Canada progressively forward with training programs such as the field school”.

Some respondents also provided suggestions for how the pedology field school should be designed, namely through mentorship and field courses. Participants also suggested that the field school should focus on region-specific soil types, include multiple sessions, and involve standardization of soil survey protocol. One respondent stated that similar training opportunities have already been developed by other organizations (e.g., Pacific Regional Society of Soil Science Summer (PRSSS) soil ID course) and that a national field school should expand the existing initiatives (see comments in Supplementary Material B).

Regarding the duration of the pedology field school, the majority of respondents (46%, n = 17) asserted that the field school should be 3 to 5 days in length or 5 to 8 days (39%, n = 14). There was, however, some discrepancy in participants’ responses, since one participant stated that the field school should consist of five 1-day courses offered in sequential years; while the other respondent specified that the field school should be 2 days in length. Two respondents stated that the field school should be a minimum of 2 weeks. Furthermore, one respondent was uncertain on an appropriate length for the field school and said it depends on who attends and what their objective for attending. Participants also identified a number of barriers to field training that exceeded several days, such as the need for attendees to take time off work and the cost of a longer training program. One respondent suggested that the field school should take place in May, as the summer months are too busy (Fig. 5).

The majority of respondents (44%, n = 16) stated that the cost of the field school should be less than $1,000 or between $1,000 and $2,000 (39%, n = 14), while 14% (n=5) of respondents stated that the cost should be between $2,000 and $3,000 (data not shown). None of the respondents thought the field school should cost more than $3,000.
Through additional comments (see Supplementary Material B), respondents further confirmed that the field training would need to be fairly inexpensive (<$1,000) in order for most professionals to attend. However, respondents stated that they would be able to provide a more accurate estimate if they were provided with the course outline and objectives. One of the respondents suggested that the field school could be industry sponsored.

**Obtaining Soil Science Recognition**

When asked about the importance for soil science professionals to obtain an academic credit for soil science field skills courses, by writing an exam or doing additional assignments, the majority of respondents stated that it was important or very important (64%, n = 23), with an additional 28% (n = 10) stating that an academic credit might be a good idea (data not shown). Only 8% (n=3) of respondents stated that an academic credit was not important. Over half of respondents expressed that obtaining a certification or professional designation from a professional body to recognize successful completion and competence in soil science field skills was very important or important (53%, n = 19), while an additional 42% (n = 15) of respondents stated that a certification or designation might be a good idea, and 6% considered that certification was not important.

**Need for National Web-based Training Resources**

All 37 respondents agreed that national resources for soil science knowledge and field skills training would be useful for their organization, particularly if those resources could also help with standardization of methods and protocols. They all also agreed that such resources should not be used as a replacement for field hands-on experience. The majority of respondents (61%, n = 22) stated that access to this national resource should be free, while 31% (n=11) of
respondents thought that access should be granted using a paid subscription, and a minority (8%, \( n = 3 \)) suggested pay-per-use. Generally, respondents expressed concern that a pay-per-use model will hinder usage of the resource.

Relationships Among Graduates Knowledge, Educational Needs, and Training Goals

Results from the item cluster analysis allowed us to separate the respondents’ answers into three main clusters based on how respondents answered the Likert-type questions on: (1) the perceived quality of the graduate training (Q); (2) the skills needed for the current job market (Education needs – Ed); and, (3) the reasons why people in their organization want or need additional field-focused training in soil science (teaching goals – TG) (Fig. 6). Referring to the right side of the cluster-tree and through C24 to C31 of Fig. 6, cluster 1 (C26 and C28) groups the perceived quality of graduates in terms of large-scale soil skills such as soils and environmental assessment, soils and ecosystems classification, and soil survey and mapping. The learning objectives or teaching goals assigned to this cluster were general interest and refresher. Cluster 2 (C29 to C31 in Fig. 6) groups the perception of the graduates’ knowledge in terms of soil description and soil survey skills, such as knowledge of soil profile characterisation, soil sampling design, understanding soil reports and surveys, and soil classification (national and international). The teaching goals associated with this cluster were to learn about specific topics of a directed relevance for obtaining professional designation and to become familiar with the regulatory requirements.

Cluster 3 (C24 and C25 in Fig. 6) encompassed most of the identified skills needed for the current job market (i.e. educational needs). One could consider that cluster 3 lists a series of soil skills need by the current job market (such as knowledge of soil and land reclamation, soil sampling design, understanding soil survey, Canadian soil classification, etc.). The teaching goals
associated with this cluster were: to augment previous training of employees enabling them to
supervise other employees; to be better regulators; and, to get more hands-on experience as well
as to augment previous classroom education.

