Virtual Soil Monoliths: Blending Traditional and Web-Based Educational Approaches

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ABSTRACT Since soil plays a crucial role in all aspects of global environmental change, it is essential that post-secondary institutions provide students with a strong foundation in soil science concepts including soil classification. The onset of information technology (IT) and web-based multimedia have opened new avenues to better incorporate traditional, static educational resources such as soil monoliths into post-secondary teaching and learning. The objective of this study was to develop an open access, web-based educational tool entitled "Virtual Soil Monoliths" (VSM) (http://soilweb.landfood.ubc.ca/monoliths/), based on a soil monolith collection at the University of British Columbia (UBC), Vancouver, Canada. With 197 monoliths, the UBC collection is the second largest of its nature in Canada, but due to poor storage and displays it has been underutilized in teaching. The VSM tool was developed by a team of scientists, instructional designers, IT specialists, and students and integrated into the Introduction to Soil Science course at UBC to support lectures and laboratory sections on parent material identification and soil classification. Student feedback indicated the VSM tool was helpful in facilitating student achievement of learning objectives related to basic soil classification and soil identification skills. Students used the VSM tool to complete assignments in the Introduction to Soil Science course, and students pointed out that the high-resolution monolith photographs were the most useful feature of the tool. This study provides a framework for incorporating inventory-type learning resources into an interactive teaching tool and a "living" educational resource that helps students grasp connections across disciplines.

Impact Statement An intention to enhance the post-secondary soil science education, we have created a web-based teaching tool based on a soil monolith collection. Instructors of soil science and other natural resource courses will find this framework of incorporating inventory-type learning resources into an interactive teaching tool and a "living" educational resource helpful for enhancing their own teaching practice.

Global environmental change, including climate change, ecosystem shifts, and biodiversity loss as a result of human activities, is emerging as one of the most important issues of our time. Soil plays a crucial role in all aspects of global change (Janzen et al., 2011). As these challenges to society continue to grow, it is essential that post-secondary institutions provide students with a strong foundation in soil science applicable to the context of current global issues (Baveye et al., 2006; Collins, 2008).

INNOVATIVE CURRICULA

The importance of soil as a natural resource, coupled with ongoing declining student enrollment in post-secondary soil science programs around the world (McCallister et al., 2005; Baveye et al., 2006; Collins, 2008), calls for the creation of innovative engaging curricula. In response to this reality, some universities have re-organized their soil science programs and created new courses focused on environmental issues (McCallister et al., 2005), whereas others have established interdisciplinary soil science programs (Hansen et al., 2007). Many are also introducing new educational approaches and technologies. The application of information technology (IT) to post-secondary curriculum can relieve institutional pressures of trying to educate a rising number of students with less available funding, while providing a richer learning experience for students (Bates, 2000).

Incorporating web-based learning into post-secondary education has the potential to create motivating, authentic learning environments in which students build communication and problem-solving skills. In web-based learning, there has been an emphasis on constructivist approaches (Bates, 2008), as students create their own knowledge by seeking out information and building their own informational frameworks (Chumley-Jones et al.,

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Abbreviations: IT, information technology; UBC, University of British Columbia; VSM, Virtual Soil Monoliths.

Fig. 1. A soil monolith.

2002). Web-based teaching tools reinforce learning by allowing review of multimedia content (Polsani, 2003), accommodating diversity of learning styles (Jain and Getis, 2003), and aiding in the development of a deeper knowledge base (Najjar, 1995). Student motivation may be enhanced because the inclusion of varied multimedia into course content presents multiple avenues to access the information (Polsani, 2003; Cox and Su, 2004). Students from the "net generation" are generally interested in having online multimedia resources at their fingertips (Mohanna, 2007) and one of the driving factors in the creation of web-based educational resources is on-going student demand.

Soil Monoliths

New educational technologies also have a potential to enhance the appeal and accessibility of some of the traditional educational resources such as soil monoliths. A soil monolith (Fig. 1) is a vertical section of soil profile preserved in its natural (undisturbed) condition. Soil monoliths are used in teaching and for demonstration purposes (Allaire and van Bochove, 2006) as well as in comparative studies in variety of disciplines (e.g., pedology, soil chemistry, hydrology, plant science, biometeorology, biology, engineering). They are portable and allow an easy comparison of numerous soil types. Each monolith tells a story through its morphological features (e.g., texture, structure, color, horizon thickness). Some provide obvious evidence for soil-related limitations to land use, whereas others serve as historical records of sites and soil types no longer in existence.

