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EXTENSION

Soil Science Education Practices Used in Canadian Postsecondary, K–12, and Informal Settings

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Abstract

This study explored practices that Canadian soil scientists use to educate postsecondary students, K–12 students, and the general public. The most commonly used type of educational activities described by survey respondents, regardless of the settings and the type of target audience, were field-based hands-on activities. The other two commonly used educational activities were lectures and laboratory activities; and they were predominantly implemented at the postsecondary institutions. Educational activities in K–12, outreach, and professional development settings were generally delivered through one-time events (e.g., workshops, school visits, field days), offering less opportunities for a greater variety of practices relative to the postsecondary settings. At postsecondary institutions, where soil science education is delivered in a more structured manner, there are more opportunities for educators to implement a range of educational practices (e.g., lectures, laboratory activities, games, case studies, quizzes). The learning objectives of the field-based hands-on activities and lectures were to describe specific soil properties or to describe and classify soils, whereas for laboratory activities, the learning objectives focused more on the application of those concepts. The insights offered by this study on educational practices used by Canadian soil scientists to encourage more students to study soil science and raise awareness about the importance of soil are valuable teaching resources for both new and seasoned educators within Canada and abroad.

Core Ideas

- The general public is not aware of soil's importance.
- Integration of soil science into K–12 curricula will help raise soil awareness.
- Various activities can be used to educate students and the general public.
- Field-based, hands-on activities are the most popular type of educational activity.

Soil scientists recognize that soil is a non-renewable, dynamic ecosystem with numerous important functions, including the strengthening of our resilience under the threat of climate change. This understanding of soil's importance is not, however, shared by the general public (Lobry de Bruyn et al., 2017). More than 80% of Canada's population lives in urban areas, largely clustered along the Canada–United States border (Statistics Canada, 2014), and there is an increasing disconnect between the urban population and the land base on which it depends. Many city dwellers are not aware of the origin of the resources they depend on, such as food and fiber, nor the vast distances often traveled before reaching the consumer (Brown, 2009), and are generally unaware of the important ecosystem services that healthy soils provide (Adhikari and Hartemink, 2016). Soils in urban environments are not a central focus of city dwellers' daily lives; they are hidden under roads, sidewalks, and grass lawns. People may not be aware of the impacts that their activities have on soil, and its associated beneficial functions. This disconnect is further exacerbated by the underrepresentation of soil science in the curricula of elementary, middle, and high school (also referred to as K–12) programs of many countries around the world, including Canada (Landa, 2004; Hayhoe, 2013).

The integration of soil science into the K–12 curricula is an important part of addressing the lack of public knowledge about the importance of soils in local and global contexts, and in turn will enhance overall scientific literacy of the general public (Lobry de Bruyn et al., 2017). In addition, exposing students to soil science concepts during their K–12 education may also encourage increased enrollment in soil science courses at the postsecondary level, which historically have been low, not only in Canada but around the world (Baveye et al., 2006; Brevik et al., 2014).

A review of Canadian and international elementary, middle, and high school programs revealed that soil science is explicitly mentioned in the high school curricula of several Canadian provinces, various states in the United States, and in South Africa, but not as frequently as other sciences such as geology and astronomy (Hayhoe, 2013). Some encouraging examples of integration of soil science into the high school curriculum in Canada are from

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Abbreviations: AQSSS, L'Association Québécoise de Spécialistes en Sciences du Sol (Association of Quebec Specialists and Scientists); CSSS, Canadian Society of Soil Science; PRSSS, Pacific Regional Society of Soil Science.

Ontario, British Columbia, and Saskatchewan, where soil science components have been incorporated to increase understanding of the fundamental concepts of ecosystems and sustainability (Ontario Ministry of Education, 2007, p. 19–20; British Columbia Ministry of Education, 2013, p. 1–3; Saskatchewan Ministry of Education, 2012, p. 30). The initiative to expose high school students to soil science cannot solely be left to school teachers, who often lack an in-depth knowledge of the discipline (Landa, 2004), and active involvement of professional soil scientists is needed. It is imperative that soil scientists become involved in communicating the relevance and excitement of working in this field to youth and the general public. This is especially timely since knowledge about soil resources is more vital today than ever before, due to ongoing pressures brought about by climate change, growing world population, and a shrinking arable land base.

