Introductory Soils Courses: A Frontier of Soil Science Education in Canada

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Abstract

As the focus of soil science education in Canada and elsewhere has shifted towards non-soil science majors, it is important to understand if and how this has affected the scope of introductory soil science courses. The objectives of this study were to inventory Canadian postsecondary units that offer introductory soil science courses and to document attributes of instructors, students, and teaching approaches in these courses. We surveyed 58% of the instructors of introductory soil science courses across Canada, and most of these courses were offered by geography and environmental science units. The majority of instructors followed a traditional lecture (86%) and laboratory (76%) delivery format, while 36% used online teaching resources. Introductory courses were delivered by primarily one instructor, who held a PhD in a tenure track position and in most cases developed the course themselves. Over half of the instructors surveyed used either a required or a recommended textbook; pointing to the need for creation of a Canadian-authored soil science textbook. Several follow-up studies are needed to evaluate teaching methods used in the upper level soil science courses, student's perceptions of teaching in soil science, and instructors' knowledge of resources available for online and/or blended learning.

Key words: soil, education, postsecondary, college, university

Introduction

Soils are fundamental to life on Earth, and they are critical for the delivery of major ecosystem services integral to human wellbeing and nature conservancy. The maintenance or enhancement of global soil resources will only be possible if land managers and the general public have an understanding of the importance of soil. It is therefore essential that postsecondary curricula provide adequate coverage of the soil's roles in global issues such as climate change, loss of biodiversity, environmental

risk management, and food shortages (Dobrovol'skii, 2007; Hartmink et al., 2014; de Bruyn et al., 2017). In spite of the importance of soil science education for future land stewards and citizens, there has been a long-term decline in student enrollment in soil science programs in Canada and the United States (Baveye et al., 2006; Brevik et al., 2014). A more recent Canadian study by Diochon et al. (2017) found that there are indications of a reversal in the trend that is accompanied by a shift from teaching soil science to disciplinary soil science majors to teaching students of related disciplines such as environmental science, renewable natural resources, geography, and geology. Diochon et al. (2017) also found that of 207 soil science courses currently offered at Canadian universities and colleges, 56% are introductory level courses, and that among institutions offering just one course, that course is introductory soil science.

The importance of introductory or foundation courses is well understood in the sciences. They are considered to be fundamental to the students' broader understanding of the discipline (Druger 2006), the important initial contact for prospective students to major or minor in the discipline, and for some the only venue for gaining scientific literacy (Labov, 2004). Various studies have evaluated introductory undergraduate science courses by assessing teaching methods, curriculum, student performances and student experiences (Wuellner, 2015; Daniel, 2016; Tasch and Tasch, 2016). For example, Macdonald et al. (2005) conducted a >2,000-participant study on teaching methods in geoscience that surveyed instructors from academic units in the United States including earth science, environmental science, and hydrology. They found that even though instructors of introductory geoscience courses still relied heavily on lectures and in-class exams, most instructors also used a range of teaching strategies including interactive lecture techniques, problem-solving activities, and assessment strategies that challenged students to demonstrate higher order learning. This reflects an understanding that lecturing has limitations in terms of student learning, and that the active engagement of students is important to improve students' overall attitudes toward science and

learning. Haffie et al. (2000) evaluated Canadian introductory genetics courses through a survey of 47 academic institutions, and similar to the findings of Diochon et al. (2017) regarding the current state of soil science, found that genetics has been offered across a range of related units - biology, zoology, botany, plant science, and life sciences.

Introductory soil science courses have been recently assessed by Turk (2016), who reported on the development and use of lecture tutorials, Sandall et al. (2014) who studied metacognitive activities, Mikhailova et al. (2014) who used e-portfolios for assessment of student performance, and Andrews and Frey (2015) who delivered an introductory soil science course in a studio structure instead of the traditional lecture classroom. In addition, Hartemink et al. (2014) outlined in 15 interviews with experienced soil science instructors from nine countries the unique aspects and challenges in teaching soil science. It was their intention to explore the teaching of soil science as it changes from the deeper disciplinary focus to a more general approach that addresses the contemporary needs of related disciplines, like environmental science and resource management. Despite cultural and personal differences among instructors interviewed, several trends emerged, namely: (1) a considerable portion of soil science teaching is delivered to non-soil science majors, and for many of these students soil science may be a mandatory course, (2) instructors are faced with a challenge to balance teaching in-depth soil science concepts with creating a sense of wonder about the soil and its roles in various global issues, and (3) a shared satisfaction in teaching soil science courses that comes from students having gained understanding of soils, which also serves as a motivator for innovative teaching.

As the focus of soil science education has shifted, or at least broadened, to include the needs of the non-soil science majors, it is important to understand how this has affected the scope and range of introductory soil science courses. The objectives of this study were to document: (1) which Canadian postsecondary units offer introductory soil science courses and attributes of the students taking the courses, (2) the academic backgrounds of instructors teaching the introductory courses, and (3) the

89 scope of teaching approaches used for introductory soil science courses. The outcomes of this study will
90 provide better understanding of current offerings of this essential soil science course and will form a
91 baseline against which we can evaluate future changes. Today, we can only compare current practices to
92 past recommendations, while in the future we will be able to compare to our baseline data to answer
93 questions such as: How did instructors continue to change in response to new insights from research on
94 learning, particularly as research focuses more directly on soil science learning? How did instructors
95 adapt their teaching to increase student interest and motivation? How did instructors adapt their
96 teaching strategies as new technology makes different kinds of activities possible?
97
98 **Methods**
99 To address the study objectives, we adapted a survey recently conducted by the Soil Science
100 Society of America (Havlin et al., 2010) that was designed in cooperation with the Social and Economic
101 Sciences Research Center at Washington State University, Pullman, WA. Our survey was conducted using
102 Fluid Surveys (FluidSurveys™, Ottawa, Canada) and included 49 quantitative, categorical questions and
103 seven open-ended response questions. The complete list of survey questions can be found at the web
104 site of the Canadian Society of Soil Science (http://csss.ca/education-committee/). The quantitative
105 questions were grouped to provide insight into the following: (1) types of postsecondary institutions
106 (and associated programs) that offered the introductory soil science course in Canada, (2) information
107 on the instructors who taught/teach these courses, and (3) the scope of the teaching and learning
108 resources used for the courses (i.e., course pre-requisites, laboratory sections, textbook and online
109 educational resources, type of assessments). Open-ended response questions allowed respondents (i.e.,
110 instructors) to reflect on aspects of teaching the introductory soil science course, which included:
111 teaching goals, most exciting components, main challenges, course evolution over the years, and
112 potential course improvements.

