BLENDING MULTIMEDIA AND CAMPUS-BASED LEARNING TO ENHANCE LEARNING ABOUT FOREST FLOOR AND HUMUS FORMS

by

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ABSTRACT

Given the functions of forest organic soil horizons in carbon sequestration, biodiversity and nutrient cycling, coupled with the fact that the forest floor is often not described in soil surveys, it is important that forestry professionals learn to classify organic horizons and humus forms. The current generation of undergraduate students appreciate having access to multimedia and online resources in their learning, and prefer active, collaborative experiences of the concepts they are learning in the classroom. With technological advances, modernizing curriculum by blending campus-based learning and multimedia is ever easier to accomplish. The objectives of this study were to: (1) develop blended-learning activities, combining campus based learning and multimedia web-based resources, to teach forest floor description and classification; and (2) conduct exploratory factor analysis of student survey responses to assess student opinions about the application of the blended-learning method. The Forest Floor web-based educational resource and campus-based activities were developed with the contributions of a team of experts in soil science, web and multimedia design, and science education. Ninety-four percent of students agreed or strongly agreed that the Forest Floor web-based resource was helpful for learning forest floor concepts, 79% that describing samples in class was essential for understanding the properties of organic horizons, and 81% that they were able to relate information in the Forest Floor web-based resource to their own samples used in an in-class activity indicating that students appreciated the blended learning methodology. Based on the survey responses five implicit factors were interpreted: (1) satisfaction with the web-based educational resources as learning enhancements; (2) success of presentation of concepts using a blended learning method; (3) student self-assessment of learning; (4) student learning preferences in accessing materials; and (5) website usability. Student feedback suggests that the blended learning activities were appreciated and met the learning objectives. This study also provides an example for conducting exploratory factor analysis of blended learning interventions and provides factors that may be verified through confirmatory factor analysis.

PREFACE

The Forest Floor website and videos were designed by Krzic, M., Schmidt M., Dyanatkar, S. and myself. Web-development work on the Forest Floor website in Chapters 2 and 3 was done by Ho, S. and Dyanatkar, S. Videos were filmed and edited by Scott, T. and feature Schmidt, M. as the expert. Graphics appearing on the website and in videos were developed by Karasin, K. and Roan, C. Principal Component Analysis for the Pilot Study (Chapter 2) was done by Nashon, N., Alder, D. and I.

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1 General Introduction

We rely on soils for food and fiber, energy and nutrient cycling, improving water and air quality and preserving biodiversity, all of which provide us nutrition, medicine and more (Wall 2004). It is important for land managers to gain an understanding of these important soil services. The forest floor, comprised of the organic horizons at the soil surface in forest ecosystems, plays a particularly important role in carbon storage, nutrient cycling and biodiversity. The amount of carbon stored in the forest floor of Canadian forests is comparable to that in vegetation (Goodale et al. 2002). In addition, the forest floor is where most interactions among vegetation, fauna and microorganisms occur, influencing the makeup of plant, faunal, and microbial communities (Ponge 2003).

The forest floor is reflective of the overall site quality (Klinka et al. 1990), biodiversity, soil fertility, and soil productivity (Ponge at al. 2002). For these reasons, humus form classification is used in forest site such as Biogeoclimatic Ecosystem Classification (BEC) in British Columbia. Though knowledge of forest floor properties is important in determining appropriate forest management practices, different groups are involved in describing the forest and describing the soil and the forest floor is often not described during soil surveys because changes to forest floor properties occur rapidly compared to mineral soil (Broll et al. 2006). In addition, training in forest floor description and identification of organic horizons is not often part of university curriculum where the number of soil science courses is decreasing (Collins 2008) or where soil science is becoming a required component of more generalized, integrative programs (Hansen et al. 2007). Since most postsecondary forestry programs still require at least an Introduction to Soil Science course (Collins 2008), it is during these courses that the opportunity exists to introduce future forest and land management professionals to the important roles and properties of the forest floor.

Forestry, agriculture, climate change research and environmental policy have all relied on a better understanding of soils (Hartemink and McBratney 2008) and soil scientists will need to continue to play an integral role in meeting global environmental challenges including food security and mitigating and adapting to climate change. As these global issues are increasingly exerting demands on soil resources; the requirement to provide soil science education to the next generation of land managers and even the general public is becoming more imminent. The United Nations (UN Millennium Project 2005; UN Development Programme 2007) and the Intergovernmental Panel on Climate Change (Hartemink 2008), among other international organizations, have highlighted the increasing necessity of enhancing soil science education and providing adequate soil information. This will occur within the context of our increasingly urban societies – where the majority of people spend more time indoors and online, away from natural ecosystems.

Soil integrity is being threatened and reduced by soil degradation (Lal 2010), including erosion, fertility loss, increasing salinity, acidification, loss of soil carbon and compaction (CEC 2006). The Soil Carbon Initiative (2011) uses the term "soil security" to refer to: *the maintenance or improvement of the world's soil resource so it can provide sufficient food and fiber, fresh water, contribute to energy sustainability and climate stability, maintain biodiversity and overall environmental protection and ecosystem services.* McBratney et al. (2014) have explored how these factors of soil security are related to the major global environmental challenges we currently face: Food Security, Water Security, Energy Security, Climate Change Abatement, Biodiversity Protection and Ecosystem Service Delivery. With the global population projected to reach 8.9 billion by 2050 (UN-ESA 2004), competition for soil resources and demands on those resources will continue to grow. "Knowing the soil," suggest Janzen et al. (2011) is the place to start in dealing with global environmental challenges.

The clear connection between global environmental challenges and healthy soil functions has resulted in the declaration of 2015 as The International Year of Soils (IYS) by the 68th UN general assembly (2014). The goal of the IYS is "raising awareness of the importance of soils for food security and essential eco-system functions." Meeting the IYS goals will require soil scientists to participate in interdisciplinary research teams focused on land management, but also to identify, promote and fill niche roles that only soil scientists can occupy (Bouma 2009). Soil must be presented as a "connecting keystone" in a large proportion of environmental issues (Bouma and McBratney 2013). Giving more attention to ecosystem services could help raise awareness about importance of soils with the public and policy makers (Robinson et al. 2012). As the majority of practicing soil scientists are “mature” (Collins 2008), there is a need to attract new students who will go on to become professional scientists with a strong foundation in soils. New types of soil scientists, ready to adopt new methodologies such as digital soil mapping, DNA finger printing in soil ecology and pedometrics, are necessary (Hartemink and McBratney 2008). Soil educators face the challenge of attracting and training students with the abilities to fulfill these requirements.

1.2 Turning around Decreasing Enrollment in Postsecondary Soil Science Courses and Programs

While the importance and utility of scientific knowledge is commonly recognized (Osborne et al. 2003), there is also distrust of science and scientists by many people in the developed and undeveloped world alike, sometimes culminating in anti-science movements (UNESCO 1999). The passive nature of teaching and learning of science in high school and undergraduate courses (Loynachan 2006), accompanied with a perceived lack of relevance of science to the lives of many students (Raes and Schellens 2012) is resulting in reduced number of students pursuing careers in science (Osborne et al. 2003). Postsecondary science programs, such as geology, geography and chemistry have been experiencing challenges with recruiting students (Lynch 2002; Derr 2004; Baum 2004). This trend is evident in soil science as well. A survey of 54 US universities found that between 1984 and 2003, there was a drop in the number of BSc degrees awarded in agronomy or crop science from 764 to 523 (McCallister et al. 2005). Similar trend was also observed with the number of soil science graduate students in the US and Canada that declined 40% between 1992 and 2004 (Baveye et al. 2006).

1.2.1 Urbanization and the Shift Away from Agriculture

Increased urbanization and fewer people working in agriculture have been identified as some of the reasons for decreased enrollment in soil science undergraduate programs in developed countries (Hansen et al. 2007; McKenna and Brann 1992; Dalmoasso 1990). Often, urbanites have a very limited perception of the importance of soil (Jacobson et al. 2009), and in the absence of students coming from rural and agricultural backgrounds, soil science has not been seen as a desirable career choice (Handelsman 1992).

A shift to attract students from urban settings with interests in a broader environmental context and/or urban agriculture and forestry is necessary if declining enrollment in soil science is to be reversed. However, it appears that the shift is not occurring fast enough in North American postsecondary institutions (Hartemink et al. 2008). A survey of US universities carried out by Hansen et al. (2007), found that the majority of soil science programs were still offered by agricultural colleges. Decline in student enrollment and keeping soil science programs focused on agriculture are accompanied with declining university appointments for soil scientists (Letey 1994), closure and/or merger of soil science departments (Young 1991), and reducing grant funding (Mermut and Eswaran 1997). As student tuition fees are increasing postsecondary institutions are redirecting resources towards programs that are attracting greater numbers of students (Hansen et al. 2007); further undermining sustainability of soil science programs.

1.1.1 Decreasing Enrollment and Increasing Attention

There are further challenges outside the post-secondary setting to recruiting students to soil science courses or majors. Soil science is not part of high school curriculum – and many students may not even be aware of the discipline. In addition, there has long been a disconnect between the actual range of work carried out by soil scientists, and the ambiguous public perception of what they do (Kellog 1961). Furthermore, the most common job opportunities in US (and Canada) for students with a background in soil science include environmental science, land management, *soil science*, agronomy and engineering (Havlin et al. 2010) so that many soil science graduates are not employed with the title of "soil scientist," reducing the visibility of potential employment in the field. Along with the lack of well-defined soil science majors and departments in most universities, it is not surprising that the discipline of soil science is not on the radar of many potential students.

Interestingly, a decline in enrollment in soil science graduate programs since 1990s has co-occurred with a steady increase in the number of soil science articles published (Baveye et al. 2006). Looking into the growth rate in soil science publications, Hartemink and McBratney (2008) found an average increase of 545 publications per year, the majority published in non-soil science journals and very few published in the top journals such as *Nature* and *Science*. The increased numbers of soil science publications are having an impact (Minasny et al. 2007) substantiated by the attention soils are receiving by organizations such as the UN, FAO, IPCC and governments in China, the US and EU. Moreover, the recognition of the role of soils in providing other ecosystem services, like clean water and climate change mitigation, are increasingly bringing soils into the fore of environmental research.

This increasing global attention to soil importance, highlighted by the 2015 IYS, emphasizes the need to provide our current and future natural resource managers and policy makers with a solid understanding of soil processes and roles. Without sufficient soil science course offerings in postsecondary programs, many natural resource professionals are left unprepared to face soil-related issues (Collins 2008). Soil science is often taught as a part of other disciplines – undergraduate degrees in soil science are not common (Hartemink and McBratney 2008). According to Smiles et al. (2000), in Australia, no single postsecondary soil science program is able to offer the range of courses necessary for students to develop a complete skillset in soil science. In North America, many universities do not offer soil science majors, and those that do most often offer the major from departments with names other than soil science (Collins 2008). For example, at the University of British Columbia, soil science courses are taught within the Applied Biology Program in the Faculty of Land and Food Systems.

Reduced enrollment, underprepared graduate students, and the shifting focus of soil science research are increasingly catching the attention of soil science educators. How do we bring attention to the importance and unique qualities of soils (and soil science research) in the minds of potential students? Some universities have altered soil science courses or whole programs to focus on environmental issues (McCallister et al. 2005), or created interdisciplinary soil programs (Hansen et al. 2007). Interdisciplinary "soils and civilizations" courses, making connections between people around the world and the soils they rely on, have been created by a number of universities and targeted at a wider audience beyond strictly natural sciences students (Jacobson et al. 2009). At the 2014 Canadian Soil Science Society Annual Meeting, a soil science education committee was established with the goal of reaching more students and improving the educational resources available to those students. A similar committee on Soil Education and Outreach within the Soil Science Society of America was established in 2013. Time will tell how much of an impact these strategies will have.

1.1.2 Soil Science as a Unique Discipline and Skillset

While basic knowledge of soil science is important for any land management position, it is also essential to distinguish the roles that only well-trained soil scientists, equipped with specific skillsets needed to fully understand soil properties and processes, are able to fill. "Soils are too complex and too heterogeneous, and they encompass too complex an array of interacting processes" to be studied strictly by experts of other disciplines such as environmental chemists or microbiologists operating from more narrow views of soil (Baveye et al. 2006). Since the early 1990s, undergraduate and graduate majors in environmental science have been offered at many universities and the number of students pursuing environmental sciences, who need to gain an understanding of how soils factor into a wide range of environmental issues, has been increasing (Pepper 2000). Soil science courses are often taken by students from a diverse range of majors and interests (Brevik 2009), many of whom do not plan to work as soil scientists. Introductory soil science courses are included in forestry, natural resource, horticultural and landscape engineering programs (outside of the traditional agronomic focus). These courses tend to have high enrollment and the potential to establish interest in soil science in students who had not previously planned to take additional soil courses or major in soil science (Collins 2008). To turn around on-going declining enrollment will require educators to highlight the unique roles of soil scientists in global environmental challenges, the many functions of soils and the potential for careers in soil, through the development of innovative curriculum and course offerings.