The first record of soil monolith use dates back to late 19th century, when several monoliths collected in Russia were displayed at the Columbian Exhibition in Chicago during the international exhibition in 1893–1894 (Vanderford, 1897; van Baren and Bomer, 1979). The next documented use of soil monoliths was at the First International Congress of Soil Science held in 1927 in Washington, DC, where 18 large soil monoliths from Latvia were displayed (Truog, 1928). The most notable recent example of soil monolith use is the "Dig It! The Secrets of Soil" exhibit of the Smithsonian's National Museum of Natural History, Washington, DC, with 53 monoliths from the 50 U.S. states, District of Columbia, Guam, and Puerto Rico (Megonigal et al., 2010).

Soil monolith collections are often displayed in hallways or rooms (so called pedolariums) with relatively limited access, which confines their effectiveness for teaching and learning. The onset of IT and web-based multimedia have opened new avenues to incorporate and revitalize these traditional educational resources into student instruction and raise the general public awareness about the importance of soil as a natural resource. Information technologies allow the information contained within soil monoliths to be distributed without the need to physically handle these relatively fragile objects. The objective of this study was to develop an open access, web-based educational tool entitled "Virtual Soil Monoliths" (VSM) based on a soil monolith collection at the University of British Columbia, Vancouver, Canada. The VSM was designed for use in the lower-level undergraduate Introduction to Soil Science course as a self-study resource that supports campus-based, hands-on laboratory sections focused on parent material identification and soil classification.

THE VIRTUAL SOIL MONOLITH TOOL

The University of British Columbia Monolith Collection

The University of British Columbia (UBC) collection of soil monoliths, gathered between the early 1960s and late 1990s, includes monoliths from several Canadian regions. The majority of monoliths originate from the province of British Columbia including the Peace River and Cariboo regions, the East Kootenay's, Vancouver Island, and Fraser River Valley. A smaller number of monoliths were collected in Alberta to include "true" grassland soils, Chernozems according to the Soil Classification Working Group (1998) or Mollisols in the USDA Soil Taxonomy (Soil Survey Staff, 1999), and the Yukon, to illustrate the effects of cryoturbation (soil formation process that causes mixing of soil material due to freezing and thawing). At 197 monoliths, it is the second largest collection of its kind in Canada. Only the University of Alberta, Edmonton has a larger collection of about 300 monoliths. The Department of Soil Science at UBC played a major role in maintaining the collection, but due to faculty reorganization in the late 1990s, the monolith collection was scattered among various locations on campus, which substantially reduced its visibility, accessibility and utilization as an educational tool.

The on-going global demand for accurate and up-to-date soil information as well as digital soil maps (Hartemink and McBratney, 2008), underlines the need to equip postsecondary students, our future land managers and planners, with solid knowledge on soil identification and classification. Soil classification is the grouping of soil into classes based on similar properties and potentially similar behavior. The purpose of soil classification is to provide a basis for soil mapping as well as framework for formulating hypotheses about soil formation and the response of soil to management (Anderson and Smith, 2011).

The UBC's collection follows the Canadian system of soil

Table 1. Summary of the principles used for differentiating classes of the Canadian system of soil classification (based on Soil Classification Working Group, 1998).

Class	Principle used	No. of classes
Order	dominant soil-forming process	10
Great group	strength of soil-forming process	31
Subgroup	type and arrangement of horizons	231
Family	parent material characteristics	~10,000
Series	detailed features of the pedon	~100,000

classification (Soil Classification Working Group, 1998), which uses a hierarchical scheme to group soils into classes ranging from general to specific. This is a rigorous taxonomic system in which pedons[1] are assigned to soil classes and each class occupies a distinct position within the overall system. Environmental conditions cause a certain set of soil processes to occur in a given area during the period of soil formation, which leads to the creation of distinctive sets of soil horizons. These horizons are the basis for categorizing the soils in the Canadian system of soil classification. In this system, classes of the broadest, general level (i.e., soil orders) are grouped according to the effects of the dominant soil-forming processes (Table 1). Soil orders are then subdivided into great groups based on properties that reflect differences in strengths of dominant processes.