Building on the recent work of Diochon et al. (2017), which included an extensive on-line search of postsecondary programs and their course offerings, we identified 63 Canadian postsecondary academic units that offered the introductory soil science (or equivalent) courses. Those units ranged in their offerings from undergraduate and post-graduate degrees to diplomas and certificates.

In June 2017, an email was sent to 72 former and current course instructors at postsecondary academic units identified by Diochon et al. (2017) inviting them to participate in the online survey. An email containing the survey link was sent two days later, followed by a reminder after two more weeks to those who had not yet completed the survey. A final reminder was sent two months after the initial invitation. The survey was open for three months.

Results and Discussion

1. Institutions, offerings, and enrollments in introductory soil science courses in Canada

In total, 36 institutions and 39 associated departments or schools are represented in this survey (Table 1 and Fig. 1). Of the 72 instructors who either have offered the introductory soil science course in the past 10 years or who currently teach the course, 42 completed the online survey; resulting in a 58% response rate. The majority of the respondents (n=34) were university instructors, seven were college instructors, and one was from an academic institute. The survey respondents were from units that offer bachelors degrees (n=32), diplomas (n=6), and both bachelors and diplomas (n=4). The expected degree completion time ranged from two to four years [2 years (n=9), 3 years (n=5), 4 years (n=28)].

All but five introductory soil science courses were offered once per year, with two offered every other year and three offered twice yearly. About half of the courses surveyed (Table 1) were titled Soil Science or similar (e.g., Introduction to, or Principles of, Soil Science). Five of the course titles included references to the environment, ecosystems, or landscapes, likely to highlight the integrated and

dynamic roles of soils in the broader environment. Five other respondents highlighted that the introductory soil science course also dealt with another subject such as sediments, vegetation, geomorphology, earth sciences, or horticultural growing media. Three course titles made reference to "resources" or "conservation" and one to "fertility" with no other explicit reference to agriculture or agronomy in titles. One interesting anecdotal highlight of a course name was a course entitled *Les sols vivants* (the living soils), highlighting perhaps both literally the biological component of soils, but also the dynamic and evolving nature of soils as they form/evolve and are dynamically influenced by other components of the environment and humans. Although universities were better represented than colleges in the survey respondents, the scope and tone of the range of introductory soil science course titles were not noticeably different between these two types of institutions.

Among the institutions surveyed, a limited number of them offered more than one introductory soil science course. The University of British Columbia (with a strong former soil science department and strong contemporary forestry program) offers three courses, while the University of Saskatchewan and University of Manitoba (both with strong soil science programs as well as agriculture and environmental science foci) and McGill University, each offer two introductory soil science courses in bachelors programs. In addition, at Dalhousie University, the University of Alberta[1], and Université du Québec à Chicoutimi different introductory soil science courses were also offered in shorter diploma programs and full degree programs. As far as we know, Laval University offers two introductory soil science courses named "Science du Sol" and "Sols Forestiers", which are available for students enrolled in agriculture, forestry, and biology bachelor programs.

Course enrollments ranged from fewer than 10 to 250 students per year. The average and median course size was 53 and 46, respectively with ca. 11% of courses having 100 or more students, 43% having 50 or more students, and 23% having 25 or fewer students. More than one quarter of

[1]through Yukon College

159 respondents noted that an increase in course size capacity was needed, though a number also stressed
160 that increases in enrollments would strain resources and the overall experience of hands on learning in
161 laboratory and field sessions.

162 There were a broad range of departments/academic units offering introductory soil science
163 courses, from biology to natural resources, to earth science/geology themed units, with geography and
164 environment (or combined geography and environment) focused units appearing to most commonly
165 teach this course (Table 1). An introductory soil science course was only offered within a soil science
166 department at the University of Manitoba and the University of Saskatchewan, two of Canada's three
167 remaining soil science departments[2]; however, there were nine natural resources and environmental
168 science departments that offer soil science majors, certificates, or other specializations, without the
169 departmental name "Soil Science."

170 Small, medium, and large sized units (based on numbers of faculty members and students[3]) that
171 offer introductory soil science courses were represented, and 30-40% of units had more than 20 faculty
172 members and more than 100 students. Only eight of the courses in the survey were cross-listed with
173 other disciplines such as environmental science and geology.

174 More than 60% of the courses reported in the survey were required for at least one degree or
175 certificate program, and these programs were quite diverse (e.g., soil science, geography, agriculture,
176 environmental science, restoration ecology, forestry). Furthermore, about the same percentage of
177 respondents pointed out that this course was a pre-requisite for another course. The postsecondary
178 units that offered additional, upper-level soil science courses often had introductory soil course as a
179 required course.

[2] Laval University also has soil science department, but there was no participant in our survey from that department

[3] Small unit had <5 to 10 faculty members and <20 students; medium unit had 11-20 faculty members and 21-100 students; large unit had >20 faculty members and >100 students

180 Noting that our survey included programs that are 2 and 4 years in length, we found that the
181 introductory soil science courses were mainly taken by the second year students (33%), closely followed
182 by third year (28%), and first year (24%) students. Students in their fourth years represented 13% and
183 graduate students and professionals were 2% of introductory soil science course registrants.

184

185 ***2. The instructors of introductory soil science courses in Canada***

186 Participants were asked if teaching of the course required one or several instructors of equal
187 responsibility or status, and 93% indicated that one instructor was teaching this course, while 5% of
188 courses were taught by two primary instructors (note, one respondent indicated "none" probably due to
189 misunderstanding what was asked). These results reflect that the majority of small or medium units
190 need only to offer one section of the introductory course while the larger units with higher enrollments
191 (e.g., the University of British Columbia, Vancouver) offer multiple sections of the same course or
192 delivered it in multiple semesters. Also, at the University of Saskatchewan, more than one introductory
193 course was offered and there was one primary instructor for each course. The Haffie et al. (2000) study
194 on introductory genetics courses reported that 51% of the students were enrolled in courses that were
195 team taught, while the remaining students were enrolled in courses with one principle instructor.
196 However, enrollments in introductory genetics courses, with some institutions reporting class sizes up to
197 500 with multiple offerings in the same year, were considerably higher than for introductory soil science
198 courses with enrollments ranging from <10 to 250 students as reported above. Teaching assistants or
199 technicians provided instructional support for the majority of introductory soil science courses (74%).
200 This may reflect multiple course sections, but it is likely aligned with the observation that most courses
201 had a laboratory section associated with them that required extra instructional support.