1.2 Soil Classification and the Forest Floor

"The purpose of any classification is to organize our knowledge so that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective" (Cline 1949). Soil classification aims to "organize the knowledge of soils so that it can be recalled systematically and communicated, and that relationships may be seen among kinds of soils, among soil properties and environmental factors, and among soil properties and suitabilities of soils for various uses" (Soil Classification Working Group 1998). Soil classification provides a "ready-made map legend" for soil surveyors to make specific statements to be made about mapped units (Rossiter 2007) and understand distributions of different soil resources (Dijkerman 1973). Hierarchical organization allows increasingly detailed sub-divisions of soil types to be made (Whyte et al. 1969) and soil data to be condensed and ordered (Dijkerman 1973). Classification of soil pedons requires an understanding of classes of horizons and soil properties, such as texture and structure (Dijkerman 1973). De Bakker (1970) differentiated between the theoretical and practical purposes of soil classification. In the theoretical realm, origins, genesis and development of soils, and the relationships between soils are studied through classification. The practical purpose of soil survey essentially comes down to optimizing land use through better understanding the soil (Kellogg 1962).

Classification is important in furthering knowledge in soil science, understanding relationships between data from different sites and even providing satisfaction in organizing knowledge into "a coherent and mutually consistent scheme" (Hallsworth 1965). It is important for scientists to be able to effectively communicate what they are seeing in the field (Avery 1965). The "language" of soil classification allows comparisons among soils and the effective use of data (Harris 1960). For example, understanding management practices for one soil of a particular taxa can give an idea of how to deal with other similar soils (Kovda 1967). While soil surveys have traditionally targeted agricultural and rural land resources, there are increasing numbers of reclaimed sites and changing uses of industrial areas requiring assessments of soil formation and behavior (Rossiter 2007). Survey data compiled during the development of the Canadian System of Soil Classification was used in planning economic development, producing large scale agricultural and forest land capability maps, soil and water conservation programs, land use and land protection decisions, and accounting of greenhouse gas emissions (Anderson and Smith 2011).

1.2.1 Outdated Data and the Need to Share

Beginning in 1996, several Canadian soil science research centers were closed, administrative changes were made and the number of retirements increased – hindering nationally coordinated mapping projects (Anderson and Smith 2011). Meanwhile, with growing resource development, largely in western Canada, detailed, specific-purpose private sector soil surveys are becoming increasingly common, most often they are contracted from soil experts by the private sector to prove that regulations are being followed in development projects (Anderson and Smith 2011). Unfortunately, these private sector surveys do not tend to be publicly shared emphasizing the growing decline in accurate, up-to-date, digitally available soil information worldwide (Hartemink and McBratney 2008; Bouma and McBratney 2013). Recognizing the importance of soil data in land-use planning, the soil survey community will have to do more to counteract the lack of coordination, sharing and use of this data (Bouma 2001).

1.2.2 The Integral Roles of the Forest Floor in Forest Ecosystems

With the transfer of soil information to computers, such as with geographic information systems (GIS), there is the potential for process modeling of climate change impacts, greenhouse gas (GHG) emissions, water contamination risks, biomass production and more (Anderson and Smith 2011). Going forward, it is important not to ignore the many functions of the forest floor, especially in northern forests, where the role of the organic horizons in carbon storage is immense. For example, in boreal forests, the soil and forest floor account for 80% of total carbon storage (Dixon et al. 1994). Furthermore, the forest floor is integral to functional diversity in terrestrial ecosystems (Ponge 2003). The organic material contained in the forest floor supplies nutrients, retains moisture, promotes soil structure (Prescott et al. 2000), contains a concentration of biodiversity and intense microbial activity (Bauhaus et al. 1998) and influences biogeochemical cycles, ground flora, forest canopy species, productivity and litter quality (Ponge and Chevalier 2006). As much as 90% of nutrient mineralization in soil occurs as the result of microbial communities (Lavelle and Spain 2001), a large majority of which inhabit the organic horizons. For these reasons, Jabiol et al. (2013) suggest that the organic horizons must be described for sufficiently precise characterizations of forest soils.

In Canada, forest humus form classification is mainly based on the system developed by Klinka et al. (1981). This system allows characterizations of forest soils through descriptions of the surface organic horizons. The system, later updated by Green et al. (1993) and Green et al. (1997) was created in response to the inconsistent use of terminology among classification systems as well as stagnation in the development of forest floor classification systems. It was based on a number of existing classification systems from North America, Great Britain and Europe, with the objective of being internationally comprehensive with a consistent hierarchical structure. The forest floor includes the organic horizons (LFH and O) at the soil surface, while classifications of forest humus forms also include Ah horizon, in which organic material is mixed with mineral soil (Ponge 2013).

Distinguishing between organic horizons is important, as they will react differently to disturbance, or ecological changes, depending on the stage and type of decomposition (Prescott et al. 2000). Litter (or L) horizons are composed of fresh, recognizable material at the surface of the forest floor; fermented (or F) horizons are more decomposed but still recognizable, often with roots present; and humic (or H) horizons are "humified" to fine, unrecognizable substances (Green et al. 1993). The organic O horizons occur where the water table is at or near the soil surface, and are often associated with wetlands (Green et al. 1993). Lower case suffixes are added to identify the type of decomposition, disturbance or non-conforming materials. For example, in Green et al. (1993) an Fm horizon indicates the presence of abundant fungal mycelia and roots, while an Fz is associated with faunal casts and loose consistence.

In the late 19th century, P.E. Muller first identified the two main forest humus forms, mull and mor (Muller 1889). Humus form classification systems continue to use these as the major humus form orders. It is the type of decomposition, rather than necessarily faster decomposition in mull compared to mor, that determines the accumulation of organic matter and the form it takes (Weetman, 1980). Mull humus forms have organic matter incorporated into the mineral soil, and tend to have more rapid decomposition (Klinka et al. 1981). In mull, the comminution and mixing of organic material with mineral soil by soil fauna is followed by bacterial decomposition (Prescott et al. 2000). In a mor, plant litter accumulates in a compact matted structure (formed due to incomplete fungal decomposition) on top of the mineral soil, with a sharp transition between organic and mineral horizons (Brethes et al. 1995). Humus forms with properties insufficient to meet the criteria of either mull or mor are referred to as moders. Moders, may have properties of both mor and mull, such as upper organic horizons with fungal mycelia and faunal casts, overlying A horizon of mixed organic faunal casts and mineral soil (Brethes et al. 1995).

Humus forms are often thought to be closely related to overall site quality (Klinka et al. 1990), with the succession of mor, moder, and mull associated with increasing biodiversity in soil microbes, plants and animals, increasing soil fertility and improved productivity (Ponge et al. 2002). Slower, incomplete fungal decomposition in mors can result in some immobilization of nutrients, preventing nutrient cycling and accessibility for plant growth (Prescott et al. 2000). Mulls are associated with more complete decomposition, higher nutrient availability (Prescott et al. 2000), more fertile soil and greater species richness (Ponge 2003). Generally, mulls tend to develop under deciduous stands, mors under coniferous forest. Broadleaf litters decompose more quickly than coniferous litters under otherwise similar conditions, especially in the short term (Sorenson et al. 2011) and tend to attract more soil fauna and bacteria, while coniferous litters often favor fungal decomposition (Green et al. 1993; Swallow et al. 2009). Deciduous litters are, in general, more nutrient rich with lower C:N ratios compared to coniferous litter. Due to the relationships between humus forms and other important ecosystem processes and properties, along with greater sensitivity to changes in the ecosystem compared with mineral soil, Ponge and Chevalier (2006) advocate using humus forms to assess the complexity of soil communities and ecosystem level changes resulting from management, climate change or pollution. However, the utilization of humus forms as site indicators requires subjective identification of forest floor and soil horizons and the recognition of variability within those horizons (Ponge and Chevalier 2006).

1.2.2 Proposals to Include Forest Humus Forms in World Reference Base for Soil Resources

Even though knowledge of forest floor properties is important to planning and management practices, the forest floor is often not described during soil surveys or research because changes in forest floor properties occur rapidly compared to mineral soil (Broll et al. 2006). Routine practice of humus form classification and monitoring will help to: assess the impacts of global warming on carbon storage in organic horizons (Ponge et al. 2011); and better understand nutrient cycling, biodiversity (Prescott et al. 2000), soil acidification, hydrology and eutrophication (Pinto et al. 2007). Jabiol et al. (2013) have proposed the inclusion of a comprehensive range of forest humus forms in the World Reference Base for Soil Resources. This occurred as an update to a similar proposal, including a less exhaustive range of humus forms, by Broll et al. (2006) that was not ratified. In recognition of the potential benefits of forest floor classification and monitoring, it is important to teach students, who may go on to work with forest soils, to recognize and describe forest floor horizons and humus forms. To train these students in soil and forest floor classification within the changing frameworks of soil education, soil survey, technology and global environmental challenges will require novel and innovative teaching approaches.

1.3 Urban Students and the Use of Technology in Education

An increasingly urban population spends most of its time indoors, while life moves at a faster pace with accumulating and changing flows of information (Hill 1998). We make fewer trips into nature than past generations (Gelter 2010) and within the city environment, even if we go outdoors, soils are hidden out of site, below ground. It is rare under these circumstances for urbanites to consider the important functions of soils within cities or in the wider environment. Meanwhile, most formal learning occurs in specialized indoor settings, while the properties and processes being studied by soil scientists are "natural and outdoors." Students entering universities spend a large proportion of their time online: learning (formal and informal), socializing and entertainment increasingly take place with the use of Internet resources.

1.3.1 Millenials in the Age of Information

Our current time has been referred to as the age of information, communication, knowledge, technology, etc. Common labels for the generation currently engaged in postsecondary education include the "Net" generation (Tapscott 1998), "Digital Natives" (Prensky 2001), the "Gamer" generation (Beck and Wade 2004) and "Millenials" (Oblinger and Oblinger 2005). Since the 1980s, digital technologies have become entrenched in the lives of students (Tapscott 2008). "The vast majority of students make extensive use of mobile technologies and computing facilities for communication and for access to course materials and resources" (Jones et al. 2010). For them, Internet resources have become the principal place to search for information (Loynachan 2006). It has been thought that these students adapt to these technologies more naturally, having grown up with computers and Internet connections, while older generations are considered to be slower to pick up skills using these rapidly changing technologies (Jones et al. 2010). This perception originates from the idea that students have undergone cognitive changes resulting from growing up with computer games and using modern digital technologies (Prensky 2001). The current generation of students has been thought to be more adept at learning from visual media and engaged activity rather than listening to lectures or reading texts (Aubrey and Dahl 2008).

While discourse previously suggested that learners have changed as a result of the increasing role of technology in their lives, evidence suggests that cognitive changes have not occurred from growing up with computers, Internet, visual media, etc., but rather students undergo normal development and socialization with technology-facilitated learning (Schulmeister 2009). According to Jones et al. (2010), the term "Millenials" best describes the current generation of postsecondary students, due to the diversity of technological skillsets within this generation, and the ability of many outside this generation to utilize digital technologies to equal effect as those who have grown up using them. In fact, interest in technology-rich learning is not necessarily dependent on technology use outside of the education context and more people from all age groups are becoming "tech-savvy" (Bekebrede et al. 2011). Furthermore, while the majority of students will have "a core set of technology based skills," abilities outside this core are very diverse within the population of students (Kennedy et al. 2008). Students may use a certain set of technologies for social use and entertainment, and another set for learning (Margaryuan and Littlejohn 2009). The common use of technological enhancement of curriculum is to meet the desire of current students to learn in participatory, experiential environments. In response to rising student numbers and often declining resources within the postsecondary setting, enhancement and support of course content with technologies can alleviate some pressure on instructors and institutions (Bates 2000).