Development of the Virtual Soil Monolith Tool

The interactive, web-based VSM teaching tool (http://soilweb.landfood.ubc.ca/monoliths/) was created to enhance the visibility of UBC's monolith collection and support teaching and learning in the (campus-based) Introduction to Soil Science course, which is a second-year course required by a range of undergraduate programs at UBC. The development of the VSM tool occurred during 2009 and 2010 and took about 1800 person-hours for the entire development process. Generally, the development of a web-based educational tool is time consuming and involves planning, conceptualization, implementation, and refinement (Polsani, 2003). Developing the VSM tool was a collaborative effort of soil scientists, instructional designers, IT experts, and students. This approach was in agreement with findings of other studies (Naidu, 2003; Polsani, 2003) that showed developing effective web-based material requires a multidisciplinary team that includes the end-users (e.g., students).

The VSM website was developed using Joomla! (Open Source Matters, Inc., New York), an open-source content management system, which allows educators to easily update or alter content. The VSM tool features high-resolution digital photographs, detailed descriptions of each monolith, basic information on the Canadian soil classification system, instruction on how to approach soil description and identification, and an interactive soil map of British Columbia. The diversity of media was included to help maintain student interest and enhance learning (Cox and Su, 2004; Jacobson et al., 2009). In addition, we took into account the observation by Jacobson et al. (2009) that

BRUNISOL

1-01 Orthic Sombric Brunisol

UBC No. 1-01
Series: O.SB-1
Subgroup: Orthic Sombric Brunisol (O.SB)
Great group: Sombric Brunisol
Order: Brunisol

Horizon sequence

LFH (2-0 cm)
Ah1 (0-20 cm)
Ah2 (20-45 cm)
Bm (45-68 cm)
C (68-88 cm)

Additional information

Parent material: glacial-fluvial
Geographic location: Kootneys

NAVIGATION TIP

The number in the bracket beside each great group indicates the

Fig. 2. An example of type of information and level of detail provided for each soil monolith in the University of British Columbia (UBC) collection.

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[1] Pedon is the smallest volume that can be called *a soil*. It has three dimensions. It extends downward to the depth of plant roots or to the lower limit of the genetic soil horizons. Its lateral cross-section is roughly hexagonal and ranges from 1 to 10 m^2 in size, depending on the variability in the horizons.

the complex (i.e., non-linear) organization of web-based educational tools engages students in active learning and encourages novel idea association.

The VSM is a unique web-based educational tool that not only showcases a monolith collection as a central feature to explain soil classification, but also enables blended learning strategies by combining online and campus-based teaching and learning. There are several other well-established soil classification web-based educational resources, including "Twelve Soil Orders" (McDaniel, 2012), "Soils of Canada" (Department of Soil Science, 2007), and "The Australian Soil Classification" (Isbel, 2012); however, none of those resources are based on soil monolith collection or support blended learning approaches.

Organizational Structure of the Virtual Soil Monolith Tool

The VSM homepage opens with an introductory paragraph to orient students to the website and an interactive map of soils of British Columbia to capture student interest at the onset of website exploration. The legend of the soil map provides basic information on each of the 10 soil orders in the Canadian system of soil classification and a photograph of a typical landscape in which each soil order occurs. The website has two menu bars: a navigational menu across the top of the page with logistical links and the content menu down the left-hand side.

The website's content menu includes 10 tabs, one for each of the soil orders. Basic information about each soil order and the criteria used for its subdivision into great groups are provided on individual soil order pages. From each soil order page, the user can access (1) pages featuring great groups within a particular soil order and (2) information about the soil monoliths present within each great group. The information about each monolith includes detailed soil classification information (soil order, great group, subgroup, and soil series name), UBC archiving code, horizon sequence and thickness, type of parent material, and geographical location where the monolith was collected (Fig. 2). Photographs of each soil monolith are linked to large high resolution photographs that open on separate pages for detailed viewing. Fine details such as soil aggregates, coarse soil fragments, cracks, root fragments, etc. are visible on the high resolution photographs. A metric scale is included on the left-hand side of each monolith to reference the size of various soil features.