202 The highest level of education attained by primary course instructors identified in the survey
203 was predominantly a PhD (86%), followed by MSc (12%), and BSc (2%). The academic institutions

associated with the primary instructors who held MSc degrees were almost exclusively associated with either a college, technical institute, or a polytechnic university. The instructors who held a PhD were primarily employed at a university. Three respondents indicated that they held a PhD and worked at a college. Haffie et al. (2000) also found that most instructors held PhD degrees (90%) although they did not include colleges, technical institutes or polytechnic universities in their survey. In addition, the majority of the primary instructors in our study (66%) were either tenured or in tenure track positions (i.e., assistant, associate, or full professor) (Fig. 2). Twenty four percent of respondents held the position of Instructor (which included Lab Instructor), followed by Sessional (5%), and Lecturer[4] (2%). Similarly, Haffie et al. (2000) reported that the majority of instructors held tenure or were in tenure track positions (91%).

The disciplinary background of primary instructors was varied, but the largest number of instructors (41%) indicated a background in soil science (Fig. 3). The survey question allowed participants to name more than one discipline, as the focus of their study may be different between their MSc and PhD. A background in forestry or related areas like resource management, and a background in geography were also common to primary instructors of introductory soil science courses (Fig. 3).

Participants were also asked if, as primary instructor, they had developed the course themselves or had they adapted/modified an existing course. The majority of respondents (56%) indicated that they developed the course that they teach, with 44% indicating that they modified or adapted an existing course. Overwhelmingly, 99% of primary instructors indicated that they would choose to teach the introductory soil science course to which they are currently assigned.

The general profile of a primary instructor of an introductory soil science course in Canada is someone who holds a PhD and has a disciplinary background in soil science. Also, they are tenured or

[4] Depending on an institution, "Lecturer" may refer to either tenured or non-tenured position.

227 are in tenure-track positions at their academic institutions and are excited to be teaching the course.
228 These are all indications that postsecondary institutions recognize the importance of the discipline to
229 their programs and are committed to ensuring that the course is delivered by enthusiastic subject
230 matter experts. Thus, the rigor in the delivery of the soil science content in introductory courses likely
231 remains high in terms of the core principles of the discipline. This also speaks to the long-term currency
232 and viability of offering these courses. Rotating instructors, which in turn leads to discontinuities in
233 content coverage, are potential problems that may arise if administrative units do not pay attention to
234 introductory courses (Labov, 2004). Even though our study provided only a snapshot of the state of
235 introductory soil science courses at the time of the survey, our results imply the long-term stability of
236 offering these courses in Canada.
237
238 ***3. The scope of teaching and learning practices in introductory soil science courses in Canada***
239 Seventy-six percent of the introductory soil science courses surveyed had pre-requisites, while
240 24% did not. This agrees with our finding that 61% of students enrolled in these courses took the course
241 in the 2nd and 3rd year of study, which implies that students should have background knowledge of basic
242 scientific concepts needed to understand soil science principles.
243 The introductory soil science courses in Canada are predominantly offered in the classroom
244 lecture format with just 7% of courses offered as online distance education courses. This might reflect
245 the lack of support and resources needed to develop online distance education courses, but it also may
246 be indicative that soil science instructors still favour face-to-face teaching approaches. Even though
247 many colleges and universities see online distance education as a way to grow student enrollments,
248 often for revenue generation and on the false premise of not having to invest in more staff and
249 resources, the increased accessibility and flexibility of online courses would benefit working

professionals, life-long learners, and students located in small and isolated communities in Canada (Bates, 2015).

A textbook was required in 52% of surveyed courses, while 18% had a recommended textbook (Table 2). Brady and Weil's "The Nature and Properties of Soil" or one of its abridged versions was the most commonly used textbook with 68% of classes listing it as required and 78% listing it as required or recommended. The survey also found that 29% of respondents utilized a variety of online resources as reference materials. The most popular web site at 19% of respondents was the Virtual Soil Science Learning Resources (www.soilweb.ca) with its affiliated YouTube videos and other multimedia, followed by 10% of respondents using unspecified YouTube videos, and 10% of respondents highlighting various government websites and online documents.

Overall, textbooks used in Canadian introductory soil science courses were primarily written by authors from the United States, which uses a different soil classification system. The only Canadian textbook mentioned in our survey was "Geomorpholgy, a Canadian Perspective" (2016) by Alan S. Trenhaile from the University of Windsor; however, the focus of that textbook is geomorphology and it addresses soils from that context. The only other Canadian publication mentioned in the survey was the "Canadian System of Soil Classification" (Soil Classification Working Group, 1998), which is a valuable resource, but it was not intended nor designed to be an introductory textbook for soil science. Clearly, there is a need, and a potential demand, for a comprehensive Canadian introductory soil science textbook. The only notable past effort is a textbook by Noorallah Juma entitled "Introduction to Soil and Soil Resources" (1999) but it has not made its way into general use in Canada. Major publishers may be wary to offer Canadian textbooks for soil science due to the small market compared to the broad appeal of more well-known international textbooks. A Canadian soil science textbook would require a collaborative effort and perhaps it could be produced as an open education resource or an e-textbook. Potential examples include Steven Earle's open textbook "Physical Geology" (2015), produced by

BCcampus open textbook initiative and which contains a section on soils, and on open-source laboratory manual for introductory, undergraduate soil science courses developed by Moorberg and Crouse (2017) at the Kansas State University.

The top four educational activities indicated by instructors of introductory soil science courses were lectures (86%), laboratory (76%), field trips (57%), and use of online learning resources (36%) (Table 3). Among courses that include field trips, the highest percentage (44%) were in units with 21-60 enrolled students, followed by units with >100 students (36%), and lastly units with 61-100 students (20%). Thus, field trips were not restricted by course size per se, but perhaps other limitations like having meaningful sites nearby, availability of busses and teaching assistants, or by climate (i.e., duration of snow cover or frozen ground).

Our results indicate that instructors are combining traditional forms of instruction (lectures, labs, and field trips) with more innovative approaches such as use of open education resources, online discussion sessions (26%), and flipped classrooms (12%), signaling that soil science course instructors are willing to innovate and diversify their teaching methods. Similar findings were reported in Hartemink et al. (2014) and Turk (2016). Since just over a third of Canadian introductory soil science courses incorporate some type of online resources, there is room for improvement and educational innovations in these important soil science gateway courses.

The Virtual Soil Science Learning Resources - VSSLR (www.soilweb.ca) is an example of Canadian collaborative effort to develop open access online educational resource focused on soil. The VSSLR could be expanded into a shared pan-Canadian soils educator portal, where instructors could share any type of course material (not just online resources as is currently the case) and have a platform for an ongoing discussion about soil science education. Another initiative that deserves more attention in postsecondary soil science curricula in Canada is blending of in-person and online teaching approaches.