1.3.2 Need to Adapt Soil Science Curriculum

To improve the learning experiences of students in sciences, it is important to understand how students view and understand the world (Nashon and Anderson 2013). Soil science education must establish the role of soils in dealing with global environmental challenges, such as food and water security, climate change mitigation and adaptation, biodiversity and many other ecosystem services. With fewer students coming from agricultural and rural backgrounds and more growing up in urban centers where the functions of soils are not always immediately evident, educators should frame soils in ways that align with the motivations of students interested in environmental issues. Students in interdisciplinary environmental science programs may not be interested in agricultural soils, but may be interested in the integral function of soils in maintaining biodiversity and water quality or mitigating climate change. Above all, it is important to keep in mind *how* students want to learn. The need for collaborative, active, participatory learning is a common theme amongst present-day students (Bekebrede et al. 2011).

Given the ongoing decreasing enrollment in undergraduate soil science programs, there is the opportunity to create innovative courses and programs within the interdisciplinary departments. Educational theory increasingly promotes active, collaborative, engaged learning experiences. Rather than simply deliver information in lectures, instructors should facilitate student learning (Raes and Schellens 2012) to allow the integration of information, knowledge, skills and values (Koppi et al. 1997).

1.4 Blended Learning

According to cognitive science, for learning to take place it is necessary that learning be meaningful to students (Ramasundaram et al. 2005). Constructivist learning theory postulates that students should search for information themselves to discover and build their knowledge (Chumley-Jones et al. 2002). Similarly, the theory of active learning suggests that we learn during active applications of the ideas and concepts we are learning (Piaget 1971). The wish of many students for active, participatory, collaborative learning appears to support the application of these theories, establishing a role for teachers to create learning environments that allow students to actively construct their own knowledge (Mutonyi et al. 2010).

Advances in technology and pedagogical theory, along with increased access to online resources make the shift away from conventional lecture-based teaching towards blended-learning models ever easier. Blended learning involves integration of computer-mediated learning into traditional, classroom-based learning (Owston et al. 2013). Both teaching and learning practices can be changed with the application of ever improving online technologies and nearly ubiquitous Internet access (Galway et al. 2014). Blended learning has generally been considered to be more effective than classroom-based or online learning alone (Means et al. 2010), improving student satisfaction (Castle and McGuire 2010) and grades (Cavanagh 2011). While online learning gives students spatial and temporal flexibility, improves their access to learning resources and facilitates more autonomous learning, face-to-face interaction with instructors gives students access to immediate direction and assistance with problems (Poon 2012). Classroom-based learning is also essential to students' feeling of community and engagement with other students (Collopy and Arnold 2009). The blended learning model allows students to access information from various sources, make associations between the knowledge they gain in and out of the class, apply their learning (Collopy and Arnold 2009) and develop communication and problem-solving skills (Strivelli et al. 2011; Krzic et al. 2013).

Traditional classroom experiences do not provide the same environment that the majority of current students are used to, in which they are connected through online and mobile technology to their peers and the web-content that they are interested in (Raes and Schellens 2012). According to Mohanna (2007), the current generation of students are often interested in having access to multimedia resources online. These online resources give students the opportunity to pursue questions that are of relevance to their own learning, opening up the bounds of the classroom (Wallace et al. 2000). Students value the ability to choose between different learning mechanisms to best suit their learning needs, and appreciate the flexibility in time and place allowed with online learning (Mitchell and Forer 2010).

The development of computer-assisted instruction was initially thought to be an improvement upon textbooks or lectures due to the ability of learners to control how they access content and the time and place of learning (Piemme 1998), leading to improved learning experiences of students (Clayden and Wilson 1988). Another potential benefit of the incorporation of online technologies is the potential for reducing the costs of course delivery, while allowing the quality of in-class interactions between students and instructors to be maximized (Vogel 2012). The addition of web elements to a traditional classroom incorporates technological advancements that allow for multimedia enhancement (Cook 2007), better facilitates updates to material, provides universal access, and can cross-reference to other sources (Wallace et al. 2000). It is important that online components in blended learning do not simply provide an online store for lecture slides, course syllabi, tests or course evaluations. Rather, the web-based elements should deliver unique material and experiences to students, such as enrichment with multimedia, that are not available in the classroom or from textbooks (Cook 2007).

There are a number of potential benefits to complementing traditional, in-class learning with web-based material in blended learning. Ubiquitous availability for any student, or any interested party with an Internet connection, allows students to interact with material when and where they wish (Cook and Dupras 2004) and facilitates sharing of resources between learning centers, so that creation of redundant materials can be avoided (Fall et al. 2005). Flexibility in time of learning provides the opportunity for asynchronous communication between students and educators (Cook 2007). Drawing on constructivist learning theory, blended learning gives students more control over what material they access and at what pace they review material – allowing them to concentrate on material they find difficult and move quickly through material they understand easily (Cook 2007). Moreover, multimedia learning-resources cater to students with a variety of learning styles, who can experience material aurally and visually through text, graphics and videos (Jain and Getis 2003). Online material is also persistent; students may decide to review material as needed after completion of the course. For enduring learning, leading to long-term knowledge and understanding, such repetition and review, distributed over time, is necessary (Polsani 2003, Ericsson 2004).

The success of student learning experiences with blended learning is dependent upon the quality of the online resources being used, requiring the collaboration of experts both in the technological and curricular aspects of content development (Garrison and Kanuka 2004). Even minor problems with a website can decrease satisfaction, participation (Cook and Dupras 2005), and increase cognitive load (Sweller 2005). Navigation problems, such as dead external web links, can lead to significant student dissatisfaction with a web-based tool (Oliver and Omari 2001). It is also important to take into account the amount of time required to complete online assignments or study so as to avoid increasing student workloads (Cook 2007). With the instructor no longer acting as the primary source of information, technology-enhanced learning requires greater motivation from students to seek knowledge for themselves (Jarvela et al. 2011).

1.4.1 Blended Learning in Soil Science

For some time there have been efforts to use web-technology to enhance soil science education. In 1995, Cattle et al. recognized the possibility of using computer-based instruction, given the already wide-availability of computers, to teach soil science to high school and university students. They created the Soil Stack, a series of computer-based lessons focused on soil science concepts (soil chemistry, physical properties of soils, soil biology, classification, etc.) and utilizing info cards, graphics and models. The goal was to more effectively engage students in the subject (Cattle et al. 1995). The concept of learning soil science concepts with the aid of computers has developed over time. For teaching about soil microorganisms, Loynachan (2006) noted that motion graphics and video are more effective in capturing the attention and interest of students, while idealized line drawings can help in identifying detailed features and still images are important for seeing actual features in context. Virtual field trips constitute another use of multimedia in soil science education. Virtual field trips provide temporal and spatial flexibility, information accessibility for students, instructor control over content and features, and reusability (Hurst 1998; Tuthill and Klemm 2002; Ramasundaram et al. 2005). Streaming videos can be used as a type of "virtual field trip" (VFT) when there is not sufficient time or resources to take students to actual field sites. VFTs "create a rich, exploratory, multi-modal experience," using multimedia to enhance descriptions of those concepts difficult to describe with text only (Jacobson et al. 2009).

1.5 Factor Analysis

In psychological research, constructs are often not clearly defined in advance and investigators are not always certain of what is being measured in advance (Browne 2000). For this reason, the idea of latent or hidden variables, that cannot be measured directly, has arisen. These latent variables are determined by examining interrelationships between observed variables. Exploratory factor analysis (EFA) was initially developed more than a century ago (Spearman 1904). In psychological research, EFA has subsequently become among the most commonly used procedures (Fabrigar et al. 1999). Factor analysis is used to uncover latent variables (factors) that cause the manifest variables (items) to covary (Costello and Osborne 2005). Shared variance is separated from the unique variance and error variance for each variable to uncover the latent constructs of those variables. Put another way, the latent constructs refer to the structure of correlations among the measured variables (Fabrigar et al. 1999). Often, principal components analysis (PCA) is used in place of EFA methods. However, PCA does not distinguish between unique and shared variance, so the values produced for variance accounted for by the factors can be overestimated (McArdle 1990). EFA and PCA can produce similar results, but EFA will not overestimate variance accounted for (Costello and Osborne 2005).

The methodology for Varimax rotation was first developed by Kaiser (1958). Being less prone to generating a general factor compared with previous methods, this technique became popular and continues to be the predominant rotation appearing in psychometric studies (Browne 2001). Varimax rotation forms new factor axes to produce correlation coefficients as close to 1, 0 or -1 as possible (Zeman et al. 2014).

It is often recommended that the number of factors be determined from the scree plot. However, if the scree plot does not give a clear indication, it is necessary to compare the item loading tables after rotation for a range of numbers of factors (Costello and Osborne 2005). The factor structure that best fits the data should have the fewest crossloadings and have at least three items loading in each factor. Determination of sample size is also an important consideration in EFA. It is generally recommended to have a case to item ratio of 5:1, but adequate sample size is dependent on the data (McCallum et al. 1999). Higher quality data can be used with smaller sample sizes in accurate analyses, and a range of ratios (smaller than 2:1 to larger than 100:1) are often used (Costello and Osborne 2005).

1.6 Summary

Many educators in soil science have noted the challenges facing university soil science programs (Loynachan 2006; Hansen et al. 2007; Collins 2008; Hartemink and McBratney 2008; Bouma 2009; Jacobson et al. 2009; Strivelli et al. 2011; Bouma and McBratney 2013; Krzic et al. 2013; Hartemink et al. 2014). There is increasing demand on soil resources worldwide, concurrent with an increasingly urban population, fewer students enrolled in soil science programs. Some important soil research centers have been terminated in Canada and fewer students graduate with degrees in soil science compared to several decades ago. Meanwhile, an increasing number of soil science articles are being published, often by specialists from non-soil science disciplines. There also appears to be greater attention to soil-related issues from global environmental and governmental associations, such as the United Nations.

Expertise in various areas of soil science is concentrated in the minds of “mature” soil scientists. As these soil professionals retire, there is the risk of their knowledge being lost. It is important to make efforts to preserve and share this knowledge and it is now possible to share information with anyone possessing an Internet connection. This is the case with knowledge of forest floor classification. While the forest floor is rich in soil organisms, important plant nutrients and carbon, the ability to describe and classify forest humus forms is an uncommon skill among postsecondary students and the younger generation of soil science professionals. The forest floor is often not described in soil surveys, in part due to its more rapid response to changes in environmental conditions or disturbance compared with mineral soil. The sensitivity of the forest floor to such changes; however, has the potential to provide early indication of changes occurring in an ecosystem. Promoting the importance of the forest floor to students and enhancing how the subject is taught is an important step in educating future soil scientists and forest management specialists.

Meanwhile, blended-learning, combining multimedia and web technology with campus-based learning provides the opportunity to encourage active, collaborative experiences in-class along with greater student control over how they interact with online learning materials, available to them at any time and place. In soil classification, learning to recognize visual features of soils and identify horizons involves "considerable visual interpretation skills," which can be developed through repeated visual exposure to different soil profiles (Krzic et al. 2013). The flexibility in time and place of online learning provides students constant access to expert knowledge and the opportunity to repeatedly review images, videos and other material. However, hands on activities are always essential in learning soil and forest floor classification, as they provide students the opportunity to apply and reinforce their learning while working collaboratively with their peers. Blended learning provides students both with modern learning technologies – the online environment that is increasingly prevalent in their daily lives – and the collaborative, active learning environment that many students view as a priority in their education (Mutonyi et al. 2010).

1.7 Study Objectives

To allow students to learn about the importance of the forest floor in forest ecosystems, the unique properties of the different organic horizons, and how to identify humus form orders (mor, moder and mull), we developed blended-learning forest floor activities, combining hands-on, campus-based learning with a web-based multimedia resource. The campus-based activity required students to describe and classify a forest floor sample according to the horizons present and an understanding of the structures and decomposer communities present in those horizons. This project was guided by the following objectives.

Objective 1: to develop blended-learning activities (facilitated by a web-based multimedia educational resource and campus-based teaching) to achieve the following learning objectives to: (i) describe forest floors, (ii) classify forest humus forms, and (iii) comprehend the importance of the forest floor in forest ecosystems.

Objective 2: to survey and interview students to assess their opinions of the application of the blended-learning method in the forest floor activities using exploratory factor analysis.

The long-term goals of this study are to (1) add to the body of knowledge and contribute to the establishment of more active ways of teaching and learning in postsecondary soil science education, and (2) develop a survey instrument, exploratory factor analysis methodology and associated factors that can be adapted for similar studies assessing blended learning experiences. As demand for innovations in general science and natural science education increase, studies like this will serve as an example of how to effectively develop multimedia and web enhancements to student learning experiences, to integrate these technologies with collaborative and hands-on activities to maximize student learning and satisfaction, and to provide statistically reliable instruments to assess the factors that explain students' perceptions of similar learning interventions.