Knowledge of regulatory requirements, international soil classification systems, and
hydric soils were grouped together, but were negatively related to the cluster 2. It is also
interesting to note that the perception of the quality of graduates’ training in the areas of soil and
land reclamation and soil and landform classification was less consistent among respondents
(both are separately and weakly clustered away from the other parameters in a small fourth
cluster) and thus not notably associated with any teaching goals or educational needs.

DISCUSSION

Soil professionals surveyed considered new graduates to have, in general, a poor
understanding of pedology. It is important to point out that this question was asked in order to
identify skills that are currently lacking among new graduates and that which could be
supplemented by a pedology field school; this was not meant to test the fundamental knowledge
of new graduates from a specific program, may it be soil science or non-disciplinary (e.g.,
geology, geography, environmental biology). Therefore, answers may reflect the fact that some
hires do not have soil science degrees, with some (or possibly many) having only taken one
introductory-level soils course. It is then possible that students trained in other subject fields are
asked to carry out the responsibilities as a pedologist, or as a broader soil professional without
adequate further training in soil science. Some respondents also stated that the quality of
pedology knowledge of a new graduate was dependent upon their postsecondary institution.

The state of post-secondary soil science education has been comprehensively examined in
both Canada and the United States in recent years (Baveye et al., 2006; Collins, 2008; Havlin et
al., 2010; Hartemink et al., 2014; Brevik et al., 2014; Diochon et al., 2017; Krzic et al., 2018).
Canadian studies by Diochon et al. (2017) and Krzic et al. (2018) have revealed that the majority of students enrolled in soil science courses come from environmental sciences, natural resource management, geography, geology, and crop science programs; yet, many of these graduates seek soil related employment in either industry or government.

The shift in the delivery of soil courses from soil science departments and programs to geography, environmental and natural resource sciences programs has had an impact on the type of soil science courses currently offered in Canada (Diochon et al. 2017). Because these programs need to offer a wider range of disciplinary topics, including social sciences, soil science skills and knowledge initially delivered in detail in several courses are being condensed into one or two introductory courses. In this context, specialized soil science courses, such as pedology, receive less attention in the curriculum planning. Of course, there are still some postsecondary programs that do continue to offer pedology courses; however, those are often not instructed by pedologists because these academic positions are often not-renewed as pedologists retire. Historically, soil science students would complement their academic pedology training through summer internships within governmental soil surveys units. As the soil survey units closed, these opportunities ceased to exist (Anderson and Smith, 2011). All of this could explain why some respondents felt that the pedology knowledge and field skills of new graduates has declined over the years.

After the closure of soil survey units, summer student opportunities existed primarily only with private companies who had to perform their own soil surveys to meet regulations (Anderson and Smith, 2011). Some companies would likely have provided similar learning opportunities as the governmental soil survey units did in the past, but as one of the respondents stated, training students is time consuming and expensive. Other professions are facing similar challenges. Abriel
(2017) speaks of this in the context of the geophysics profession serving oil and gas exploration. Geophysical companies are no longer hiring and training recent graduates and are opting for experienced professionals because of the expense and extent of the training required by the recent graduates to gain all necessary skills.

Prototype for a Pedology Field School

The main objective of this study was to collect information to guide the development of a national pedology field school that would augment current pedology training in Canada. The survey gave insight into the pedology knowledge and skills considered important by the practicing professionals for the current job market and provided an assessment of the perceived level of competency of new graduates in those skills. By comparing the ranking of skills identified as important by the respondents to their rankings of the perceived quality of training among new graduates, we were able to sort those skills into three groups and identified learning outcomes of importance.