297 Even though numerous topics covered in the introductory soil science courses are suitable for hands-on
298 teaching methods such as field descriptions of soil properties such as texture, structure, color, rooting
299 depth, there are also numerous opportunities to enhance an experiential learning experience in soil
300 science through blending of in-person and online teaching approaches. One example is the use of
301 mobile-based games to allow students to go on self-guided fields tours (Hoffman et al., 2017). Another,
302 is the incorporation of emerging media such as augmented reality to illustrate changes of soil types
303 across landscapes thorough hands-on displays that allow learners to create topography models by
304 shaping sand that is augmented in real-time by colored elevation maps, topographic contour lines, and
305 simulated water (Vaughan et al., 2017). The blended educational approaches may also be suitable for
306 students in parts of the country (e.g., Prince Edward Island) where no soil science course are offered
307 (Diochon et al., 2017). For example, if the in-person component of a course was offered in the week or
308 weekend prior to the Fall semester or immediately following the Winter semester, students could
309 complete the online components during the regular Fall or Winter semesters.

310 A laboratory component was a part of 76% of surveyed introductory soil science courses in
311 Canada (Table 3) and they were taught by instructors (52% of respondents), lab instructors (10%),
312 graduate teaching assistants (31%), or a combination of those mentioned above (7%). Such a high
313 proportion of laboratory components taught by instructors could be indicative of the following: (1) that
314 instructors value teaching this course not just in lecture halls, but also in the laboratory and the field (if
315 they are part of the course) settings, since this consistency ensures the quality of instruction, and/or (2)
316 that postsecondary units do not have enough funding to support teaching assistants or that there are no
317 graduate students available (e.g., as with colleges).

318 Most laboratory sections of the introductory soil science courses in Canada had between 11 and
319 20 students, followed by sections with 21 to 30 students. Twenty-three respondents (55%) pointed out
320 that they had a laboratory manual or a set of reference resources in their introductory soil science

courses; and 82% of those used a self-created laboratory manual, while 23% used inherited or published manuals.

When asked "*If there were aspects of the lab component that could be improved?*", 76% of respondents said 'yes" indicating things such as a need for more up-to-date equipment, lack of technical support to deliver laboratory components, need for closer or easy-to-access sites for field trips, and a lack of appropriate space for laboratories (Fig. 4). The need for better equipment (60% of responses) topped the list of suggestions for laboratory improvements, a finding that was perhaps not surprising since instructors are constantly striving to use and showcase the most current types of laboratory techniques and equipment to their students. It was somewhat surprising that 40% of respondents do not have enough time for the incorporation of laboratory activities (Fig. 4). To overcome this issue a change in how laboratories are incorporated in the introductory soil science courses might be considered. Several universities in the United States have developed a "studio format" concept in which lecture and lab time are integrated such that discussion topics transition directly into connected laboratory activities (Andrews and Frey, 2015). It has been reported that students taking the studio format course obtained higher final grades and that the fail rate was significantly lower than those taking the traditional course. Lower performing students made greater gains in the studio relative to the traditional course. A similar observation was brought up by one respondent in our survey who stated the following "*Students are now less willing to read long texts and journal articles, and much of the learning has to be done in the labs with practical exercises.*"

The learning assessments were primarily done using in-class examinations (92% of respondents), though 13% of respondents also used take-home examinations. Other assessment methods included laboratory assignments or reports (14%), quizzes (27%) and term papers (6%) and lastly 6% of respondents reported using in-class presentations, self-evaluations, self-guided soil pit assessments, and/or oral presentations. The suggestion for a shared pan-Canadian soils educator resource portal (i.e.,

345 a venue to share teaching resources) could potentially broaden course activities and evaluation options
346 and lead to a collaborative and creative honing of existing resources. An example of such initiative is the
347 On the Cutting Edge Professional Development Program for a Geoscience Faculty in the US
348 (https://serc.carleton.edu/NAGTWorkshops/about/index.html), which combines workshops, websites,
349 and research activities to support high-quality undergraduate geoscience education. The program was
350 established in 2002 and it has changed geoscience education in the United States by creating a culture
351 of information and resource sharing that underpins continuous improvement in undergraduate
352 geoscience instruction.

353

354 ***4. Reflections on teaching introductory soil science courses***

355 Survey participants were asked to reflect upon their experience of teaching introductory soil
356 science courses. From the responses received, it is clear that Canadian instructors of the introductory
357 soil science courses had two main goals in teaching this course: (1) to allow their students to develop a
358 sound understanding of basic soil science (71% of respondents stated this) and (2) to inspire students to
359 appreciate soil and the vital role it plays supporting our society and culture (38% respondents specify
360 this as their goal).

361 Instructors for the introductory soil science courses in Canada truly love teaching these courses,
362 43% of respondents indicated that they enjoy working with students and 63% stated that they find it
363 exciting to witness students get excited about soil and see the “aha moments” in students’ learning.
364 Since field observations play a key role in teaching and learning about soil and its properties, it was not
365 surprising that 33% of instructors reported that they find field visits with their students as one of the
366 most exciting aspects of their work.

367 Teaching introductory soil science courses was associated with various challenges (Table 4).
368 These ranged from a lack of adequate support to deliver the course (31% of respondents), students not

having enough of science background to follow material covered in this course (26%), having students of diverse backgrounds in the course (21%), not having enough time to cover all relevant topics (21%), and too large class size (13%). Indeed, students are generally more motivated and engaged in their learning in the small classes (Harfitt and Tsui, 2015); however, the learning environment (e.g., learning supports, campus environment), the student behaviors and actions (e.g., student preferences, effort, and time engaged), and personal influences (background knowledge, workload, self-regulation) are all well known to strongly influence student success (Boles and Whelan, 2016). Therefore, challenges highlighted by some of the respondents are common and not specifically restricted to introductory soil science courses.

When participants were asked "*If they identified aspects of the structure (or administration) of their course that could be improved*", 52% of respondents answered "yes." They indicated a need for better timing of the course such as moving it to later in a student's program and allotting more time for course delivery by either offering it in two semesters or adding more contact hours. Other suggestions included the addition of more field trips, encouraging better student engagement, addition of online educational resources, stricter pre-requisites, and improving laboratory space (Fig. 5). One of the respondents offered the following suggestion regarding course improvements *"Lecture component could include more active learning activities such as debate, problem based learning, discussion; but classroom design often renders use of these methods impractical."* This emphasizes the need that soil science instructors should continue to expand opportunities for students' experiential learning by adopting innovative teaching approaches and strategies.

In our survey we also asked instructors who taught the introductory soil science courses for at least 15 years to offer their the insights on the evolution of their courses and/or students and representative responses are shown in Box 1. Those responses echo, to a large extent, reflections of co-authors of this paper, which are summarized below.