2 Pilot Study of Forest Floor Activities Blending Online and Classroom-Based Learning

2.1. Introduction

To meet the need for professionals in land management to gain a strong foundation in soil science and knowledge of forest management, a multimedia web resource was developed to be integrated with in-class forest floor description and humus form classification. Using such a blended learning approach can improve student satisfaction (Castle and McGuire 2010) and grades (Cavanagh 2011). It is considered more effective than online learning or classroom-based learning (Means et al. 2010).

The success of blended learning approaches depends on the quality of the online resources being used. Problems with navigation or other issues can reduce student satisfaction and participation (Cook and Dupras 2005) while increasing their cognitive load (Sweller 2005). The objective of the pilot study was to identify and resolve any issues with the Forest Floor educational resource that we developed, to gain initial insights into the students' reactions to the implementation of the blended learning method, and to conduct preliminary principal component analysis (PCA) of the survey instrument to assess its reliability.

2.2 Materials and Methods

PCA was used instead of factor analysis due to the small sample size – as PCA does not differentiate between sources of error. The upper-level Advanced Soil Science course, offered by the Faculty of Environment at Simon Fraser University (SFU), Burnaby, BC focuses on the ecology and management of forest soils, and is not a required course by any program or major. The course is generally taken by 15-25 students majoring in Environmental Science or Physical Geography who have already taken the Introduction to Soil Science course. In term 2 of 2014-2015 academic year, there were 19 students enrolled in the course who were in the 3rd or 4th year of their studies. The pilot study was conducted during February of 2015, beginning with the forest floor laboratory, followed by the online survey and then focus group interviews.

Prior to the campus-based forest floor activities in which students were introduced to the Forest Floor educational resource, students took forest floor samples from two sites on the SFU campus on Burnaby Mountain. There were four groups of 4 or 5 students. Each group of students took one sample from under a coniferous stand and one sample from under a mixed deciduous and coniferous stand. Class time in Advanced Soil Science course consisted of a 4-hour block per week, divided approximately into a two-hour lecture and a two-hour laboratory. The forest floor lecture preceded the campus-based activities and included a series of slides created by the course instructor and it also included all 6 of the Forest Floor videos created during this study. The lecture included detail regarding chemical properties and relationships between the forest floor and forest ecosystem. The lecture also included an introduction to the more specific group classifications within the humus form orders. All 19 students used the skeleton notes provided on the Forest Floor educational resource. At the end of the lecture, students completed forest floor description sheets (Appendix I) for each of their two samples, having access to their lab manual and the Forest Floor educational resource if they wished to use it. The SFU forest floor laboratory assignment was created by the course instructor. However, we did review the questions to make certain the educational resource presented the necessary information (or references) to complete the assignment and found that no alterations to the questions were necessary. The assignment questions required short essay answers and references to source material.

After students had completed their laboratory assignments, they were asked to complete a 40-question survey about Forest Floor educational resource and campus-based activities (Appendix IV). They were informed about details of the study before the lab and agreed that their feedback could be used for research purposes (Appendix V). Students were given time during class to complete the survey and all 19 students completed the survey. In addition, to the online survey, we also conducted one 8 minute and one 5 minute in-person interview.

PCA analysis was conducted using SPSS Statistical Software. The number of components was determined based on the Scree plot, ensuring that at least 3 items loaded in each component. We used Varimax rotation, which forms new factor axes to achieve correlation coefficients as close to 1, 0, or -1 as possible (to maximize or minimize loading of items on particular factors) (Zeman et al. 2014). Interpretation of the components was limited to analyzing any commonalities amongst the items loading in each component. We also assessed the reliability of the survey responses.

2.2 Results and Discussion

2.2.1 Survey and Interview Feedback

Based on largely positive student feedback, the Forest Floor educational resource and campus-based activities helped students to meet the stated learning objectives (Table 2.2). During group interviews, participants commented that the amount of information and its organization in the forest floor videos and website were adequate. One participant explained, "I didn't really have to go elsewhere for information, but there wasn't too much so that I felt overwhelmed." Another said of the videos, "they are very well organized… The layers, differences and even some cartoons that display more details. Overall, I'd say it was excellent." In a previous study, Strivelli et al. (2011) noted that some students found "long" videos problematic when attempting to find specific information. For this reason we kept videos as short as possible (between 2 minutes 24s and 6 minutes 32s, with an average length of 4 minutes 23s). Downloadable skeleton notes were also included with each video, as recommended by Strivelli et al. (2011) and in agreement with past research showing improved test performance for students supplied with outlines rather than complete notes by their professor (Barnett 2003). Survey responses to information density and navigation were generally positive, with 84.2% of respondents selecting disagree or strongly disagree to the statement "I thought too much information was presented in the Forest Floor videos," and 63.2% selecting disagree or strongly disagree to the statement "I think that the forest floor videos did not provide enough information."

Regarding the website, a respondent said, "I liked that there wasn't too much information on the website. I liked that it was well organized." A study at the University of Tennessee found that 73% of students preferred reading text on paper rather than from a computer screen (Oh and Lim 2005). Strivelli et al. (2011) also received comments that extensive text, in similar style to what would appear in a textbook was not palatable for reading online. Another participant pointed out a glitch on the website, whereby only one of the Humus Form Orders videos was available on the Orders page. The other videos on that page could only be viewed on the Virtual Soil Science Learning Resources YouTube channel (https://www.youtube.com/user/SoilWebUBC). This problem had to be fixed prior to the forest floor labs in the UBC introductory course. Despite this issue, 79.0% of respondents selected agree or strongly agree to the statement "I found navigation of the website to be straight forward," while 63.2% selected disagree or strongly disagree to the statement “I found it difficult to find the specific information I was searching for on the website.”

All of the participants mentioned the importance of having visuals in learning, some referring to their importance to “visual learners”. For example, one respondent said, “it was also helpful to actually see the humus form and see what it looks like,” and another explained, “I’m a visual person, I remember the videos more than I remember someone’s lecture. I don’t think a lot of people learn by sitting and listening.” Students value the ability to choose between different learning mechanisms to best suit their learning needs, and appreciate the flexibility in time and place allowed with online learning (Mitchell and Forer 2010). Furthermore, some participants noted how the videos acted as a sort of approximation of the experience they would have in the field, one saying, “It looks like you are in the environment. It is fun, you feel better, rather than a person standing there giving a lecture. This is more informative because you see the nature itself.” The videos were designed to act as virtual field trips. Virtual field trips aim to approximate the experiences students would have in the field by allowing them to virtually travel to a site through video (Cox and Su 2004). The aim was to recreate the experience of having an expert in forest soils describe the forest floor, the forest ecosystem and provide other important context that students would receive in an actual field trip. Another participant reflected, “it’s an alternative to being outside, when being outside is not practical.”

The possibility of repetitive viewing of videos was mentioned several times in the interviews and commented on by all of the participants. One participant first brought up the idea, saying, "you go home and want to see them again, again and again. You cannot do that with regular lectures." Other participants explained the utility of having access to the videos outside of the classroom. One stated, "we liked that you could go home and pause it at a certain spot," in order to see details, and another even saved images from the videos to use in their assignment.

Participants identified several aspects of the website as the most useful to them as they worked on their lab reports. The humus form order page was noted for having "the most… facts and characteristics," "key points" and "a diagram of how [the humus form orders] differ." The reference page was considered the most useful to another participant, and another said, "the videos themselves," were most important to their learning.

2.2.2 Principal Component Analysis

Based on the scree plot (Figure 2.3.1), five components were selected for this analysis. PCA does not differentiate between shared and unique variance – whereas factor analysis involves separating the shared variance of each variable from the unique variance and error variance, with only shared variance appearing in the solution (Costello and Osborne 2005). PCA can therefore overestimate the variance that the components are able to explain (McArdle 1990). However, due to the small sample size ($n = 19$) and large number of items ($p = 39$), PAF was not possible with this dataset. All five components had more than three items loading. Interpretation of the components was limited to identifying commonalities between items in each component. The reliability of the survey instrument was 0.921, which is quite high, but may be overestimated due to the fact that PCA includes both unique and shared variance (McArdle 1990). Table 2.1 presents themes among items within the components. The full tables of the items loading in each factor can be found in Appendix IX.

2.2.3 Conclusions

A pilot study was conducted to resolve issues with the Forest Floor education resource, to assess student responses to the blended learning approach and to make initial assessments of the reliability of the survey instrument. One functional problem with the website, whereby two videos could not be viewed, was identified and resolved through conducting the pilot study. During group interviews students commented that the website was "well organized" and comprehensive enough that it wasn't necessary to "go elsewhere for information," but that "there wasn't too much information on the website."

According to feedback to the online survey, learning goals were met, with 95% of students agreeing or strongly agreeing that "The forest floor lab and website effectively introduced [them] to the properties of organic horizons (L, F, H, and O)," 89% that "The forest floor lab and website effectively introduced [them] to the humus form orders (mor, moder and mull)," and 100% that "[they] believe that what [they] learned from the forest floor lab and assignment is important knowledge for forest management." In the group interviews, students explained their positive perceptions of the Forest Floor videos for the possibility of repetitive review, appealing to "visual learners," and being "more informative because you see the nature itself." The pilot study was useful in ensuring the Forest Floor educational resource had no issues with usability, that students were able to successfully learn forest floor description and humus form classification with the blended learning method, and that the survey instrument was reliable, with a Chronbach's Alpha of 0.921.

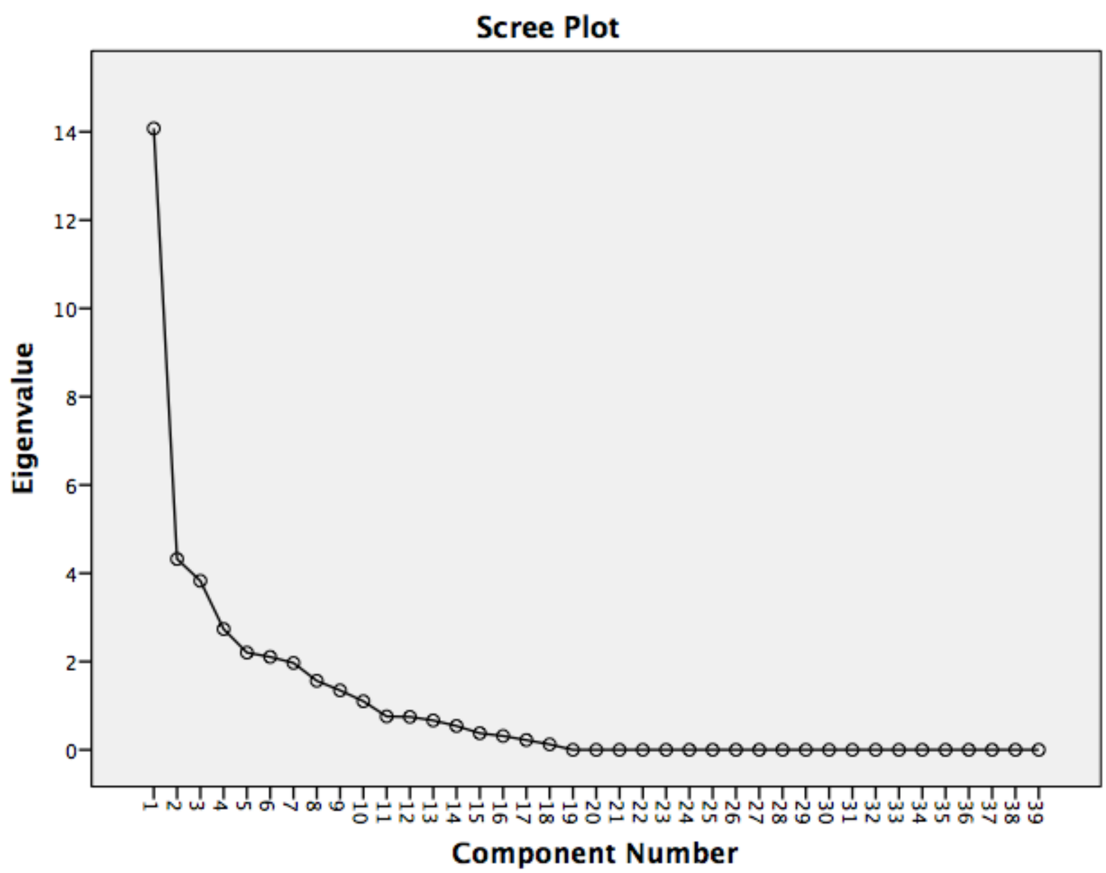

Figure 2.1 – Scree Plot of Principal Components from Pilot Study Responses

Table 2.1 – Interpretation of Components Based on Commonalities Between Items

Component	Commonalities Among Items
1	Student satisfaction with aspects of the website and videos
2	Negatively worded statements
3	Respondents' evaluations of the presentation of concepts, application of learning and their confidence in their knowledge
4	Respondents' preferences in how they accessed materials
5	Perceptions of the importance of the forest floor