The website's navigational menu includes tabs on project description, team members, history of the soil monolith collection at UBC, tutorial, links to relevant resources, and contact information. The tutorial consists of the following two components: (1) "How to Read a Soil Monolith," a step-by-step guide for students and professionals attempting to classify soil, and (2) "Practice Questions" to encourage students to identify parent material and soil horizons based on the color, texture, and other morphological features that can be observed in the monoliths. The answers to all "Practice Questions" are provided but are not immediately visible (users need to click specific parts of the tutorial page to see the answers). "Practice Questions" are aligned with the Introduction to Soil Science course face-to-face laboratory sections on parent material and soil classification providing students with a self-guided exercise that helps them complete laboratory assignments.

The VSM tool is organized in such a way that each soil featured in UBC's collection can be placed within the geographical context of location, climate, and ecosystem, enabling students to integrate and build upon various concepts and skills. This is important since understanding the process of soil formation is a multidisciplinary exercise by nature, requiring students to integrate geographical, climatic, biological, and geological information. Field et al. (2011) established that encouraging students to make connections across the sub-disciplines of soil science and other disciplines was one of the key principles behind effective teaching of soil science. The complex (non-linear) structure of the VSM was used to illustrate these interconnections and show students the need to gather information from different sources to fully understand a soil landscape.

The VSM website also includes links to other multimedia web-based resources on "Canadian Soil Orders" (http://soilweb.landfood.ubc.ca/classification/) and "Soil Formation Processes" (http://soilweb.landfood.ubc.ca/processes/) created by the Virtual Soil Science Learning Resources (2012) group led by the senior author of this manuscript. The links are displayed on the "Soil Order" and "Practice Question" pages and provide students with the opportunity to watch short video-streamed clips on (1) a particular soil order in its typical setting of soil formation factors (climate, topography, biota, parent material, and time), and (2) the dominant soil formation processes. The video design was conceptualized as a virtual field trip by including introductory panoramic views of the site with natural sound, an expert's detailed description of the site and a soil pit, and close-ups of certain soil morphological properties. These videos are representative of typical, real-life site assessments that accompany soil description and classification, simulating for students the experience of an actual field trip. This is in agreement with observation of Cox and Su (2004), who pointed out that virtual field trips need to mimic closely the experiences that students would have if they were on a live field trip. Virtual field trips have been reported to be useful educational resource since they provide temporal and spatial flexibility, information accessibility for students, instructor control over content and features, and reusability (Tuthill and Klemm, 2002; Ramasundaram et al., 2005). Combining information presented at the VSM tool with material at the "Canadian Soil Orders" and "Soil Formation Processes" websites enables students to develop a deeper understanding of the relationships between a particular soil and the landscapes and ecosystems in which it functions.

Users of the VSM resource can download and print all text and photographs shown on the website as a portable document format (PDF) document. Other studies such as Oh and Lim (2005) have reported that some students prefer reading text on paper rather than on computer screen. Similar feedback was provided by a student review group during development of another web-based educational resource created by our team (Strivelli et al., 2011).

TEACHING APPLICATION OF THE VIRTUAL SOIL MONOLITH TOOL

In addition to a conceptual understanding of soil forming processes, accurate soil classification involves considerable

Table 2. Examples of the laboratory assignment questions used in the Introduction to Soil Science course at the University of British Columbia (UBC), Vancouver, Canada, which direct students to use the Virtual Soil Monoliths (VSM) tool.