This article seeks to explore the practices that Canadian soil scientists use to educate postsecondary and K–12 students and the general public. More specifically, the authors investigated which practices were used most often with different groups of learners, and why that was the case. The findings of this study will provide better understanding of current educational practices, provide a resource for soil science educators, and will form a baseline against which we can evaluate future changes in soil science education.

METHODS

The authors conducted a survey using Qualtrics (Qualtrics XM Platform, Provo, UT), which was structured to allow Canadian soil science professionals and graduate students to provide information about two top educational practices that they either used as educators or had experienced as learners. The survey was modeled after design-based research principles (Barab and Squire, 2004; Wang and Hannafin, 2005), which provided participants with a complete disclosure of the survey objectives. The survey questions elicited: (1) the type of educational practice; (2) learning objectives; and (3) the target audience and the learning environment. Specific categories of target audiences were provided in the survey, including postsecondary, K–12, professional development, and outreach settings.

In early June 2019, an email containing the survey link was sent to members of the Canadian Society of Soil Science (CSSS), Pacific Regional Society of Soil Science (PRSSS), and L'Association Québécoise de Spécialistes en Sciences du Sol (Association of Quebec Specialists and Scientists, AQSSS). The survey was available for 3 weeks. There was some overlap of membership among those societies mentioned above; hence, an accurate number of individuals contacted could not be determined, but it was between 250 and 350.

RESULTS AND DISCUSSION

A total of 43 respondents completed the survey. The majority indicated that they work at postsecondary institutions (79%, n = 34), and the remaining were split among the government (9.5%, n = 4), consulting industry (9.5%, n = 4), and not-for-profit (2%, n = 1) organizations.

From the responses received, Canadian soil science professionals tend to use field-based hands-on activities regardless of educational settings and audience (Table 1). Field-based hands-on activities were most commonly reported in the outreach settings (90%), followed by K–12 (85%), professional development (71%), and postsecondary institutions (52%). What does this tell us? Soil professionals have found hands-on activities that promote tactile (kinesthetic) learning to be the most appealing and successful, especially for audiences who are learning about soils for the first time. At postsecondary institutions, where a greater depth of learning is expected, other practices, such as lectures, laboratory activities, case studies, and group work, play an increasingly important role (Table 1). On the other hand, educational activities in K–12, outreach, and professional development settings are generally delivered through one-time events (e.g., workshops, school visits, field days), which offer limited opportunities to deliver several types of educational activities to learners. It is not surprising that survey respondents indicated a lower variety of practices used in those three settings relative to the postsecondary institutions (Table 1).

In our survey, we also asked participants to identify learning objectives for their top two practices, and a summary of those responses are shown in Table 2. Field-based hands-on activities and lectures are mainly focused on remembering and understanding of soil science concepts; hence, their learning objectives were to introduce and describe specific soil properties (e.g., texture, soil organisms) or to describe, identify and classify soils. Laboratory activities provided opportunities for learners to deepen their understanding of soil science concepts through application of those concepts in various laboratory analyses and interpretation of analytical results.

Table 1. Types of practices used by survey respondents (n = 43) at postsecondary institutions, K–12 education, outreach events, and professional development events in Canada.

	Responses			
Practice	Postsecondary institutions	K–12	Outreach events	Professional development events
	%			
Field-based hands-on activity	52	85	90	71
Lecture	18	5	0	8
Laboratory activity	10	0	0	4.2
Games	3	5	3.3	4.2
Case studies and group work	7	0	3.3	0
Experiential learning—art	4	5	3.3	4.2
Read assignment and term paper	3	0	0	0
Quiz	1.5	0	0	0
Role play	1.5	0	0	4.2
Watch videos and discussion	0	0	0	4.2

Table 2. Learning objectives of the field-based hands on-activities, lectures, and laboratory activities used by survey respondents (n = 43) at postsecondary institutions, K–12 education, outreach events, and professional development events in Canada. Percentages sum to greater than 100% because respondents were able to indicate multiple settings for the same learning objective.