A first group encompassed skills (4 skills out of the 13 skills listed), which have more than four ranks difference between their importance to the job market and the level at which they are mastered by the graduates. This group included: “interpreting soil survey report”; “role of soils in environmental assessment”; “principles of soil genesis and development”; and, “role of soils in land reclamation”. Among those, “interpreting soil survey report” and “role of soils in environmental assessment” are ranked higher in the “importance” list than on the “mastered” list and can be interpreted as important learning outcome in which graduates were judged to be very weak. On the contrary, “principles of soil genesis and development” and “role of soils in land reclamation” were judged better mastered than they are important for the current job market. A second group encompassed skills (3 out of 13) for which the difference between their
importance to the job market and the level at which they are mastered by the graduates is different by two or three ranks. This group included “interpreting soil analysis report”, “soil classification”, and “soil sampling design”. Only “interpreting soil analysis report” was considered more important for the job market, while not being perceived as well mastered by graduates. A third group comprised of skills (6 out of 13) whose ranks are consistent. This group includes skills that are perceived as having a lower importance to the job market, such as: “role of soils in ecosite classification”; “hydric soil identification”; and, “soil classification (other non-Canadian systems)” that are perceived as not well mastered. One very notable exception within this last group was “soil profile characterization”, which was classified as being the most important for the job market and one of the most mastered skills among graduates – even though graduates were still considered to be in need of additional learning, overall.

Certain soil skills (spatial variability of soil processes; soil development for reclaimed lands; function of soils in contaminant movement and remediation; and, role of soils in risk assessment) were thought to be completely absent from the current curriculum, which led the respondents to deem that soil education needs to be updated for the current job market. The discrepancy between skills and knowledge needed for the profession and the level of knowledge demonstrated by new graduates, could partially be explained by an influx into the profession of graduates who obtained their degrees from institutions that do not offer soil science-focused training. It would also appear that some academic institutions may have underestimated or not considered the level of pedology knowledge and skills required by graduates to not only successfully work in specific environmentally related positions (e.g. environmental assessments, soil restoration/remediation), but also to conduct more “basic” soil science tasks such as interpreting soil survey and analysis reports. Certainly, more research is necessary to understand
the reliance the profession has on non-disciplinary graduates and their impact on the perceptions of soil education in Canada.

The item cluster and the ranking of the most important pedology knowledge and skills indicated by the respondents could serve as a road map for the development of a set of courses for a pedology field school. Hence, we propose that a national pedology field school covers at least the following three areas: (1) large-scale soil skills such as soils and ecosystems classification and soil mapping; (2) basic soil skills needed for soils and environmental assessment such as soil sampling design, soil description, profile description, interpretation of soil survey reports, and interpretation of soil analysis reports; and, (3) skills that are thought to be completely absent from the current academic curriculum such as spatial variability of soil processes, soil development for reclaimed lands, function of soils in contaminant movement and remediation and the role of soils in risk assessment.

It was also recommended that an additional course could focus on career preparation skills such as on the knowledge of soil practice standards, professionalism, working with contractors, and work quality. It should be understood, however, that the proposed pedology field school can not be the answer to all questions identified by the respondents. Mainly because identified training needs are numerous and because some of them are beyond the typical scope of pedology, as a profession. In addition, the short duration of the proposed pedology field school can not be a replacement for existing pedology or broader soil education programs delivered in Canadian universities and colleges. It is meant to be an enhancement in pedology trainings to help bridge new graduates to the work environment.

Based on the previous discussions at the CSSS annual meetings, we originally considered a pedology field school that would be composed of one course to complement academic soil field courses already available in Canada. Based on the answers of the professionals surveyed, it is
now clear that the needs of augmenting soil field skills of graduates (and professionals) are more important than anticipated. To be able to cover most of the learning outcomes identified by the respondents, it is obvious that a pedology field school should offer more than one course. Most of the respondents suggested a 3-to-5 or 5-to-8 day training for a pedology field school. We recommend a 5-day course, amendable depending on the host institution and instructors chosen, as well as on the location of the training and the characteristics of soil distribution and site availability in a hosting region. In order to cover most of the soil landscapes in Canada, a pan-Canadian rotation of host-locations for the field course was suggested. Cost should also be limited to less than $2,000, and should be kept ideally around $1,000, not including travel, accommodation and meal expenses. Potential industry sponsors should also be identified for at least partial financial support.

Additionally, respondents suggested that the CSSS coordinates with local programs in which either private consultants, governmental professionals, or academics combine their effort to offer students additional pedology education and field skills. Among those, the Pacific Regional Society of Soil Science (PRSSS) summer ID course in British Columbia has been providing a 4-days training in soil description and classification since 2009 (http://www.prsss.ca/summer-soil-course/). The Soil Classification and Mapping course from the University of Alberta’s (UofA) Faculty of Extension also provides 39-hours of training with a focus on soil forming processes and principles of the Canadian soil classification (https://www.ualberta.ca/extension/continuing-education/courses/exerm-4297). These training opportunities seem to be limited to western Canada. The CSSS could first list all the available pedology training courses in Canada. Then, it could either offer to collaborate with already-establish training programs or to co-create with local organizations new pedology field schools in regions devoid of those training courses. The idea behind this initiative would be to ensure that
good-quality training courses in pedology and in soil mapping are offered throughout Canada and to guarantee a national standardization of soil survey protocol; most respondents claimed that those two aspects were critical for them.