Table 2.2 – Survey Responses for Questions Regarding Learning Objectives

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The forest floor lab and website effectively introduced me to the properties of organic horizons (L, F, H, and O)	42.1% 8	52.6% 10		5.3% 1	
After completing the forest floor lab and assignment with the help of the website, I feel confident differentiating between the organic horizons (L, F, H and O).	47.4% 9	21.1% 4	31.6% 6		
The forest floor lab and website effectively introduced me to the humus form orders (mor, moder and mull)	52.6% 10	36.8% 7	10.5% 2		
After completing the forest floor lab and assignment with the help of the website, I can tell the difference between the humus form orders (mor, moder and mull)	31.6% 6	57.9% 11	5.3% 1	5.3% 1	
The forest floor lab and website taught me the differences between the decomposer communities in the different humus form orders	15.8% 3	52.6% 10	26.3% 5	5.3% 1	
The forest floor lab and website effectively explained the chemical properties of different types of litter to me	15.8% 3	36.8% 7	21.1% 4	26.3% 5	
The forest floor lab and website effectively communicated the importance of the Forest Floor in forest ecosystems and soils	31.6%% 6	42.1% 8	15.8% 3	10.5% 2	
After completing the forest floor lab and assignment with the help of the website, I understand the impacts of the forest floor on soil properties	26.3% 5	52.6% 10	15.8% 3	5.3% 1	
I believe that what I learned from the forest floor lab and assignment is important knowledge for forest management	26.3% 5	73.7% 14			

3 Blending Multimedia and Campus-Based Learning to Enhance Learning About Forest Floor Description and Humus Form Classification

3.1 Introduction

There is now widespread recognition that soil must be considered when dealing with global environmental challenges such as mitigating climate change, food production and maintaining clean air and water. Especially in northern forests, the organic horizons at the soil surface play key roles in carbon storage, biodiversity and nutrient cycling (Dixon et al. 1994; Bauhaus et al. 1998; Ponge and Chevalier 2006). For forestry and land resource professionals to effectively manage our forests, they must understand the functions of forest soils. This begs the question of how post-secondary institutions can most effectively educate future land managers about the crucial roles of soils in forest ecosystems.

The current generation of students has different learning experiences outside of the classroom than their predecessors and this needs to be reflected in the adoption of emerging technological and pedagogical innovations by educators. To improve learning experiences of science students, it is necessary to understand how they view the world (Nashon and Anderson 2013). Digital technologies are currently at the forefront of students' experiences in their everyday lives (Tapscott 2008). For many of them, Internet resources have become the primary place to search for information (Loynachan 2006). Current students have also expressed the desire to learn collaboratively with their peers, through active experiences of concepts (Bekerbrede et al. 2011).

It is now easier to incorporate multimedia and web technologies into post secondary education than ever before. Blended learning involves integration of computer-mediated learning into classroom-based learning (Owston et al. 2013). Blended learning has generally been considered to be more effective than classroom-based or online learning alone (Means et al. 2010), improving student satisfaction (Castle and McGuire 2010) and grades (Cavanagh 2011). While learning online gives students spatial and temporal flexibility, improves their access to learning resources and facilitates more autonomy (Poon 2012), classroom-based learning is essential to students' feeling of community and engagement with their peers (Collopy and Arnold 2009).

The forest floor reflects overall site quality (Klinka et al. 1990), but is often not described during soil surveys, partially because the properties of organic horizons can change rapidly, requiring information to be updated more frequently (Broll et al. 2006). Routine practice of humus form classification and monitoring will help researchers to assess the impacts of climate change on carbon storage (Ponge et al. 2011) and better understand nutrient cycling and biodiversity in forest ecosystems (Prescott et al. 2000). For these reasons, Jabiol et al. (2013) suggest that the organic horizons must be described for sufficiently precise characterizations of forest soils. Since most forestry programs still require at least an Introduction to Soil Science course (Collins 2008), it is during these courses that the opportunity exists to introduce future forest and land management professionals to the important roles and properties of the forest floor.

The objective of this study was to develop blended learning activities, facilitated by an educational website combined with a campus-based forest floor laboratory, to teach students about the importance of the forest floor in forest ecosystems, the unique properties of the different organic horizons, and how to identify humus form orders (mor, moder and mull). To assess student opinions of the application of the blended-learning method, we conducted exploratory factor analysis of responses to an online survey, interpreted with the aid of responses in group interviews with students.

3.2 Materials and Methods

The Forest Floor educational resource, a web-based multimedia resource, and the campus-based forest floor activities were developed for the lower-level (2nd year) undergraduate course with no prerequisites, Introduction to Soil Science, offered by the Faculty of Land and Food Systems, UBC. The course is required by several programs in the Faculties of Land and Food Systems and Forestry (Table 3.1). The overall course learning outcome is to introduce physical, chemical and biological properties of soils; soil formation, classification, use and conservation. During the term 2 of 2014/2015 academic year, 232 students were enrolled in this course through two lecture sections (section 001 = 119 students and section 002 = 113 students) and eight lab sections (approximately 29 students per lab section). The breakdown of students' years of study and majors are presented in Table 3.1.

3.2.1 Development of the Forest Floor Educational Resource

Information presented on the Forest Floor educational resource is based primarily on *Towards a Taxonomic Classification of Humus Forms* by Green et al. (1993) as well as *Taxonomic Classification of Humus Forms in Ecosystems of British Columbia* by Klinka et al. (1981). It is important to note that these systems for classification of humus forms were developed primarily based on the forest soils of the Canadian west coast, though efforts were made to represent a broader range of humus form orders and groups, outside of this region (Green et al. 1993). In developing the Forest Floor educational resource, we consulted the following supplementary sources: Bernier 1968, Fisher and Binkley 2000, Fox and Tarnocai 2011, Green et al. 1997, Klinka et al. 1984, Muller 1889, Ponge 2013, Prescott et al. 2000, and the Soil Classification Working Group 1998.

Development of the Forest Floor educational resource, as with the videos, followed the recommendations of Polsani (2003) to plan for sufficient time to conceptualize and execute the web and video components of our learning intervention. Development of the Forest Floor educational resource involved three stages, a planning phase, a development phase and an editing and problem solving phase. The planning phase involved consultation with an expert in web development to determine the website layout and with three soil science experts to verify accuracy and utility of content. The website was developed using WordPress CMS (Content Management System) and hosted on the UBC CMS. An outline of the page layout is provided in Figure 2.2.1. This stage involved the continued input from the soil science experts and was completed by two website developers.

The content of the Forest Floor educational resource includes: videos, tutorials, text, definitions, graphics, animations, photographs and references. On the Forest Floor educational resource, text was reduced as much as possible while still providing as much information as any user carrying out a forest floor description and classification would need. "Accordion" style menus were used to break up and reduce the amount of text that users were viewing at one time. Navigation to all pages is possible from any page on the website, using the content menu running vertically along the top of each page. Also available to the right of the navigation menu is a search bar. The individual pages are described in Table 3.2 During January and February 2015, editing and verification of website functionality were carried out by both soil science and web development experts.

To fully conceptualize and execute a blended learning intervention requires a significant investment of time – as much as two years (Polsani 2003) – and the Forest Floor educational resource involved approximately 1300 person hours to develop. Video production involved a planning stage, two days of filming, production of motion graphics and an editing stage. The video planning stage involved taking humus form samples at two sites, one mor sample (from a site with forest floor directly overlying bedrock) at the Malcolm Knapp Research Forest in Maple Ridge, BC, and both mull and moder samples at the UBC Farm at the University of British Columbia. The mor sample was taken from a 120 year old stand in the Coastal Western Hemlock biogeoclimatic zone (Meidinger and Pojar 1991), from a sloped site near Loon Lake. The site experiences a humid maritime climate with approximately 2200 mm of precipitation per year. Soils in Malcolm Knapp Research Forest are Buntzen, Ferro-Humic Podzol and Cannel, Humo-Ferric Podzol. The mull sample was taken from under a stand of red alder, bigleaf maple and black cottonwood, while the moder sample was taken from under a stand of western hemlock, Douglas-fir and western red cedar. Both stands were approximately 50 to 60 years old. The UBC Farm receives about 1200 mm of precipitation per year and rests within the Coastal Douglas-fir biogeoclimatic zone (Meidinger and Pojar 1991). The soil at the UBC farm is Bose, Humo-Ferric Podzol.

Video scripts were developed with the oversight of a forest soils expert, an education expert and educational multimedia expert. Filming was done in the UBC Soil Science teaching laboratory and the UBC Farm. Two videos were filmed at each site, although one video filmed in the laboratory was later split into three sections. A videographer and assistant videographer captured the videos, as well as providing direction for maintaining continuity between shots. Videos featured a graduate student interviewing forest soils expert Dr. Margaret Schmidt (Associate Professor at Simon Fraser University, Burnaby, BC) on-site. A blended learning expert provided oversight to ensure clarity of the information presented. The camera used was a Canon XF300 and sound recording was done with Sennheiser EW100 microphones. A graphic artist designed the graphics using Adobe Illustrator (Adobe Systems Incorporated, 2015) from photographs, drawings and descriptions provided by the authors. Motion was added by another graphic artist using AfterEffects (Adobe Systems Incorporated, 2015). The voice over was recorded at UBC Studios. Video editing was done by the videographer using Final Cut Pro (FCPX) version 10.1.2 (Final Cut Studio, Apple Inc., Cupertino, CA). Table 3.3 provides descriptions of all six of the videos.

3.2.2 Development of Campus-Based Forest Floor Laboratory Activities

The forest floor laboratory of the Introduction of Soil Science course consisted of an introduction to key forest floor concepts, viewing of supporting forest floor videos, an explanation of the laboratory tasks, hands-on descriptions of forest floor samples and a laboratory assignment to be completed with the assistance of the Forest Floor educational resource. The learning objectives of the campus-based forest floor activities were to allow students to differentiate among the humus form orders, organic horizons and decomposer communities, as well as to understand the importance of the forest floor in forest ecosystems.

Before coming to the lab, students were encouraged to review the information provided in the laboratory manual and website. The lab manual allowed students to review information from paper-based text if that was their preference. Much of the information presented in the laboratory manual was adapted from the Forest Floor educational resource, though shortened to include only what was necessary for completion of the lab activities. Mor and moder samples, with Fm and Fa diagnostic horizons, respectively, were used during the campus-based laboratory sections. The samples were taken from the same site at the Malcolm Knapp Research Forest where the mor sample, used in the videos, was obtained.

During the campus-based forest floor activities, students worked in groups of 3 to 5 to (i) designate the F horizon (which was present in all samples) as either Fm, Fa, or Fz based on its properties such as structure, roots, flora and fauna type and (ii) classify humus form as mor, moder and mull based on the diagnostic horizon (Data entry sheet, Appendix II). The forest floor laboratory assignment was one of seven laboratory assignments during the semester. Students had one week after their laboratory activity to complete the assignment, certain questions of which required that they use the Forest Floor educational resource and videos in particular.

3.2.3 Development of Survey

Development of the survey instrument was accomplished within a framework to assess to what extent the blended learning approach used in this study met the following objectives: (1) student ability to identify organic horizons; (2) student ability to differentiate between humus form orders; (3) student recognition of importance of forest floor; (4) student ability to explain forest floor influences on soil properties and forest ecosystems; (5) learning from videos and graphics; (6) students satisfaction with learning independently using the Forest Floor learning resource; (7) minimization of potential drawbacks of website use; (8) importance of inclusion of varied media such as video, photos, text and hands-on components; (9) navigability and attractiveness of the Forest Floor learning resource; and (10) appropriateness of level of difficulty. It is important to note that the survey instrument was created to assess students' perception of their learning and learning experiences, rather than assessing how much students learned or comparing student learning within our blended learning approach to other teaching methods. The full list of survey items (Appendix IV) were created to assess to what extent our approach met the learning and experiential objectives presented above.