Learning objective	Responses			
	Postsecondary institutions	K–12	Outreach events	Professional development events
	%			
Field-based hands-on activities				
To describe, identify, and classify soils	79	28	51	40
To determine soil texture	16	9	7	0
To show that soils are alive	2	5	7	2
To understand importance of soil sampling	5	2	2	0
To understand how soil properties affect management practices	5	2	5	0
To create artwork focused on soil	2	2	0	0
Lectures				
To learn basic concepts of soil science	19	2	0	14
To link soil science concepts to various applications	2	0	0	0
Laboratory activities				
To learn basic concepts of soil science	14	0	0	2
To understand linkages among soil science concepts	7	0	0	0
To learn how to interpret data	5	0	0	0

Once we identified educational practices commonly used in the four settings, we then searched for specific practices that could be used as examples to illustrate types of learners typical of those four settings. Here, we provide detailed descriptions of three frequently described practices from the survey that are reflective of different types of learners/learning environments.

Creation of Mini Monoliths

This simple, easy to set up activity, adapted from USDA-NRCS Soil Education Lesson Plans (USDA-NRCS, 2019), is appropriate for K–12 education as well as outreach events targeting the general public. The learning objectives of this activity are to illustrate that soils exhibit distinct horizons within the soil profile and to differentiate characteristics among the A, B, and C horizons. Materials and supplies needed for this activity include paper, double-sided tape (or glue), and three air-dried, ground, and sieved soil samples representative of A, B, and C horizons, preferably collected locally (Fig. 1). To create a mini monolith, double-sided tape (~10 cm long) is applied to a pre-cut paper card (pre-labeled with A, B, and C horizons). The soil sample from the A horizon is sprinkled onto the top one-third of the tape, the B horizon to the middle one-third of the tape, and the bottom part with the C horizon sample. Excess soil remains until the tape is covered. The soil is then gently pressed down onto the tape, the card is tilted at about a 45-degree angle, and the excess soil is gently tapped off the paper, revealing the mini monolith (Fig. 1).

This versatile activity can be used to illustrate various soil concepts. For example, the instructor can explain that the differences in color among the horizons are due to differences in organic matter content and type of mineral components. Alternatively, the mini monolith can be used to explain the importance of horizon depth on root growth by altering the depth of the three horizons. An advantage of this practice is that learners can learn about various types of soils collected from different locations (e.g., forest, farm, city park) without actually going on a field trip. When this activity is used, learners of all ages, but especially young students, were very keen to keep these mini monoliths as an art piece.

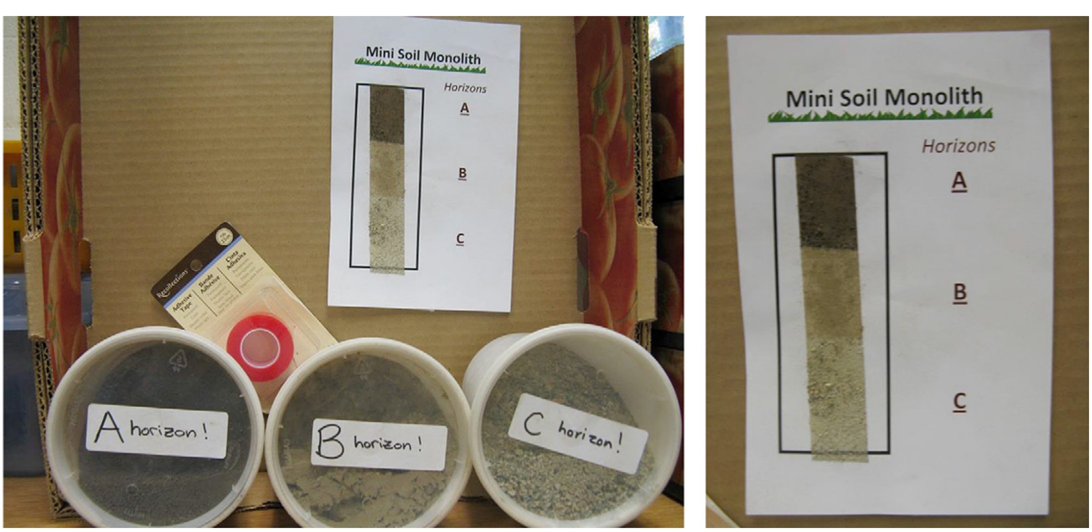

Fig. 1. Material needed to create mini monoliths (photo credit: Dru Yates, University of British Columbia, Vancouver).