Topic	Question
Parent material	•At the VSM website find a monolith with (1) a glacial till parent material and (2) a glacio-fluvial parent material. Describe the differences between the two parent materials and identify the most important feature(s) allowing you to tell them apart. •In the monolith no. 8-02, the parent material is identified as colluvium. What properties are typical for this type of parent material?
Soil classification	•Explain what soil formation processes were responsible for formation of the Btg horizon of the monolith no. 4-03. •In the monolith no. 8-03, no B horizon has been identified. Can this be the case? If yes, please explain what events could have prevented development of the B horizon.

visual interpretation skills. In other words, to be able to identify soil horizons and diagnostic features correctly, students need to be exposed to a wide range of soil profiles, have enough time to examine them in detail, and have the opportunity to reflect and revisit them as often as required. Soil classification is complex and an important topic, which at UBC is only taught as a part of a lower-level undergraduate course on Introduction to Soil Science. There has been no upper-level course on soil formation and classification at UBC since early 2000s. This short-coming pointed to the need to develop an innovative, blended teaching approach, using classroom and online resources, to help students grasp this complex topic, gain exposure to a broader range of naturally occurring soils, and acquire basic classification skills, all within the constraints of a large, lower-level undergraduate course. The VSM tool was developed in response to these challenges.

In the Introduction to Soil Science course, the VSM tool complements lectures and two laboratory sections focusing on parent material and soil classification. In these two, 2-hour long campus-based sections, students review a selection of 20 to 30 soil monoliths with guidance from the course instructor and teaching assistant. The laboratory section objectives are to help students to (1) identify different types of parent material, (2) learn about dominant soil formation processes, (3) identify diagnostic horizons, and (4) distinguish among 10 soil orders. At the end of the section on types of parent material, students are asked to identify the parent material of three "mystery" monoliths, while at the end of soil classification section, students describe and classify three "mystery" monoliths. For both sections, students are asked to prepare a written assignment in which they answer several questions (similar to those shown in Table 2) and provide a detailed description of the mystery monoliths.

For many students, 2 hours are not sufficient to accomplish the assigned tasks, and the VSM tool provides an opportunity to continue the learning process at their own pace. As a web-based tool, the VSM offers students greater control over their learning processes (Koppi et al., 1997; Muller et al., 2008) and provides a more engaging learning environment. The "Practice Questions" of the VSM Tutorial are designed to encourage students to browse through multiple monolith photographs and thus build their visual interpretation skills and appreciation for the range of features exhibited by each soil order. This helps students understand how context may shape the application of theory (Field et al., 2011) and is believed to result in more resilient learning (i.e., students are less likely to be confused by the occurrence of an unusual feature in the soil they are attempting to classify). Because the monoliths included in the VSM are the same as those used during the on-campus laboratory sections, there is a coordination between the on-campus and online teaching strategies. The content presented in the VSM is richer than what can be presented during a 2-hour laboratory section since it includes, for example, visual representations of environments in which each soil type occurs. Blended learning strategies combine on-campus lectures, laboratory sections, and online resources and have the potential to cater to a range of learning styles. It has been shown elsewhere that students appreciate having a choice of learning mechanisms and the spatial and temporal flexibility afforded by online components (Mitchell and Forer, 2010). Other studies (Chumley-Jones et al., 2002) have shown that web-based tools have a positive effect on student learning and interest in subject due to open access and connections between topics presented.

The VSM tool directly benefits teaching and learning of about 180 UBC students per year. In addition, it also serves as reference material in several other undergraduate courses offered at UBC that also touch on the topic of soil classification (e.g., Sustainable Soil Management, Forest Ecology, Agroecology, Soil and the Global Environment). Due to its open access, the VSM tool also could be used by students and instructors at other Canadian postsecondary institutions for a broad range of distance education courses, traditional campus-based lectures and laboratories, workshops, and training sessions.

There are other potential applications for the tool, beyond the university curriculum. For example, the VSM tool could be used for continued professional development of natural resource practitioners. Soil description, identification, and classification skills are essential for practitioners in a variety of disciplines such as agronomy, forestry, environmental protection, land planning, and site reclamation. Reviewing the soil monolith photographs, associated descriptions, and the tutorial enables practitioners to refresh their existing soil classification knowledge and provide them with information about soils with which they may not be familiar.