A Canadian Soil Certification or Recognition

The majority of respondents also indicated that it was important for them to have either the CSSS or another professional body recognize successful completion and competence in pedology and in soil field skills. We believe that CSSS could have an important role to play as it could provide recognition to academic programs that either offer a comprehensive curriculum in soil science or have upper level courses that cover topics of relevance for pedology knowledge and field skills (e.g. soil mapping). In addition, CSSS could also identify a subset of academic courses that needs to be taken to get the CSSS recognition. This is in line with a comment: “Having some kind of recognition may help government and industry as right now there are a myriad of environmental degree programs.”

Such recognition, but in the format of more formal certifications overseen by national soil organizations, exist elsewhere in the world. For example, the Soil Science Society of America (SSSA) offers the certified Professional Soil Scientist (CPSS) program. In order to be a recognized CPSS, a candidate needs to hold either a Bachelor’s Degree in Soil Science or a closely related degree in agriculture, earth or environmental science, with at least 15 credits of soils coursework, and have 5 years of work experience in soil science, or hold a MSc or PhD in soil science or closely related fields and 3 years of work experience (see application form for more details: https://www.soils.org/files/certifications/cpss-cpsc/cpss-application.pdf). Once the committee has recognized the education credits and professional experience, the CPSS’s candidate needs to pass the Fundamentals of Soil Science exam designed by the Council of Soils
Science Examiner, which covers notions of soil genesis, classification, and morphology, soil chemistry and mineralogy, soils physics, soils fertility and nutrient management, soil biology and soil ecology and land use management (SSSA, 2019). Finally, the applicants also need to comply with The SSSA Soils Certifying Board’s Code of Ethics (https://www.soils.org/files/certifications,cpss-cpsc,code-of-ethics.pdf). This certification assures a standardization of soil knowledge and practices across the US and is also designed to protect the public interest.

Similarly, Soil Science Australia (SSA) manages the Australian Certified Professional Soil Scientist (CPSS) program, and its certification process also requires both educational and work experience. Applicants may pass the Soil Science Australia Fundamentals Exam to get recognition even if they have not completed at least four university courses in soil science at the undergraduate or postgraduate level. Applicants must also demonstrate that they possess a number of skills from a list of standards for professionals in soil science, a list that includes professional responsibility, project management skills and soil science knowledge (see the complete list of standards at: https://www.soilscienceaustralia.com.au/media/content/files/CPSS-Standards2019.pdf). Once accredited, a CPSS must also engage in an average of 50 hours of professional development each year and must sign the Australian CPSS Codes of Conduct (https://www.soilscienceaustralia.com.au/media/content/files/cpss-code-of-conduct.pdf) and of Ethics (https://www.soilscienceaustralia.com.au/media/content/files/cpss-code-of-ethics.pdf) (SSA, 2019). This certification provides the recognition of a basic level of soil knowledge and skills standardized across the country and assures a level of professionalism amongst certified soil scientists.

In Canada, similar certifications exist in some provinces and are mostly available through provincial professional agrology organizations. The CSSS could work with these provincial
organizations to develop and include certifications specific to soil science professional practice. We propose that CSSS representatives develop standards and scope-of-practices for certification that could be inspired by already established soil scientists’ certification programs such as the American (SSSA) or Australian (SSA) programs discussed above. Once a general structure is agreed upon, CSSS representatives could then work in collaboration with provincial agrology institutes, to establish soil scientists’ certifications that could be then added to their current certification programs. There may also be a role for the CSSS to encourage the creation of a professional soil Masters program that could include the pedology field school as one of the required courses. As a one-year, course-based program, professional Masters program could serve recent graduates and current professionals, whose undergraduate training did not prepare them specifically for professional pedology, by providing them with a basic soil science concepts and field skills.

A National Web-based Training Resource

All 37 respondents agreed that web-based national resources for soil science knowledge and field skills training would be useful for their organizations, particularly if those resources could also help with standardization of methods and protocols. It was also suggested that this resource should have modules relevant to each province, considering differences in local soil types as well as key industry requirements and governmental regulations.