Field Description of Soil Horizons in a Soil Pit

Building from the simple illustration of soil horizons achieved by the mini monoliths activity mentioned above, more advanced learners would benefit from a field description of soil horizons in a soil pit (Fig. 2). This activity is suitable for postsecondary students enrolled in introductory soil science courses or practicing professionals with a limited background in soil science, who require a basic understanding of soil formation. The learning objectives are to illustrate the key properties of soil horizons as well as the effects of soil formation factors and soil forming processes on horizon development and characteristics. The instructor asks for volunteers (e.g., one to three depending on the size of the soil pit) to go into the pit. To go into the pit is like a badge of honor; many students will be hesitant, but the instructor can let them know how important a role it is (i.e., they will be the soils "expert"). The instructor explains the soil profile and leads an interactive discussion with the entire group about soil formation and the resulting horizons. The instructor then asks the students in the pit to use the provided material (e.g., golf tee, pencil, even twig) to mark the location of the horizon boundaries, using the soil physical property of color as the primary method for separation. The students in the pit collect samples of each horizon (organic and mineral) and pass them to students outside of the pit, who then bring their hands together to "reform" the soil profile (Fig. 3). By doing so, the differences among horizons become even more obvious to the students.

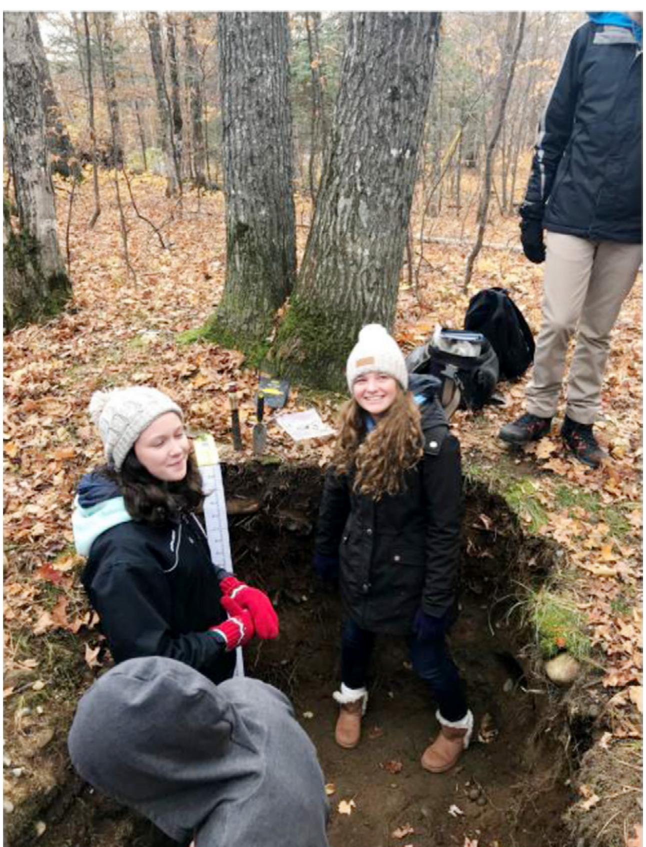

Fig. 2. Students are observing presence of different soil horizons in a soil pit (photo credit: Cathi Baber, Algoma District School Board, Sault Ste. Marie, ON).

Field School/Trip on Soil Identification and Classification

For developing a more specialized expertise in soil genesis and classification, an in-depth course that includes several field-based hands-on activities of soil description and identification is recommended. This is suitable for upper-level postsecondary courses and also professional development workshops for those with some soil science background. The learning objectives of these activities are to: (1) provide detailed, technical descriptions of soil properties by horizon; (2) learn how to classify soil using an established classification system; and (3) understand the relevance of soil classification in the context of different land-use practices. The benefit of these activities is the connection that is gained between the hands-on learning in the field and the theoretical concepts that are taught in the classroom. This approach to learning results in less memorization of material because of the direct application of knowledge to real-life land management issues and decision making. The learner's knowledge retention is greater, and the field environment leads to greater interactive knowledge sharing between the instructor and students, and among students (Ramasundaram et al., 2005). The field environment also promotes greater student participation in discussion and instills a confidence level for students to put forward ideas that many would not feel comfortable to raise in the classroom setting.