392 The students who enroll in introductory soil science courses often have very diverse
393 backgrounds and differing levels of prior knowledge of soil science, which presents a challenge in
394 keeping students' interest. To address this we use various non-traditional delivery methods such as
395 discussion, debate, student presentations, riddles, soil specimens, video games (e.g., Shroomroot
396 developed by Amerongen Maddison et al., 2018), viewing of video clips and animations, and story-
397 telling regarding our professional experience. Sometimes the more experienced students are
398 encouraged to share their knowledge with the rest of class, thus engaging them into discussing topics
399 they may feel they already know. It is important to get all students to engage as soon as the class starts,
400 but this can be a challenge as one survey respondent stated: "*Current students are more impatient with*
401 *a shorter attention span, and they require that we entertain them. They are more insecure and thus*
402 *require more rewards and positive reinforcement*." Consequently, adding some entertaining aspects of
403 our discipline and/or professional experience can draw a student's attention. The trade-off is that we do
404 not always get to review all the content that we would like to in such a course although students are
405 given access to a set of course notes to help fill in any gaps.
406 It is possible that some of today's students are exhibiting what is referred to as "academic
407 entitlement" (Goldman and Martin, 2016) and that they can find course relevant information through
408 the Internet and various technological tools. Thus, the lecture format is less relevant to what students
409 perceive to be their learning needs. The availability of online information, even during the lecture itself,
410 supports this belief and entitlement. The students also see themselves as consumers or customers
411 (Goldman and Martin, 2016); thus, they may resent the focus of traditional teaching methods on
412 content – content they can acquire themselves at no charge. Since 86% of surveyed introductory soil
413 science courses in Canada rely on the classroom lecture, this should be of concern to instructors and
414 academic units offering these courses. There is the opportunity to introduce more meaningful learning
415 activities such as case studies, problem-based learning, group work, blended learning, and other

416 activities that support the development of soft skills such as communication, teamwork and creative
417 problem-solving. If we assume that the lecture style focuses on transmitting content, which students
418 feel they can acquire themselves just a readily, then the teaching style should shift to focus on more
419 engaging active learning approaches. This would suggest that as soil science instructors we need to shift
420 the delivery method away from the lecture and towards methods that capitalize on the student's access
421 to information, and mentor the student in aggregating and understanding that information (Hosek and
422 Titsworth, 2016).

423 Consequently, two things to consider are: (1) that all activities currently included in a lecture
424 period may not necessarily be all lecture *per se*; and (2) that a lecture is not necessarily a bad learning
425 environment. As Kramer (2017) has pointed out, often the problem is not in the lecture content, but in
426 the delivery of that content. How the heavy use of lectures in soil science introductory courses
427 compares to this is not known and a future study on students' perceptions of the effectiveness of the
428 teaching methods used is needed to more fully understand how soil science teaching needs to change, if
429 at all.

430 In today's courses and students' expectations of those courses, there will be an ongoing struggle
431 to achieve balance in 'breadth over depth.' One suggestion on how to reconcile this is that some of the
432 specific and practical details of soil science could be covered more in the upper level courses. Another
433 approach could be to implementation of instructional scaffolding (Wood et al., 1976). An example of this
434 is a forest floor scaffolding module developed by Krzic et al. (*in press*) that includes a campus-based
435 lecture, online multimedia material in the *Forest Floor* educational resource
436 (http://forestfloor.soilweb.ca/), instructor-led demonstrations of forest floor description and
437 classification using samples in laboratory setting. This was followed by a collaborative hands-on activity
438 with written instructions provided in the laboratory manual, an individual written assignment, and a
439 self-guided activity (or quest) carried out on the university campus aided by a mobile game. These forms

of support were gradually removed as students developed independent learning strategies, culminating in the self-guided activity that led students to a forest on the university campus to practice their newly developed skills in forest floor description and classification.

Conclusions and Recommendations

We surveyed 58% of the instructors of introductory soil science courses across Canada. The largest numbers were offered by geography and environmental science units and results indicate that the majority of instructors followed a traditional lecture and laboratory delivery format (86% and 76%, respectively), with a relatively limited use of online teaching resources (36%).

Introductory courses offered at Canadian post-secondary institutions are delivered by primarily one instructor, who holds a PhD in a tenure track position and in most cases developed the course that they teach. Although the disciplinary background of these instructors is predominantly soil science, many of the instructors were experts in geography, resource management, and forestry. These metrics speak to the long-term viability, sustainability and multi-disciplinary high-quality instruction available across Canada.

The instructor reflections suggested that students have changed in terms of their classroom expectations and that increasing the use of alternative learning methods in the introductory courses could possibly improve student experience and overall performance. Since this study focused exclusively on course instructors, we have no knowledge of students' opinions about the introductory soil science courses. It would also be of interest to know how deep the use of traditional teaching methods go in the teaching of post-secondary soil science more broadly: Is the teaching and learning approach of advanced courses similar to introductory courses, or with purportedly smaller classes and more focused subject matter do we find more use of alternative teaching methods? Further investigations of teaching

methods used in the upper level soil science courses, and of students perceptions, preferences, and performance related to teaching in soil science are recommended.

Another important conclusion closely related to the incorporation of alternative teaching methods into traditional teaching, is the limited offering of online distance education courses and potential improvements in the use of online resources. This could be due to limited resources and instructional design support, a preference to use traditional modes of teaching, a desire to have direct contact with students, or that instructors do not know how to access resources to implement in courses. A follow up study on use of online courses and instructor's knowledge of resources available for online delivery is recommended. Also, the Canadian Society of Soil Science could promote online teaching resources that are freely available to instructors across Canada.

Over half of the instructors surveyed used either a required textbook or a recommended textbook; therefore, the lack of a Canadian-authored soil science textbook begs for the creation of such a resource. It is recommended that the Canadian Society of Soil Science initiate and manage the development of an open-source textbook for use in teaching introductory soils science courses.

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555 **Table 1. List of surveyed Canadian introductory soil science courses and their associated postsecondary institutions and departments/schools.**
556

No[§]	University or College	Department or School	Course title
1	Yukon College	School of Science	Introduction to Soil Science and Soil Resources[ŧ]
2	Vancouver Island University	Forestry	Introduction to Soil Science I and II
3	University of British Columbia	Applied Biology	Introduction to Soil Science
		Earth, Environmental and Geographic Sciences	Soil Science
4	British Columbia Institute of Technology	School of Construction and the Environment	Earth Science & Soils
5	Simon Fraser University	Geography	Soil Science
6	Kwantlen Polytechnic University	School of Horticulture	Soils and Growing Media
7	University of Northern British Columbia	Ecosystem Science and Management	Introduction to Soil Science
8	College of New Caledonia	Natural Resources and Environmental technology	Introduction to Forest Soils
9	Trinity Western University	Geography and Environment	Soils Geography: An Introduction to Soils
10	University of the Fraser Valley	Agriculture	Introduction to Soils and Soil Fertility
11	Thompson Rivers University	Natural Resource Science	Introduction to the Study of Soils
12	Mount Royal University	Earth and Environmental Sciences	Introduction to Soil Science
13	Olds College	Land and Water Resources	Fundamentals of Soil Science
14	University of Alberta	Renewable Resources	Introduction to Soil Science
15	University of Lethbridge	Geography	Soils
16	Lethbridge College	Environmental Sciences	Soil Resources
17	Lakeland College	Environmental Sciences	Introduction to Soil Science
18	University of Saskatchewan	Soil Science	Identification of Saskatchewan Soils and Plants
		Soil Science	Environmental Soil Science
19	University of Winnipeg	Geography	Introductory Soil Science
20	University of Manitoba	Geography	Introduction to Soils and Soil Conservation
		Soil Science	Soils and Landscapes in Our Environment
21	Lakehead University	Geography and the Environment	Introduction to Soil Science
22	University of Windsor	Earth and Environmental Sciences	Soil and Sediments
23	Laurentian University	Earth Sciences	Introductory Soil Science