EVALUATION OF THE VIRTUAL SOIL MONOLITH TOOL

Student Feedback

The VSM tool was implemented in the Introduction to Soil Science course during the 2011–2012 academic year and 170 students enrolled in the course were asked to complete an online feedback form. The response rate was 74%. The form 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 intentions (i.e., tool description, its

Table 3. Feedback responses of the student review team (*n* = 126), grouped by assessment topic.†

Assessment topic	No. of respondents that chose: Strongly agree	Mildly agree	Neutral	Mildly disagree
Tool addressed learning objectives				
It was effective in facilitating my understanding of soil classification.	30	75	21	0
It was effective in facilitating my understanding of parent material identification.	36	60	24	6
It was effective in facilitating my understanding of soil horizon identification.	24	48	21	33
It was helpful in completing lab assignment on parent material.	42	60	21	3
It was helpful in completing lab assignment on soil classification.	36	60	27	3
Overall appeal of tool				
The structure of the tool facilitated my understanding of soil classification.	6	69	36	15
The use of high resolution photos was helpful in understanding soil identification and classification.	27	81	18	0
The use of visual elements enhanced the appeal of the topic (soil classification).	27	72	27	0
The incorporation of weblinks, background material, and supplementary information enhanced the appeal of the topic (soil classification).	24	45	48	9
The presentation of soil classification concepts had a lasting impact on me.	21	51	48	6
I plan to use the tool in the future activities that involve soil classification.	30	54	21	21

† The feedback form also included the option "strongly disagree"; however, no respondent chose it for any of the questions. Consequently, this response option is not presented in the table.

learning outcomes, and the overall study objective). The feedback form included 11 quantitative questions (on a Likert five-point scale) and four open-ended questions. The open-ended questions were:

1. How closely did the practice questions posted in the Tutorial match activities in the course laboratory sections on parent material and soil classification?
2. Which component of the tool did you find to be most useful?
3. Which component of the tool did you find to be least useful?
4. Which components of the tool need to be improved/changed?

Five of the quantitative feedback questions (Table 3) focused on the VSM tool's ability to address its learning objectives. Eighty-four percent of students surveyed agreed, either strongly or mildly, that the tool facilitated their understanding of soil classification. In terms of helping students develop basic soil identification skills, 77 and 57% of the respondents thought that the tool was effective regarding identification of parent material and soil horizons, respectively (Table 3). Twenty-six percent of students surveyed mildly disagreed that the tool helped them with soil horizon identification, pointing out that some future refinements are needed. One potential improvement could be to outline boundaries between adjacent horizons on the high resolution photographs of soil monoliths. This addition would accompany the existing information on the thicknesses of the soil horizons.

A large majority of respondents (81–77%) found the VSM tool to be helpful in completion of the lab assignments on parent material and soil classification (Table 3). Student responses to the open-ended question, "How closely did the practice questions posted in the Tutorial match activities in the course labs on parent material and soil classification?" further confirmed this, as 101 out of 126 students thought that practice questions closely matched activities in the course laboratory sections. The VSM resource promoted self-directed learning as students individualized their learning experiences by viewing and reviewing material presented, while building their own comprehension of content.

In developing the VSM tool, we tried to target a variety of learning styles with an aim to enhance the overall student learning experience. As other studies have shown, student confidence in the presentation of material is very important. A review of 76 web-based learning resources used in medicine done by Chumley-Jones et al. (2002) revealed that pedagogy, which directly addresses learner's needs, is more important to student satisfaction than use of any particular type of technology or method of instruction. Six quantitative feedback questions in the survey addressed the overall appeal of the tool (Table 3). It became clear that high resolution photographs were valuable since 85% of respondents found photographs to be helpful to develop understanding of soil classification. As observed by Field et al. (2011), repeated visual exposure to soil profiles is essential for students to develop their soil classification skills; hence, web-based teaching tools that allow flexible access to accurate representations of field or natural features could be helpful. This was confirmed by answers to the open-ended question, "Which component of the tool did you find to be most useful?" since 107 out of 126 students valued the high-resolution monolith photographs the most among all components of the tool. Use of the visual elements (e.g., maps, landscape photographs) enhanced interest in soil classification of 78% of the respondents (Table 3). The inclusion of external web links, background material, and information made the topic of soil classification more appealing to 54% of students surveyed, whereas 39% were neutral and 7% mildly disagreed. Overall, student feedback showed that students appreciated the integration of the VSM tool with on-campus laboratory sections. Students also pointed out that the VSM was an effective answer to their need for more visual exposure to soil monoliths, which in the past were not always available for additional review after the campus-based laboratory sections.