In reviewing the survey results, an additional theme emerged that we wanted to highlight here: the *fun* of soil science and the wide variety of unique and creative learning activities that Canadian practitioners are using in their educational programs (Table 3). The words "fun" or "engag[ing]" were mentioned by 8 (18%) participants in their survey responses, and these appeared in all four learning settings included in our survey. A number of innovative and fun soil science educational practices are featured here for two purposes: (1) to showcase examples of what Canadian practitioners have found to be fun and engaging, and therefore may improve learning effectiveness; and (2) to provide resources and inspiration for other practitioners to try these and similar activities in their educational practices.

Fig. 3. Students are showing samples from different soil horizons, thus re-creating the soil profile to emphasize the differences among the horizons (photo credit: Cathi Baber, Algoma District School Board, Sault Ste. Marie, ON).

Table 3. Soil science is FUN! Some examples of "fun" or "engag[ing]" activities mentioned by survey respondents.

Activity	Learning objective	Link to resource
1. Live demonstrations on soil in situ:	To understand the influence of belowground conditions on aboveground observations.	
• Inject blue dye to show macropores		Dye tracer for macropores: http://soilandwater.bee.cornell.edu/Research/pfweb/educators/labfield/dye.htm
• Pour water–mustard mixture to bring earthworms to the surface		Earthworm extraction: http://nrri.d.umn.edu/worms/research/methods_worms.html
• Blow smoke up tile drains to show connected macropores		Smoke tracer for macropores: https://practicalfarmers.org/2011/11/cover-crops-not-just-blowing-smoke/
2. Make paint pigments from soil, then create artwork on a canvas.	To create artwork reflecting the experience the student had during a field course.	Painting with soil: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/kthru6/?cid=nrcs142p2_054304
3. Demonstrate using a drop of water on a soil sample collected from a post-wildfire environment, in class, in a petri dish. The drop of water floats and skates about on the surface, looking similar to liquid mercury.	To illustrate the concept of hydrophobicity (water repellency) of soils affected by wildfires, and the hydrological implications.	Wildfire and hydrophobic soil: https://www.youtube.com/watch?v=3a02Bf8977s
4. Build a funnel extraction apparatus to collect and identify soil macrofauna (e.g., arthropods, mites, spiders, etc.); place a collected soil sample in the funnel and a heat lamp over top. Organisms migrate down the soil profile away from the heat and are collected in a container below (overnight).	To show that soils are alive	Berlese funnel: https://soil4youth.soilweb.ca/wp-content/uploads/sites/11/2015/05/LessonPlan7-MacroandMesoFaunaExtraction-Oct2013.pdf

DIRECTIONS FOR DEVELOPMENT AND IMPLEMENTATION OF SOIL EDUCATIONAL ACTIVITIES

The need for the enhancement of soil science education and provision of adequate soil information have been highlighted by various international organizations, including the United Nations (UN Millennium Project, 2005; UN Development Programme, 2007) and the Intergovernmental Panel on Climate Change (Hartemink, 2008). The integration of soil science into the K–12 curricula and ongoing outreach efforts are needed because they address the broad issues of the lack of public knowledge about the importance of soils in a global context and the overall scientific literacy of the general public (Lobry de Bruyn et al., 2017).

One example of an initiative that addresses the need for better integration of soil science into high school (grades 8–12) programs in Canada is Soil 4 Youth (https://soil4youth.soilweb.ca/), a national collaborative program, established in 2009 with the objectives to: (1) promote the discipline of soil science to students and teachers; (2) create open access soil science educational resources that can be directly implemented in high school curricula in Canada; and (3) raise awareness among high school students about the importance of soil in the context of global issues (Krzic et al., 2014). Other similar examples of national programs focused on enhancing soil science education of youth or the general public are: On the Cutting Edge Professional Development Program for a Geoscience Faculty (https://serc.carleton.edu/NAGTWorkshops/about/index.html), and K–12 Soil Science Teacher Resources (https://www.soils4teachers.org/) in the United States and Science Learning Hub–Pokapū Akoranga Pūtaiao in New Zealand (https://www.sciencelearn.org.nz/).