If this initiative goes forward, it might be good to expand on the already existing resources such as those developed by the Virtual Soil Science Learning Resources group (www.soilweb.ca). These suggestions are in agreement with responses provided by Canadian postsecondary soil science course instructors, who also indicated that they would like to have access to more web-based resources with Canadian content (Krzic et al., 2018). Establishment of
a Canada-wide soils education resource portal could potentially follow an example of the US initiative focused on geoscience entitled “On the Cutting Edge Professional Development Program” (https://serc.carleton.edu/NAGTWorkshops/about/index.html), which combines workshops, web-based resources, and research activities to support undergraduate education. A Canada-wide soils education resource portal would also encourage creation of a culture of information and resource-sharing that would underpin improvement in soil science education, and also allow access for regions currently under-resourced due to their distant location and/or limited local soils expertise. The online resource portal should not, however, be considered a replacement of first-hand field learning in pedology, where landscape-level and site-level learnings are fundamental in the development and maintenance of professional practices.

CONCLUSIONS

The objective of this study was to collect comments and feedback from soil professionals on the learning outcomes and structure of a pedology field school in Canada. In hindsight, the need to engage soil science professionals in evaluation of the postsecondary education of our discipline in Canada was long overdue. A shift from degree programs with a focus on soil science to programs with a broader, environmental focus that include a reduced level of soil science teaching, combined with the closure of governmental soil survey units and retirements without replacement of pedologists throughout Canada, have resulted in a gradual erosion of pedology knowledge and competencies amongst new graduates. Based on the responses to the survey, we propose that the CSSS collaborate with and promote existing regional pedology field schools to support delivery of consistent and desired learning outcomes from coast to coast and sponsor new field schools in areas where regional offerings do not currently exist. Primary learning objectives of such schools should include a refresher on soil genesis, field description, and classification.
(soil and ecosite), and the basics of interpreting soil survey and analyses information, with more in-depth coverage of soil mapping and soil-landscape classification. Proposed pedology field schools would be best structured as multiple 5 day courses. This would facilitate the division of learning outcomes in a minimum of two courses – one course could cover the more basic pedology and field skills and the other could be on soil mapping and soil-landscape classification – presented in alternating years.

The CSSS should also consider the development of a national *Soil Professionals* certification program in partnership with provincial agrology institute, when possible; and a national web-based resource for soil science education for use by academic, government and industry organizations.

We also recognize that additional research is needed to understand the scope of the infiltration of non-disciplinary graduates into the professional practice of soil science, how it impacts the success of the discipline in training new graduates, and how we might make learning in soils skills and knowledge more readily available to non-disciplinary students. The Soil Education committee of the CSSS is well positioned to investigate these questions.

**ACKNOWLEDGEMENTS**

We thank the CSSS for ongoing support to our efforts to promote the discipline of pedology in Canada, and the members of the CSSS Pedology committee and the summer-field-school subcommittee for truly fruitful discussions. We also thank the Department of Soil Science, and College of Agriculture and Bioresources at the University of Saskatchewan for providing the resources to engage the SSRL of the University of Saskatchewan which were instrumental in the design and delivery of the online survey. We further thank Angela Bedard-Haughn for support with the design of the survey.
REFERENCES


   September, p. 716-718


Brevik, E., Abit, S., Brown, D., Dolliver, H., Hopkins, D., Lindbo, D., Manu, A., Mbila, M.,


   299-306.


   117-124.

Cooksey R.W., Soutar G.N. 2006. Coefficient beta and hierarchical item clustering an analytical

   procedure for establishing and displaying the dimensionality and homogeneity of


Diochon, A., Basiliko, N., Krzic, M., Yates, T.T., Olson, E., Masse, J., Amiro, B., and

   Kumaragamage, D. 2017. Profiling undergraduate soil science education in Canada: Status


   0058


Zinbarg R.E., Revelle W., Yovel I., Li W. 2005. Cronbach's α, Revelle's β, and McDonald's ωh:
their relations with each other and two alternative conceptualizations of reliability.
Psychometrika 70: 123-133.
LIST OF FIGURES

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Table 1. Selected representative comments offered by the survey participants on the quality of postsecondary soil science education in Canada.