24	University of Waterloo	School of Environment, Resources and Sustainability	Soil Ecosystem Dynamics
25	Wilfrid Laurier University	Geography and Environmental Studies	Geomorphology and Soils
26	University of Guelph	School of Environmental Sciences	Soil Science
27	Georgian College	School of Engineering and Environmental Technologies	Soil Properties
28	University of Toronto	Physical and Environmental Sciences	Principles of Soil Science
29	Trent University	School of the Environment	Soil Science
30	Carleton University	Geography and Environmental Studies	Soil Properties
31	McGill University	Geography	Soils and Environment
32	Université de Sherbrooke	Biology	Les Sols Vivants
33	Bishop's University	Environment and Geography	Soils and Vegetation
34	Université du Québec à Chicoutimi	Fundamental Sciences	Interactions Sol-écosystèmes
35	Dalhousie University	Plant, Food, and Environmental Sciences	Introduction to Soil Science
36	Memorial University	Environmental Science	Introduction to Soils

557 [§]The numbers are associated to geographical positions on Fig. 1.
558 [ŧ]This course is offered at the Yukon College in collaboration with the University of Alberta (Environmental & Conservation Sciences Program,
559 Major in Northern Systems).

560 **Table 2. Required and recommended textbooks used in introductory soil science courses in Canada**

Textbook title	Author	Publisher	Required	Recommended
-Elements of the Nature and Properties of Soil	Raymond R. Weil and Nyle C. Brady	Pearson	7[§]	5
-Unspecified variants of The Nature and Properties of Soil	Raymond R. Weil and Nyle C. Brady	Pearson	4	2
-The Nature and Properties of Soil	Raymond R. Weil and Nyle C. Brady	Pearson	3	9
-Soils: An Introduction	Michael J. Singer and Donald N. Munns	Pearson	2	
-Principles and Practice of Soil Science: The Soil as a Natural Resource	Robert E. White	Wiley	1	
-Geomorpholgy, a Canadian Perspective	Alan Trenhaile	Oxford University Press	1[§]	
-Fundamentals of Geomorphology	Richard John Hugget	Routledge	1[§]	
-The Canadian System of Soil Classification	Soil Classification Working Group	NRC Research Press	1[§]	1
-Soil Science and Management	Edward Plaster	Delmar Publishers Inc.	1	
-Soil in the Environment	Daniel Hillel	Academic Press	1	
-Common Plants of Western Rangelands	Alberta Agriculture, Food, and Rural Development, Kathy Tannas, Olds College	Alberta Agriculture, Food and Rural Development	1[§]	
-Plants of the Western Forest: Alberta, -Saskatchewan and Manitoba Boreal and Aspen Parkland	Derek Johnson, Linda Kershaw, Andy MacKinnon,	Lone Pine Publishing	1[§]	
-Custom Course Notes Package	Unspecified	unspecified	2	1
		Unique Entries	**22**	**18**

561 [§]Survey respondents included multiple entries; hence, counted as single unique response

562

563 **Table 3. Types of educational activities used in the introductory soil science courses in Canada (n=42).**

Educational activity	Number of responses	Percentage of responses
Lecture	36	86
Flipped classroom	5	12
Laboratory	32	76
Field Trips	24	57
Discussion sessions	11	26
Self-guided field trips	2	5
Online learning resources	15	36
Other	2	5

564 [§]Percentages sum to greater than 100% because respondents were able to indicate multiple activities

565

566

567

Table 4. Main challenges in teaching the introductory soil science course (n=39). Percentages sum to greater than 100% because respondents were able to indicate multiple types of challenges.

Type of challenge	Number of respondents	% of respondents
Lack of adequate support[§]	12	31
Students lacking strong science background	10	26
Students have diverse backgrounds	8	21
Not enough time	8	21
Class size	5	13

[§] Lack of support included absence of adequate lab space, insufficient technical support, absence of adequate textbook, and shortage of lab equipment

Box 1. Selected representative responses offered by the instructors of the introductory soil science course who taught this course for at least 15 years

- "*[Current students] are more impatient with a shorter attention span, and they require that we entertain them. They are more insecure and thus require more rewards and positive reinforcement*."
- *"Generally, students seem more attuned to importance of soils now than in the past. Students have good computer-related skills but poorer observational skills than in past….. most likely since students come in with typically less connecting experience to the land (e.g., through farming, horticulture, gardening)."*
- *"The fundamentals of the course have not changed much over that time; however, the emphasis has moved from theoretical foundations to more applied problems. Students are now less willing to read long texts and journal articles, and much of the learning has to be done in the labs with practical exercises."*
- *"I'm learning that I don't need to try to cover everything (the whole book); but rather cover less, and make sure the inspiring/interesting/fun bits get a little more time."*
- *"As we accept more students from the non-traditional body (that is required to have Soil Science) that uses knowledge about soils in their professions, our instruction has lost some depth in order to accommodate more breadth."*
- *"Basic material remains the same (fundamental aspects of biology, chemistry, physics etc.) but the thing that you want to evolve is the ways in which soils play an important part of current environmental problems (carbon sequestration, greenhouse gases, thawing permafrost, organic farming, soil 'health' etc.). The introductory soil science course used to be followed by a course on soils and land use, but that was cancelled. In some ways, students do not get enough opportunity to apply what they have learnt duel to absence of the 'follow-on' (upper-level) courses."*