Based on 10 years of experience with the Soil 4 Youth program, we identified the following factors that are essential for the long-term success of such programs:

1. Ensure that the target audiences (e.g., educators, outreach agents, soil science professionals) are aware of the program through an ongoing promotion and interactions with the target audience via a range of events and media,
2. Ensure continuing growth of the program by recruiting new team members and by adding and updating educational resources,
3. Establish and maintain connections with regional and national K–12 teachers' associations as well as university recruiters, organizers of science fairs, field days, and other community-based educational programs that focus on natural resources education, and
4. Collaborate with not-for-profit organizations that train science communicators and ambassadors to effectively engage the general public.

To ensure that all of these factors are addressed, ongoing funding support is critical. Developing a web-based platform with an initial set of educational resources is a good first step, but without ongoing efforts to engage target audiences, a program will not remain current and relevant. One successful program, which could serve as an example, is the "Science Learning Hub–Pokapū Akoranga Pūtaiao" (a.k.a. Hub), a national program established in 2007 and funded by the New Zealand government. The Hub's goal is to make national examples of science, technology, and engineering more accessible to the general public and K–12 students and teachers. The program uses a range of multimedia to highlight the stories of New Zealand research and development and to provide examples on how these stories can be used as contexts for creating engaging classroom and outreach activities. The Hub also has an active presence across several social media platforms, which enables it to facilitate connections between scientists and educators and promote other conversations in science/technology education.

The majority of soil scientists are not actively involved in teaching at the K–12 level, and often they are not aware of how they could get involved (Krzic et al., 2014). On the other hand, teachers may not know how to connect with scientists who can help them deliver the curriculum to students. The Soil 4 Youth program has a strong potential to facilitate these connections and to serve as a platform through which Canadian soil scientists, K–12 teachers, and outreach event organizers can collaborate to raise awareness about soils. A long-term funding investment is required to ensure that Soil 4 Youth becomes a truly functional platform.

SUMMARY AND CONCLUSIONS

As global issues continue to place increasing demands on soil resources, the need to provide soil science education to the next generation of soil scientists and the general public is becoming more important. Through an on-line survey, we explored practices that Canadian soil scientists use in the postsecondary, K–12, outreach, and professional development settings to promote soil education. Field-based hands-on activities were by far the most commonly used type of educational activities by survey respondents, regardless of the settings and the type of target audience. This is an indication that educators find these practices to be the most effective teaching tools. The other two types of commonly used educational activities by the survey respondents were lectures and laboratory activities, and they were predominantly implemented at the postsecondary institutions. Educational activities in K–12, outreach, and professional development settings are generally delivered through one-time events (e.g., workshops, school visits, field days), which offer limited opportunities to include several types of educational activities. Consequently, in those settings a lower variety of practices were used relative to the postsecondary institutions. At postsecondary institutions, where soil science education is delivered in more organized settings and where a greater depth of learning is generally expected, there are more opportunities for educators to implement a range of educational practices (e.g., lectures, laboratory activities, games, case studies, and quizzes). Learning objectives of the field-based hands-on activities and lectures were to introduce and describe specific soil properties or to describe, identify, and classify soils. Laboratory activities also allowed learners to understand concepts, but they also included learning objectives focused on the application of those concepts in various laboratory methods and concept evaluations through interpretation of analytical results and reports.

The outreach of soil science community has the two key goals, that of encouraging students to become soil scientists and educating the general public about the importance of soil. The soil science community in Canada (and elsewhere) needs to ensure that soil science finds a permanent place in the K–12 curriculum and that teachers are given adequate training, resources, and support through coordinated, national initiatives (e.g., Soil 4 Youth program, the Hub). To ensure continued growth, promotion, and engagement with learners, national initiatives need ongoing financial support from either government and/or soil science societies. Soil can only be effectively managed if we are better connected to it, and this will happen by building a strong foundation of soil science education for future professionals and the public.

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