<table>
<thead>
<tr>
<th>Generally positive comments:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• &quot;Certain post-secondary institutions provide well trained graduates. Well trained graduates in soils are not common in all institutions&quot;.</td>
<td></td>
</tr>
<tr>
<td>• &quot;Post-secondary institutions do a credible job teaching soil classification but do a really poor job teaching students how to map soils and landscapes&quot;.</td>
<td></td>
</tr>
<tr>
<td>• &quot;Recent graduates from post-secondary institutions tend to have sufficient theoretical knowledge for soils classification, but depending on the focus of their undergraduate curriculum, may or may not be confident in the field identification of soils&quot;.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Generally negative comments:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• &quot;I find that most new grads who do have some soils knowledge have graduated in &quot;environmental sciences&quot; or geology (or worse geography!) and have not had courses in soil genesis / classification, soil chemistry and soil physics&quot;.</td>
<td></td>
</tr>
<tr>
<td>• &quot;At times we have had difficulty finding candidates with a soil science specialization. Students with general agronomic backgrounds generally do not have the required knowledge and skills to be qualified for specialized positions&quot;.</td>
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</tr>
<tr>
<td>• &quot;Most so-called soil graduates coming from Canadian universities had a very poor knowledge of soil within the landscape context, including process, geography, and taxonomy&quot;.</td>
<td></td>
</tr>
<tr>
<td>• &quot;The soil science training needs to be updated to reflect the needs of current job markets. Should be service- and environment-oriented, as there are less and less employment opportunities in research&quot;.</td>
<td></td>
</tr>
<tr>
<td>• &quot;In my opinion, soil science is waning and will die in Canada, unless there is more attention paid. Simply count how many soils scientists we used to have vs now. We need less systematics and more applications to real world problems&quot;.</td>
<td></td>
</tr>
<tr>
<td>• &quot;I have been hiring &quot;soil science&quot; graduates for close to 35 years, and am dismayed by the dwindling skills and education that these graduates have offered our organization over that time. Most of them have been trained by us on the job, which is expensive for us and for our clients&quot;.</td>
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</tbody>
</table>
Table 2. Participants’ assessment of the level of preparedness of new graduates for additional soil knowledge and skill areas that should be addressed in the postsecondary courses in Canada. Each area suggested and assessed represents the view of an individual participant.

<table>
<thead>
<tr>
<th>Soil knowledge and skills</th>
<th>Poor</th>
<th>Satisfactory</th>
<th>Good</th>
<th>Excellent</th>
<th>Exceptional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil chemistry</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Spatial variability of soil processes and form</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surficial geology and geomorphology</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GIS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Predictive mapping</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessing soils regarding sustainable agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Contaminant behavior</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding the significance of soil biology</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role of soils in risk assessment</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surficial geology</td>
<td>X</td>
<td></td>
<td></td>
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</tbody>
</table>
Table 3. Participants’ suggestions for additional knowledge and skills needed by new graduates in Canada.

<table>
<thead>
<tr>
<th>Soil theoretical knowledge</th>
<th>Soil field and laboratory skills</th>
<th>Other skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Soil chemistry</td>
<td>• Appropriate laboratory analysis to meet study objectives</td>
<td>• Team work and orienteering</td>
</tr>
<tr>
<td>• Spatial variability of soil processes</td>
<td>• Field experience in boreal, agriculture, and grassland</td>
<td>• Communication with contractors</td>
</tr>
<tr>
<td>• Nutrient regime</td>
<td>• GIS</td>
<td>• Wilderness survival and animal awareness</td>
</tr>
<tr>
<td>• Surficial geology and geomorphology</td>
<td>• Predictive mapping</td>
<td>• Driving on gravel roads</td>
</tr>
<tr>
<td>• Significance of soil biology</td>
<td>• Salinity mapping</td>
<td></td>
</tr>
<tr>
<td>• Soil development for reclaimed lands</td>
<td>• Environmental toxicity assessments</td>
<td></td>
</tr>
<tr>
<td>• Functions of soils in forest development</td>
<td>• Assessing soils with regards to sustainable agriculture</td>
<td></td>
</tr>
<tr>
<td>• Function of soils in contaminant movement and remediation</td>
<td>• Soil health assessment</td>
<td></td>
</tr>
<tr>
<td>• Best management practices</td>
<td>• Identification and mitigation for construction on sensitive soils</td>
<td></td>
</tr>
<tr>
<td>• Role of soils in risk assessment</td>
<td>• Soil handling during construction</td>
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