3.2.4 Online Survey

The online survey was opened to responses one week after the forest floor lab and after students completed their lab assignments and the survey remained open for 7 days. Prior to completing the campus-based forest floor activities, students were provided with details of the study (Appendix VI) and were asked to agree that their feedback could be used for research purposes. The survey instrument used for the Introduction to Soil Science course students consisted of 39 questions. . The survey also asked participants to identify their program (major), year of study, why they are taking the Introduction to Soil Science course (Options: Required Course, Personal Interest, Other), and lab section. Out of 232 students in the course, 91 students completed the online survey (79 of which were completed fully).

3.2.5 Respondent Focus-Group Interviews

Seven focus-group interviews (each at about up to 8 minutes in duration) were conducted with the students in the Introduction to Soil Science course. The interview groups ranged between 1 and 6 participants. A total of 31 students participated in these interviews. Participants were required to sign consent forms (Appendix VIII). The interviewer had a number of prepared questions, but whenever possible allowed the participants to lead the discussion and interact with one another in an open conversation about their experiences with the Forest Floor learning resource and activities. Comments from the interviews were taken to support interpretations of the factors arising from factor analysis and to help explain survey responses.

3.2.6 Psychometric Analysis

Analysis of survey results was conducted using SPSS Statistics software (IBM Corporation 2013). Items were tested first for correlation and correlations were tested for reliability and reliability if deleted. Two items, "I liked having access to the forest floor website while working on the lab assignment" and "Having access to the forest floor website while working on the lab assignment helped me to learn about the forest floor" were correlated above 0.8, suggesting that participants responded as though the two items were posing questions that were too similar to be differentiated. The first item was deleted, as reliability if deleted remained 0.903, whereas had the second item been deleted, reliability would have dropped to 0.902.

Exploratory factor analysis (EFA), used to evaluate the structure of the correlations between items representing measured variables (Fabrigar et al. 1999), was chosen over principal component (PCA) analysis or confirmatory factor analysis (CFA). When there is not sufficient theoretical or empirical foundation to make assumptions as to the number of factors or what measured variable the factors may influence, EFA is preferable to CFA (Fabrigar et al. 1999). The drawback to EFA, compared with CFA, is that the statistical significance of identified factors cannot be tested, and described factors can only be used as guides for future research (Zeman et al. 2014).

Principal axis factoring (PAF) was used, having the advantages of making no assumptions as to the distribution of data, as well as being less likely to generate improper solutions (Finch and West 1997). This method attempts to understand the shared variance in a number of measured variables through the creation of a smaller number of latent variables (factors). However, PAF does not allow for confidence intervals, significance tests or goodness of fit indexes to be evaluated (Fabrigar et al. 1999). Varimax rotation was used. The number of factors was determined based on the scree plot and to be consistent with the pilot study analysis, while also ensuring that each factor had at least 3 items loading.

3.3 Results and Discussion

3.3.1 Survey Feedback

Of the 79 surveys that were completed, 53 respondents identified themselves as being in their first year of study, 22 in their second year, 2 in their third year and 2 in their 4th year (Table 3.1). Comparing the mean response (on the scale of 1 = strongly disagree to 5= strongly agree for positively worded questions and vice versa for negatively worded questions) between first year students (mean = 3.82) and the students in the remaining years (mean = 3.90) showed no significant difference at $p \leq 0.05$ (Appendix X). 53 respondents identified themselves as attending lecture section 1 of the course (the course of 230 students was offered through two simultaneous, lecture sections of 115 students each), while the remaining 26 identified themselves as attending lecture section 2 of the course. Comparing the mean response of section 1 (mean = 3.82) with the mean response of section 2 (mean = 3.89) showed no significant difference at $p \leq 0.05$ (Appendix X). The number of respondents in each laboratory section along with the mean responses are presented in Table 3.4. The ANOVA showed a statistical difference between the laboratory sections (p = 0.22; Appendix X); however, Tukey's HSD (Appendix X) test showed no significant difference between any two of the lab groups. Lab section 5 had p = 0.80 and p = 0.052 for labs 2 and 3 respectively, which may have contributed to the significant result in the ANOVA. The lack of significant differences between the sub-populations among the respondents supports the factor analysis of the entire group of respondents together.

3.3.2 Exploratory Factor Analysis of Primary Study Results

Two questions, "I liked having access to the forest floor website while working on the lab assignment" and "having access to the forest floor website while working on the lab assignment helped me to learn about the forest floor," were correlated above 0.8. The former item was deleted prior to EFA, having a higher Reliability if Deleted value (0.903 vs. 0.902 for the latter item). Based on the scree plot (Figure 3.1), we chose to interpret five factors, all of which had at least 3 items loading. The Kaiser-Myer-Olkin (KMO) Test of Sampling Adequacy gave a value of 0.76. The cases to items ratio was low (~2:1) and many studies have suggested minimum case to item ratios of 5:1 (Hatcher 1994). However, the sampling adequacy value of 0.76 obtained in this study is a relatively strong value for psychometric research. The Chronbach's Alpha for the reliability of the survey instrument was 0.903 and all of the factors had Chronbach's Alphas above 0.6. The five factors selected accounted for a total of 46% of variability. Factors one to five are presented in Tables 3.5 – 3.9.

Factor 1 included 16 items, and explained 15% of the variation in responses. Six items loaded above 0.6, meaning they were at least 60% correlated with the factor itself. The items loading in this factor tend to refer to the benefits to students of having access to the Forest Floor educational resource during the campus-based forest floor activities and laboratory assignment. For this reason I have called this factor "Satisfaction with the educational resource as a learning enhancement."

The statement “Having access to the website at any time and place was helpful for learning forest floor concepts,” had a loading of 0.713, with 84% of respondents selecting agree or strongly agree. A number of previous studies have demonstrated how information technology can be used to reinforce learning by allowing students to repeatedly review content (Hoffman and Ritchie, 1997; Moore and Gerrard, 2002; Polsani 2003) and learning soil classification in particular requires repetitive review of material (Krzic et al. 2013). For enduring learning, leading to long-term knowledge and understanding, such repetition and review, distributed over time, is necessary (Polsani 2003, Ericsson 2004). One participant in the focus group discussions highlighted this, saying, “…if I did not understand something, I can go back many times. [In class] you can’t ask to ‘say again, and again,’ I really liked that part.” The concept of repeated review of material arose in several of the interviews (once with the prompting of the interviewer). Another respondent stated, “I watched the videos again while I was doing the lab report. It really helped seeing it before, then doing [the sample description], then [seeing it] after.” An ESL participant noted, “it was good to watch the videos. They didn’t have subtitles, but I could still repeat so that I could understand.” This suggests an added benefit of online material and multimedia over traditional instruction for students who have some difficulty following strictly auditory lectures. It may be advisable to include subtitles in future videos to ensure that all students can understand the material as well as possible.

The statement "I found having access to skeleton notes while reviewing the videos helped me to identify important points," had a loading of 0.680, with 78% of respondents selecting agree or strongly agree. This is in agreement with Strivelli et al. (2011), who found that students had trouble finding particular information in videos, suggesting that future videos created for teaching purposes include outline notes to help students to retrieve information. Providing outlines or skeleton notes can increase student performance (Barnett 2003). During group interviews, students tended to respond positively to the amount of information presented in the videos, nonetheless, one student noted that they found "watching a whole video and picking out information [was] hard," preferring reading text to watching the videos. Maintaining short video lengths, identifying key words with text labels and providing skeleton notes all aim to reduce this difficulty, but alternative sources of information are necessary to ensure that all students can approach learning in the best possible way for them.

The statement "Having access to the forest floor website while working on the lab assignment helped me to learn about the forest floor," had a loading of 0.627, with 95% of respondents selecting agree or strongly agree. This statement had the strongest agreement of any item in the survey. The success of student learning experiences with blended learning is dependent upon the quality of the online resources being used, requiring the collaboration of experts both in the technological and curricular aspects of content development (Garrison and Kanuka 2004). The design of the forest floor website aimed to maximize student engagement with the material. Klemm and Tuthill (2003) have noted how complexity in the organization of a website encourages students to explore information independently, leading to novel idea associations and greater learning. Variability in the medium of information presentation on each page and across the site, including video, text, photographs, graphics and tutorials, can help to maintain student interest in the online teaching resources (Cox and Su 2004), and to cater to a variety of learning styles (which will be addressed in the discussion of Factor 4) (Jain and Getis 2003).

When asked if they found the website helpful in doing their assignments, one respondent replied simply, "Yes, very much," while another elaborated, "I think the website is good enough to finish the assignment. I found all the information for the assignment on the website." In another group discussion one participant commented, "…this course is really intensive for me, so having a place where we can find what we need was really helpful." A second agreed, saying that they thought "the website was a better design than the textbook. It was very good for me."

The statement, "I thought that the in-class portion of the lab was complemented by the addition of the forest floor website," had a loading of 0.641, with 80% of respondents selecting agree or strongly agree. A similar statement, "Combining multimedia and web-based elements with in-class learning was beneficial to my learning," had a loading of 0.611, with 84% of respondents selecting agree or strongly agree. The blended learning model can improve student satisfaction (Castle and McGuire 2010) and has generally been considered more effective than classroom or online learning alone (Means et al. 2010).

During the group interviews, a participant specified that "watching the videos" was most useful during the lab for learning how to identify the organic horizons and humus form orders. In another response regarding the use of videos during the lab, a participant said, "I think it helped a lot because, the soil is too similar, it's hard to know right away what are the differences." In order to compare the blended learning experience with a more traditional lab, I asked the participants in one group if they thought an explanation from their TA or Instructor, rather than including the videos, would have given them an equally good introduction to the topic. One participant replied, "I think that the video was able to give the topic more relevance and that it was a more efficient use of time. It shows where the forest is before looking at the samples solely." This was echoed in another group, where a participant said, "I like your videos because they filmed in the field, so you could see what it really looks like."

The statement "I thought the website was aesthetically pleasing overall," had a loading of 0.638, with 84% of respondents selecting agree or strongly agree. This can be an important determinant of users' evaluation of a website, as impressions are formed in the first moments of exposure to a site and these impressions are maintained over time (Lindgaard et al. 2006). Furthermore, a positive initial aesthetic impression instills in users a positive expectation of the website

(Tractinsky et al. 2006). One student commented on the aesthetic of the website, saying, "I liked that it was a pretty website… very nice designs."

Factor 2 had ten items loading, four of which loaded above 0.5, meaning that the item was correlated more than 50% with the factor. Factor 2 accounted for 12% of total variance explained. The items loading in Factor 2 tend to refer to how well concepts were presented using the blended learning model and the relate-ability of information presented on the videos and website to the laboratory samples. For this reason, I have called this Factor "Success of presentation of concepts using the blended learning method."

The statement "Describing the forest floor samples in the laboratory was essential to my understanding of the properties of the different organic horizons," loaded at 0.736, with 79% of respondents selecting agree or strongly agree. While the success of active learning is dependent on the design of curriculum and effective pedagogy (Andrews et al. 2011), it has been shown that active learning has significant benefits for learning in science (Udovic et al. 2002). The theory of active learning promotes the concept that we learn best during active application of the ideas and concepts that are being presented to us (Plaget 1971).

Having the opportunity to interact with the samples while engaging their senses of vision, touch and even hearing gave students deeper insight into what they saw in the videos and read in their lab manuals. This was supported by a number of student comments in group interviews. One participant stated, “A lot of the time I find that when I look at a definition, I have no idea what it is, but then when I look at the hands on, it’s like ‘Oh, of course.’” Another student in the same interview agreed, saying, “Once you pull stuff apart you kind of realize, ‘that’s what the definition means.’” A third student, when asked during another interview for their thoughts on the hands-on aspect of the laboratory, said, “It was more fun. It was more like I’m actually learning from it. The sample is better than just sort of memorizing. More hands on experience, everything hands on – I learn better.” The fact that the physical aspect of the lab was enjoyable in itself came up again in another interview session, with a respondent saying, “it was really fun pulling the samples apart, to get your hands dirty.”

There exists a desire among many students for collaborative, active learning (Bekerbrede et al. 2011) that requires them to discuss and build consensus together (Laal 2013). These discussions give students deeper insights into the concepts they are learning (Udovic 1998) as they are required to persuade others in their groups of that their opinions are well founded (Peterson and Jungck 1988; Prunuske et al. 2012). The in-class experience of learning is essential for students to have a sense of community and engagement with other students (Collopy and Arnold 2009).