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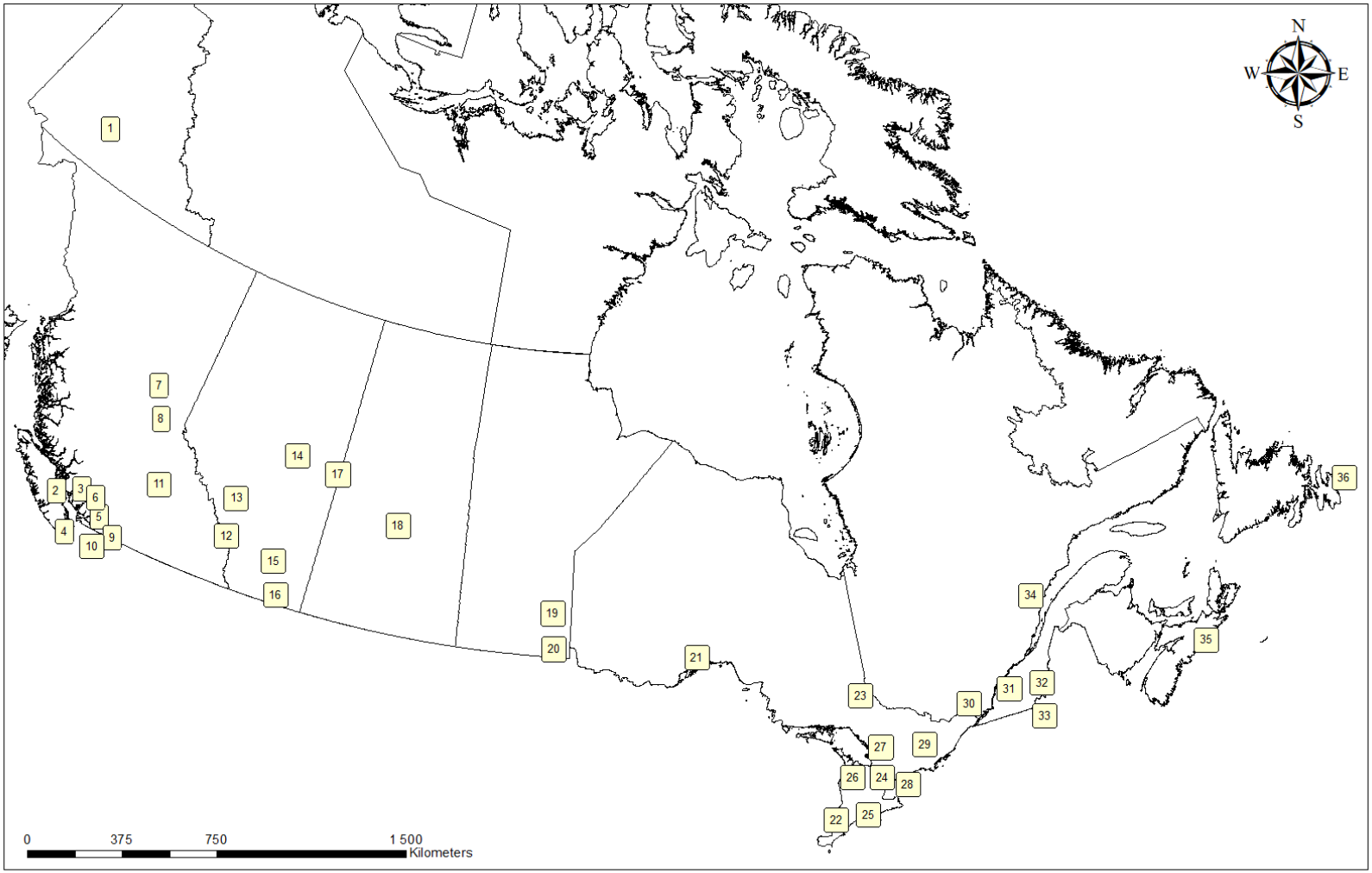

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579 **Fig. 1.** Geographical locations of surveyed Canadian postsecondary institutions that offer introductory soil science courses
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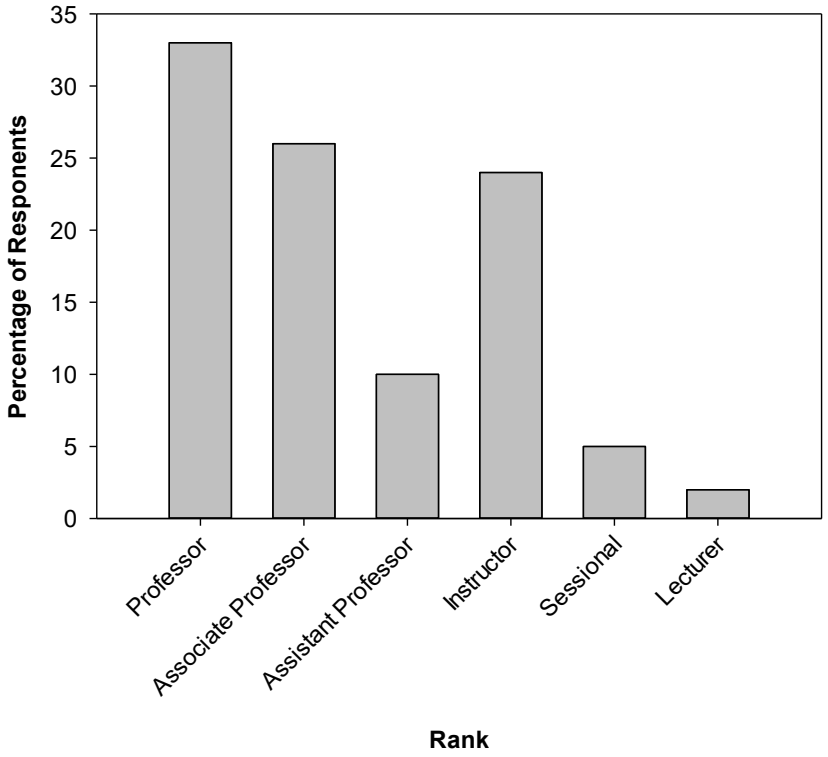

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583 **Fig. 2.** Participant responses showing the rank of primary instructors of introductory soil science courses.