Student feedback also pointed to some limitations of the VSM tool. Even though 59% of respondents agreed (strongly and mildly) that the tool's structure facilitated their understanding of soil classification (Table 3), 12% of respondents disagreed mildly with this. Responses to the open-ended question, "Which components of the tool need to be improved/changed?" revealed that 60 out of 126 students who responded to this particular question wanted to have a soil classification key and more references regarding soil classification literature included into the tool. Consequently, links to both were added to the "Resource" page of the VSM tool. Another shortcoming of the tool that was revealed by the student feedback, was the absence of a searchable index of parent material types. About one-fifth of the respondents pointed out that they could not easily locate monoliths with specific types of parent materials and suggested that we include an option that would allow them to search the collection to locate specific parent materials. We are currently compiling the index list and plan to add it to the website in a near future. The high response rate to the volunteer survey and the overall agreement among students that the VSM helped meet learning objectives, while at the same time being clear to state the shortcomings of the tool in terms of understanding soil classification, indicates strong student engagement in their learning.

Lessons Learned

From the process of developing the VSM resource we can offer several suggestions for others interested in creating similar educational tools.

1. Use well-defined learning objectives to guide development efforts. Begin the process by identifying student learning needs and desired learning outcomes. Identify if the tool is for a specific course or for more general use by students. Use this information as a guide for the design of your educational resource, so that you utilize the technology and teaching methodologies best suited to your purpose. The concepts being taught, the learning environment, and student needs will dictate the type of technology implemented. Studies showed that technology is best used when it supplements, supports, and enhances curriculum that has already been well thought out (Chumley-Jones et al., 2002).

2. Emphasize planning and consultation phases. Allow sufficient time for planning and feedback. As noted by Polsani (2003), a project has greater likelihood of being thoroughly conceptualized and executed if you include a substantial planning and consultation phase.

3. Encourage student engagement. Involve students in the design and evaluation of the resource, as well as in the consultation and review stage. Student engagement in the development process will allow for creation of an effective tool that reflects actual student needs.

4. Favor diversity in your team. Assemble a multidisciplinary team to oversee tool development, since the expertise of a wide range of professionals and students is essential for the integration of multiple perspectives needed to develop an effective resource that targets a variety of learning styles.

CONCLUSIONS

There is an on-going need for land resource professionals with solid soil classification and identification skills. One approach to increase this knowledge and skill capacity is to create open access, online educational resources, which support traditional methods of teaching and learning. For more than a century, soil monoliths have been used in teaching, demonstration, and research, but their use has been limited to users who had access to the buildings where collections were housed. The collection of 197 soil monoliths at UBC was no exception, and inappropriate storage and display even further limited its usability in teaching. The web-based VSM tool developed in 2009 and 2010, in answer to this challenge, features high-resolution digital photographs, detailed descriptions of each monolith, a self-guided tutorial on how to approach soil identification and classification including the practice questions, basic information on the Canadian soil classification system, and an interactive soil map of British Columbia. Each soil featured can be placed within the geographical context of location, climate, and biotic type.

Student feedback about the VSM tool was generally positive and indicated that the tool was successful in addressing the learning objectives regarding students' understanding of soil classification and building of basic soil identification skills. Students pointed out that the VSM tool was helpful in completing two laboratory assignments in the Introduction to Soil Science course. The feedback also revealed that the high-resolution monolith photographs were the most useful feature of the tool. Finally, feedback indicated that additional refinements are needed to help students distinguish among different soil horizons and quickly search for specific types of parent material. The development of this open access, web-based tool did not just increase the accessibility and usability of UBC's collection, but it also supported student engagement and opened new avenues for teaching and learning of soil science that require students to make connections across disciplines.

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About the author...

Maja Krzic

I am soil scientist with a passion for student focused communication of soil science. To augment and extend my research on land-use impacts on soil processes, I have integrated research, teaching, and community education through application of information technology and multimedia. I strongly believe that integration of research and effective communication allows science to become useful knowledge. To that extent, I helped the establishment of the Canada-wide group on Virtual Soil Science Learning Resources—VSSLR (http://soilweb.landfood.ubc.ca/promo/). The goal of VSSLR is to enhance soil science education through cooperation and innovative approaches to teaching and learning.