Several students commented on the advantages of working collaboratively in their groups. In one group, a student said, “I was in a group with four people. We often have differing ideas on how much of a property is a lot, how much is a little, because we'd never looked at a forest floor sample before. It was important to have a group." Another student agreed, "I think it was good to work in a group, sometimes we would end up discussing and have to review the definitions. I couldn't just say, 'this is what it is.' I had to justify it. In the group setting you have to justify your views, you actually have to use the vocabulary that you learned to express yourself." There is evidence that discussing questions in groups can help to improve the answers of all the students involved in the discussion. Posing conceptual questions to students individually, and again after discussion in pairs in an undergraduate soil science class, Edinger-Marshall (2014) found that 75% to 94% of students improved their answers after peer consultation. The idea behind these ConcepTests is that the students learn from one-another as they explain what they are thinking (Furtak et al. 2010).

The statement, "I was able to relate the information in the videos and on the website to what we were seeing in our sample in the lab," loaded at 0.671, with 81% of students selecting agree or strongly agree. A negatively worded statement of a similar nature, "I found it difficult to make connections between the information presented in the forest floor videos and on the website with what we saw in our lab samples," loaded at 0.573, with 76% of students selecting disagree or strongly disagree. The blended learning model allows students to make associations between the information presented with multimedia and online technologies and their experiences in-class, where they apply their knowledge (Collopy and Arnold 2009) and develop communication and problem-solving skills (Strivelli et al. 2011; Krzic et al. 2013). Improved learning and better retention of material results when students engage in active construction of their knowledge (Knight and Wood 2005).

The statement, “The forest floor lab and website taught me the differences between the decomposer communities in the different humus form orders,” loaded at 0.627, with 71% of students selecting agree or strongly agree. This agrees with the positive response of students to how information was presented and the benefits of blended learning in promoting active, collaborative learning. One student provided examples of how they related information presented in the videos to their laboratory sample, saying, “[the video] mentioned that for a specific horizon you pull the roots and you can hear them being pulled apart. Or when you touch the H it will leave a stain on your hands. I think that helped.” Another said “it gave a good visual context for it.” A third student in another group explained how the videos provided an advantage compared with plain text, “Often I find when I read things, I have to read it at least a few times for me to be able to come up with a visualization… When it’s a video, you can see that first hand.”

Factor 3 had 5 items loading, 3 of which loaded above 0.5, and accounted for 8% of variance. The items loading in Factor 3 tend to reflect students’ assessments of how confident they were in their own learning of the information presented by the forest floor lab. For this reason, I have called this factor, “student self-assessment of learning.” Factors 2 and 3 demonstrate that students responded positively to questions regarding learning objectives (Tables 3.7 and 3.8). Students responded more positively to questions regarding how the blended learning method presented information, compared with how they assessed their own learning of that information.

The statement, “After completing the forest floor lab and assignment with the help of the website, I still feel unsure about the differences between the humus form orders,” loaded at 0.66 with 51% of students selecting disagree or strongly disagree (25% of students selected agree or strongly agree). The statement, “After completing the forest floor lab and assignment with the help of the website, I feel confident differentiating between the organic horizons (L, F, H and O),” had a loading of 0.592, with 73% of students selecting agree or strongly agree. The statement, “After completing the forest floor lab and assignment with the help of the website, I do not feel comfortable explaining ways the forest floor influences soil properties or impacts the forest ecosystem,” had a loading of 0.578, with 48% of students selecting disagree or strongly disagree (17% selected agree or strongly agree). Drawing on constructivist learning theory, blended learning gives students more control over what material they access and at what pace they review material – allowing them to concentrate on material they find difficult and move quickly through material they understand easily (Cook 2007). Students value the ability to choose between different learning mechanisms to best suit their learning needs, and appreciate the flexibility in time and place allowed with online learning (Mitchell and Forer 2010). One student explained, “we could visualize what you guys did on video and then apply it to what we were doing so that it was easier to identify the mor, moder and mull." Referring to the different decomposer communities in relation to the humus form order, another student said, "the decomposer part is [harder] to memorize for me – whether you have fauna or fungi – I think it's very clear on the website."

Factor 4 had four items loading, three of which loaded above 0.5, and accounted for 6% of variation. The items loading in Factor 4 referred to student preferences in which material they accessed in order to learn the topics presented in the forest floor lab. For this reason, I have called this factor "Student learning preferences in accessing materials."

The statement "I found the videos to be the most useful medium for learning about the forest floor," had a loading of 0.634, with 66% of students selecting agree or strongly agree (15% selected disagree). The statement "While working on the forest floor lab and assignment, I preferred learning from reading text rather than watching video," had a loading of 0.624, with 28% selecting agree or strongly agree, and 42% of students selecting disagree or strongly disagree. The statement "I found videos and graphics to be more effective than plain text in learning about the forest floor," had a loading of 0.594, with 88% of students selecting agree or strongly agree.

Traditional classroom experiences do not provide the same environment that the majority of current students are used to, in which they are connected through online and mobile technology to their peers and the web-content that they are interested in (Raes and Schellens 2012). A variety of studies have shown how the inclusion of varied multimedia into course content can improve student motivation by providing a variety of viewpoints and catering to different learning styles (Hoffman and Ritchie, 1997; Moore and Gerrard, 2002; Polsani, 2003; Cox and Su, 2004). Multimedia learning-resources cater to students with a variety of learning styles, who can experience material aurally and visually through text, graphics and videos (Jain and Getis 2003). Even distribution of visual media among web pages can help to maintain students' interest as they explore the online learning resource (Jacobson et al. 2009). Constructivist learning theory encourages students to search for information, make discoveries and build their knowledge (Chumley-Jones et al. 2002). There was support for this from students regarding how they accessed materials – most identifying both videos and supporting text as important, but having accessed the materials in different ways. For example, one student said, "you can get more in depth with the writing part, and then watch the video to see in general and understand all the components." Another student took an opposite approach, saying, "The reading was more in depth than the videos, so after I watched the videos, if that wasn't enough then I could read to supplement that." One student enthusiastically acknowledged the tutorial page as the most helpful for completing the assignment, explaining, "I was really stoked on this assignment. It helps you find the answers. I told people afterwards, they're all on the website."

Factor 5 had three items loading, one of which loaded above 0.5, and accounted for 5% of variation. The items loading in Factor 5 refer to students' positive response to the multimedia and web-based elements and website navigation. For this reason, I have called this factor, "Usability of the website." The statement, "I could have learned the material equally effectively from the multimedia and web-based elements alone," had a loading of 6.84, with 41% of students selecting agree or strongly agree, and 28% of students selecting disagree or strongly disagree. The large number of students who selected agree or strongly agree to this statement is somewhat surprising, given how many also expressed appreciation for the importance of the in-class, hands-on portion of the lab. However, it does reflect the satisfaction students expressed with the website and videos. My assumption is that students may have been referring to the usefulness of the website and videos for answering the assignment questions or preparing for test questions. Furthermore, it appears that students tended to respond with a positive bias to the statements, for example, to the remaining two items in Factor 5. While the statements are similar, the negatively worded statement had 23% agreement, while the positively worded statement had only 9% disagreement, and no students strongly disagreed.

The statements, "I found it difficult to find the specific information I was searching for on the website," and "I found navigation of the website to be self-explanatory," had loadings of 0.457 and 0.373, and 23% and 76% of respondents selecting agree or strongly agree, respectively. The success of student learning experiences with blended learning is dependent upon the quality of the online resources being used, requiring the collaboration of experts both in the technological curricular aspects of content development (Garrison and Kanuka 2004). Even minor problems with a website can decrease satisfaction, participation (Cook and Dupras 2005), and increase cognitive load (Sweller 2005). Navigation problems, such as non-functional external web links, can lead to significant student dissatisfaction with a web-based learning tool (Oliver and Omari 2001).

The majority of students did not have difficulty exploring the website, however, some students expressed that they found it difficult to find particular information. For example, one student said that, "it was easy, because you actually gave instructions on where the right page [was] to answer the questions," while another in the same group stated that they, "had a hard time finding stuff on the website." A number of studies have suggested that non-linear website organization compels students to explore independently and thus, improve learning (Tuthill and Klemm 2002; Jacobson et al. 2009). While we do not wish to discourage students with unnecessary complications during exploration of the website, the majority of students did not appear to have had difficulties and the potential learning benefits of student "construction of knowledge" make a somewhat complex website design preferential over a more simple and straight-forward design.

3.3.3 Challenges with Implementation of Blended Learning Model

While students generally regarded learning collaboratively in groups as a positive experience (Bekerbrede et al. 2011), there were some negative comments regarding group sizes, dominance of particular group members during discussions and a lack of participation on the part of other group members. During the forest floor lab, students were encouraged to work in groups of five. One participant in the focus group discussions stated that their initial group of five was too large, "when there are five hands in one sample it doesn't really work. Afterwards, we split up and it was a lot easier. " Two participants who had worked together on the lab explained that they had a group of seven students working on one sample; however, two of the seven had not participated in the discussion but instead "[sat] behind us and [copied] us." Other participants in the focus group compared their experiences, describing their group of four as the "perfect" number. Counter to the copying complaint, a participant in another group brought up the difficulty with expressing differing opinions in a group where certain students were dominating the discussion. Another participant agreed, saying "it is important for everyone in the group to discuss and tell everyone what they think…it's not good if you don't feel like you are participating in it." The participant continued, echoing a sentiment in other groups, "I think smaller groups can be better."

One negative comment was received in the open ended response question at the end of the survey as follows: Navigation-wise I didn't like how the heading of each of the menus took you to a completely separate page that you couldn't then navigate to the submenu options. This reflects the fact that, with the exception of the "Definitions" page on the website, the main menu items (About, Definitions, Classification, Activities) acted as stand-alone pages, rather than simply introductions and junctions of navigation to the subpages available from the menus that open up when a user scrolls over the main menu items. Besides the student who commented that they had difficulty finding things on the website, another student commented that some information was not where they had expected it to be. 9% of students disagreed that “navigation of the website [was] self-explanatory,” and 23% agreed or strongly agreed that “it [was] difficult to find the specific information [they] were searching for on the website.” One student commented, “if I had watched the videos the night before, I think the lab would have been easier.” In the future it could be more effective to have students review the material in advance of the lab and possibly answer a small number of assignment questions or implement a short quiz during the forest floor laboratory.

2.4 Conclusions

There is an on-going need for forestry and land resource professionals to gain a solid understanding of how to sustainably manage our forests. One approach for acquiring this knowledge is to enhance current educational methods with innovative, active learning approaches. Blending face-to-face interaction and exchange of information between instructor and learners with online learning are well suited to foster learning outside traditional educational settings. The Forest Floor web resource was developed to help meet the challenge of educating the current “net generation” of students as future forestry and land resource professionals.

Responses to the online survey and during focus group interviews were predominantly positive and demonstrate that learning objectives were met by using a blended learning approach. The EFA gave us the opportunity to explore the factors that influenced students' positive responses to the online survey, supported by pedagogical theory and interviews with students themselves. The five factors that we interpreted: satisfaction with the educational resource as a learning enhancement, success of presentation of concepts using a blended learning method, student self-assessment of learning, student learning preferences in accessing materials and usability of the educational resource, have the potential to be verified in similar learning interventions. The majority of students agreed or strongly agreed that the Forest Floor website was helpful for learning forest floor concepts (94%), that describing samples in class was essential for understanding the properties of organic horizons (79%), and that they were able to relate information in the videos and on the website to their own samples (81%).

Using a blended learning method in the forest floor lab allowed us to take advantage of the active and collaborative hands-on learning in the laboratory combined with website and multimedia elements, which gave students greater control over their learning and allowed them to connect what they saw on their screen to their samples in the lab and their assignment questions. Student responses highlighted the importance, as one focus group participant put it, "getting your hands dirty," along with the advantages of working in a group, participating in discussion and using the soil science vocabulary. This study provides initial factors and a survey instrument that can be adapted to assess students' experiences with blended learning in science and demonstrates that adapting curriculum to suit the learning preferences of contemporary students with a blended learning approach can successfully teach difficult concepts such as forest floor description and humus form classification.