584 Results shown as % of total response.

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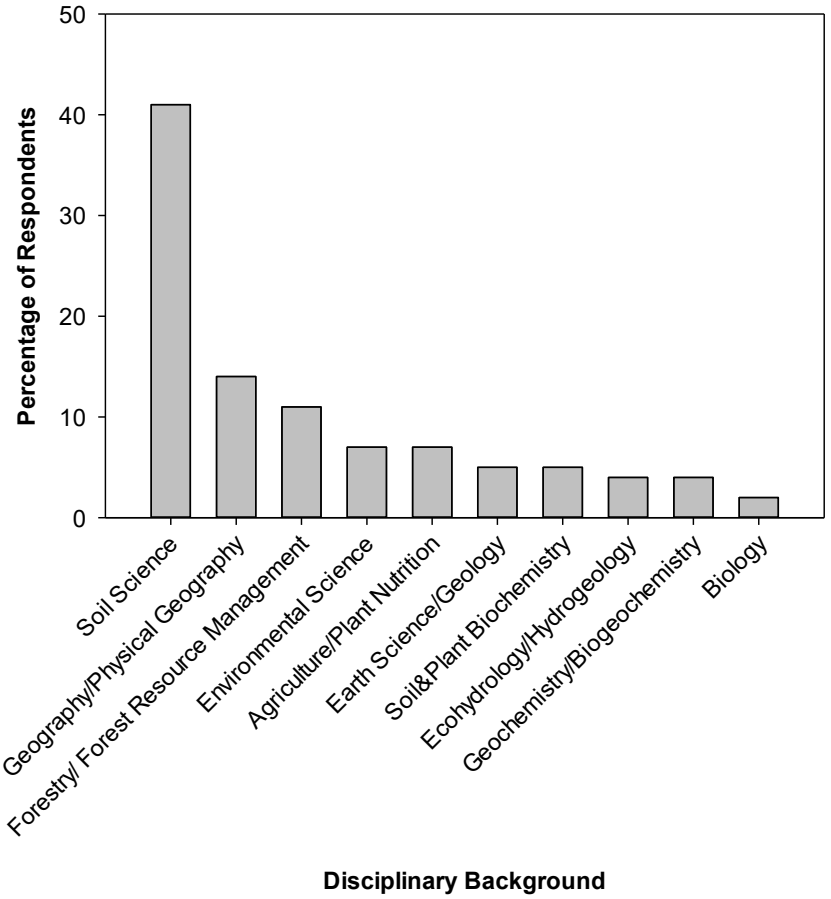

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589 **Fig. 3.** Participant responses showing the disciplinary backgrounds of primary instructors of introductory

590 soil science courses. Results shown as % of total response.

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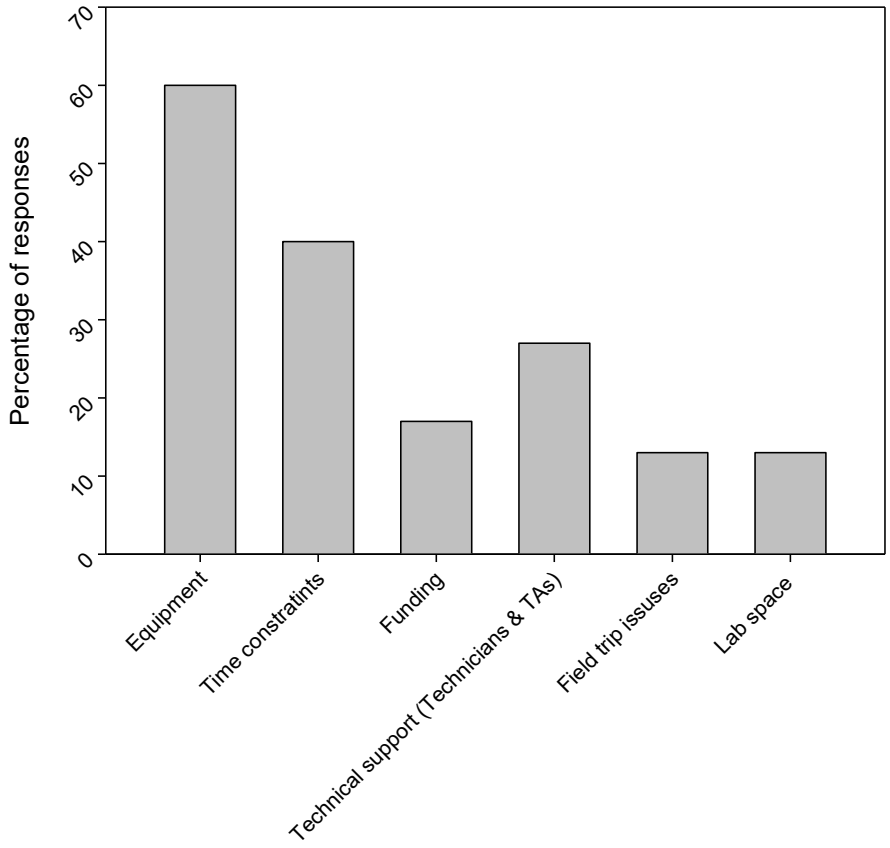

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594 **Fig. 4.** Main types of suggested improvements for laboratory sections in the introductory soil science
595 courses (n=30). Percentages sum to greater than 100% because respondents were able to indicate
596 multiple types of laboratory improvements.

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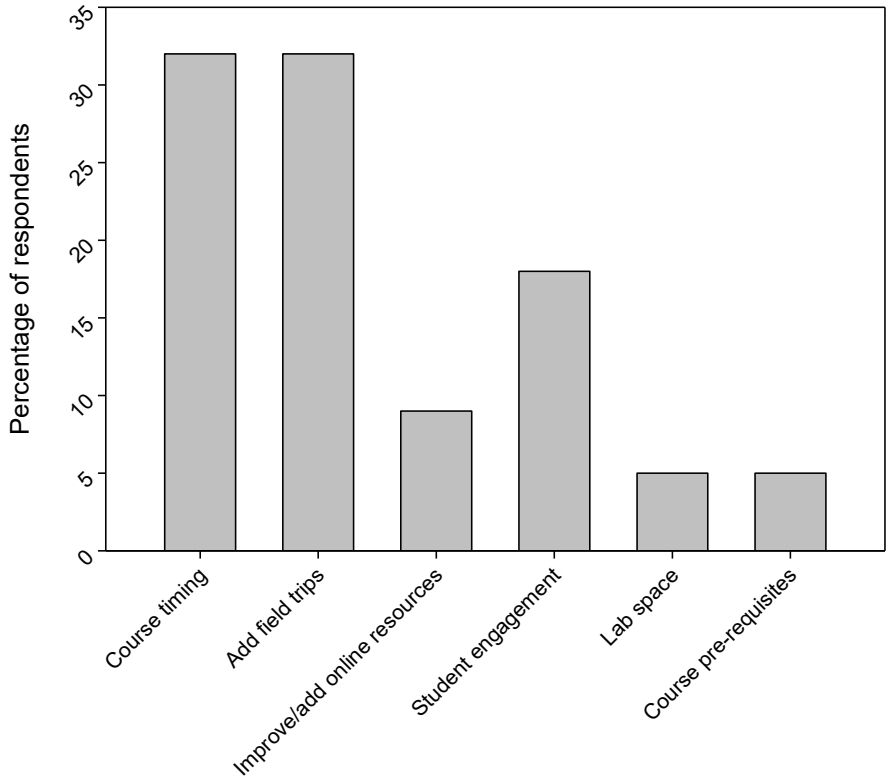

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599 **Fig. 5.** Suggested types of improvements for the introductory soil science courses (n=22). Percentages

600 sum to greater than 100% because respondents were able to indicate multiple types for course

601 improvements.