Table 3.1 – Student make up within the Introduction to Soil Science Course

Year of Study	Number of Students		Major	Number of Students	
	Section 1	Section 2		Section 1	Section 2
1	104	93	Conservation	42	39
2	8	13	Forest Resource Management	50	35
3+	7	7	Forest Sciences	15	18
Total	119	113	Other	12	19
			Total	119	113

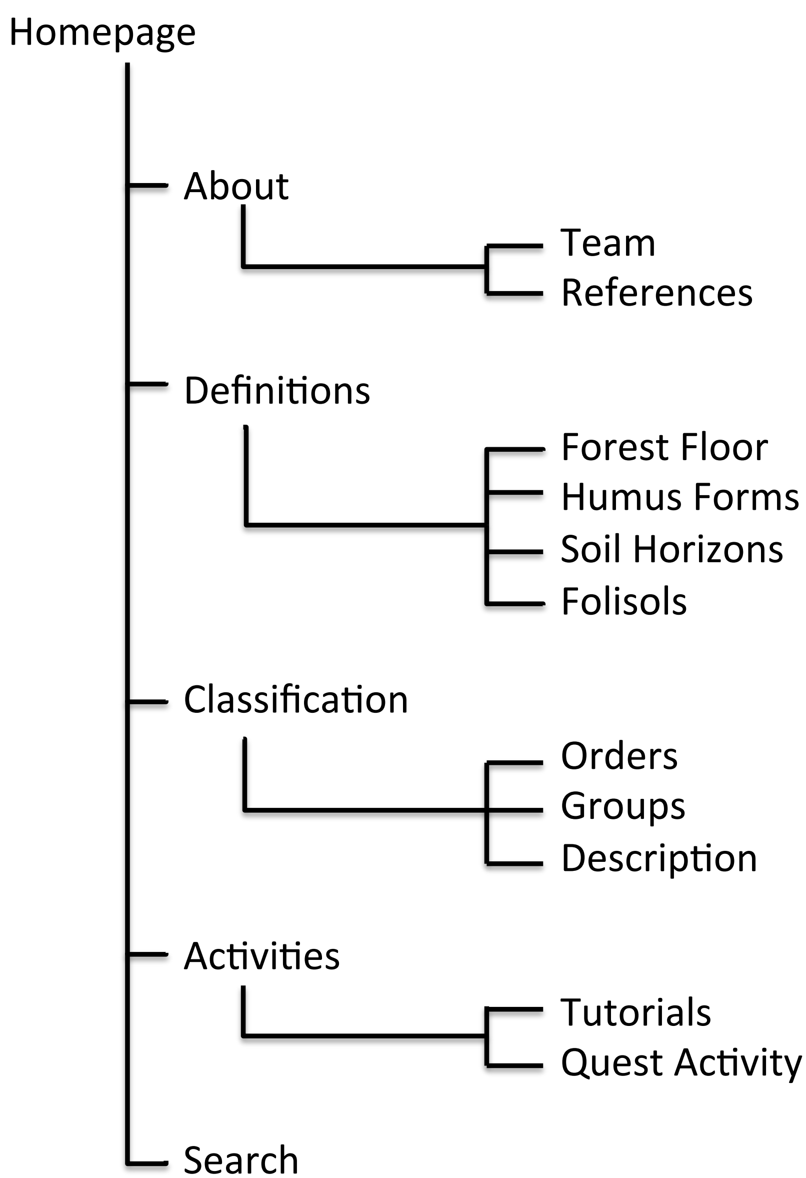

Figure 3.1 – Navigation Outline of Pages on Forest Floor Website

Table 3.2 – Information Presented on Forest Floor Website by Webpage

Main Page	Subpage	Video Featured	Information Presented on Webpage
Home		-	- statement of the website objectives - primary sources serving as the basis for the site (Green et al. 1993; Klinka et al. 1981) - graphic depicting typical mor , moder and mull humus forms under coniferous, mixed, and deciduous trees, respectively - the graphic links to the "Orders" page.
About		-	- describes the purpose of the website and provides details about how it was developed
	Team	-	- features photos and bios of the people involved in development of the site
	References	-	- provides a list of references to documents used in development of the site - meant to give users access to a greater depth of information
Definitions		In the ecosystem	- a brief description of the role of the forest floor in forest ecosystems - links to forest floor, humus forms, soil horizons and Folisols pages
	Forest Floor	In the ecosystem	- provides a definition of the forest floor - explains how the forest floor accumulates in response to different climates, the importance of soil biodiversity, nutrient cycling, carbon storage and temperature and moisture effects
	Humus Forms	In the ecosystem	- distinguishes between "forest floor" and "humus forms" - provides brief descriptions of mor, moder and mull humus form orders and recognizes some different humus form classification systems - provides examples of conditions under which different humus forms may occur
	Soil Horizons	Organic horizons	- explains criteria for the differentiation of organic and mineral horizons - identifies and describes common organic horizons under both well-drained and poorly drained conditions - lists and explains lowercase suffixes used to denote modifications to horizons - describes Ah horizons
	Folisols	-	- features the interesting case of an organic soil occurring on dry upland sites, often over bedrock, yet supporting vegetation including large trees - notes, importantly, that folisols are not a humus form order or group

Table 3.2 – Information Presented on Forest Floor Website by Webpage

Main Page	Subpage	Video Featured	Information Presented on Webpage
Classification		-	- provides details of the humus form classification system developed by Green et al. (1993) - differentiates between humus form orders (more broad) and groups (more specific sub-categories of orders) and presents a summary of the humus form taxa presented in Green et al. (1993)
	Orders	Humus form orders, parts 1, 2 and 3	- provides a simplified key for differentiating between mor, moder and mull - provides detailed information about the conditions for development and properties of mor, moder and mull, as well as identifying diagnostic horizons - features cartoon graphics showing horizon sequences and idealized features of mor, moder and mull
	Groups	-	- describes each of the humus form groups presented in Green et al. (1993), which are more specific classifications of the humus form orders
	Description	How to sample	- provides students with a link to download a sample humus form profile description sheet - explains step by step how to carry out a humus form description - explains in detail how to describe: horizon depth, moisture status, colour, fabric, structure, consistence, character, roots, non-conforming materials, biota, soil fauna, and soil flora
Activities			- explains the purposes of the tutorials and quest activity pages (giving students further practice and review of what they have learned)
	Tutorial	-	- provides questions under three headings: forest floor, humus forms and multiple choice - forest floor and humus forms questions require written answers - meant both to help students navigate the website and to review what they learned in the laboratory - answers to all of the questions are also provided, so users can verify whether or not they answered correctly
	Quest Activity	-	- describes the Forest Humus Forms Quest: a scavenger hunt-style game requiring students to visit soil pits at the UBC farm and, using the Questogo app, answer questions about the forest floor at the site

Table 3.3 – Forest Floor Video Descriptions

Video Title	Location	Description
Organic Horizons	UBC Soil Science Teaching Lab	- introduction to the properties of and differences between the L, F and H horizons as well as mineral Ah horizons, using samples of each, along with a mor humus form sample to explicate a typical horizon sequence
Humus Form Orders Part 1	UBC Soil Science Teaching Lab	- a mor and mull sample were presented, with the expert identifying and describing the diagnostic horizons' (Fm and Ah, respectively) clear structural differences - differences between the litters from which the samples formed and identifiable soil organisms present in the samples (fungi in the mor and earthworms in the mull)
Humus Form Orders Part 2	UBC Soil Science Teaching Lab	- the difference between definitions of the forest floor and humus forms are explained - the samples are classified as mor and mull - the structures of each sample are further explained in relation to decomposition and the mixing of mineral and organic material in the mull, compared with the lack of mixing in the mor - provides visuals of fungal mycelia in an Fm (mycogenous) horizon and faunal castes in an Fz (zoological) horizon (which is not present in the mull sample)
Humus Form Orders Part 3	UBC Soil Science Teaching Lab	- includes the additional feature of motion graphics of mor and mull, along with a voice over, used to review the main points presented in parts 1 and 2 and highlight potential differences in soil pH, nutrient contents and C:N ratios between mor and mull humus forms - also features a moder sample, described as having properties in-between a mor and mull, with an Fa (amphi) diagnostic horizon featuring elements of both fungal hyphae and the impacts of faunal activity
In the Ecosystem	UBC Farm	- covers a fairly wide variety of topics - begins in a deciduous stand at the UBC farm - explains the importance of organic horizons for nutrient availability, moisture retention, temperature effects, and carbon storage - explains the relationship between the deciduous litter and soil organisms and the formation of an Ah through the mixing action of soil fauna - covers the relationship between season and litter accumulation and how to measure organic horizons, compared to mineral horizons (depth 0 being the top of the mineral soil) - a second, coniferous site is visited, exhibiting a deeper litter layer, which the expert explains is in part due to higher lignin content and C:N ratios, and potentially lower pH - role of invasive earthworms in the thin or in some places absent F horizon is also explained
How to Sample	UBC Farm	- the methodologies of taking a 20x20 cm forest floor sample for determining landscape nutrient contents or a humus form sample for description are explained

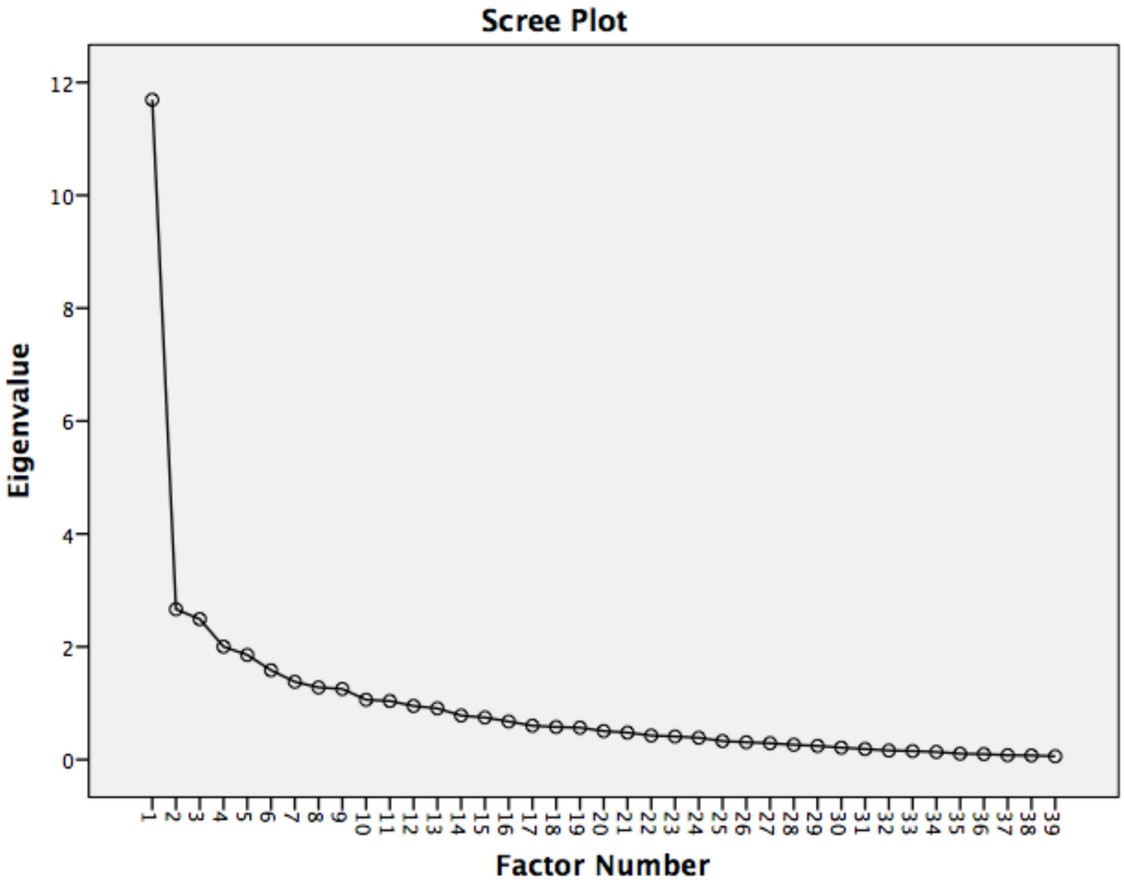

Figure 3.2 – Scree Plot of Factors from Primary Study Responses

Table 3.4 – Number of Respondents and Mean Response by Laboratory Section

Laboratory Section	Number of Respondents	Mean Response
1	16	3.78
2	11	4.08
3	15	3.81
4	11	3.63
5	7	4.17
6	8	3.85
7	5	3.84
8	6	3.62

Table 3.5 – Factor One, Satisfaction with the educational resource as a learning enhancement

Statement	Loading	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Having access to the website at any time and place was helpful for learning forest floor concepts	**0.71**	38% 30	56% 44	4% 3	3% 2	
I found having access to skeleton notes while reviewing the videos helped me to identify important points	**0.68**	25% 20	53% 43	21% 17	4% 3	2.5% 2
Having access to the forest floor website while working on the lab assignment helped me to learn about the forest floor	**0.67**	52% 43	43% 35	5% 4	1% 1	
I thought that the in-class portion of the lab was complemented by the addition of the forest floor website	**0.64**	27% 21	53% 42	18% 14	3% 2	1.3% 1
I thought the website was aesthetically pleasing overall	**0.64**	30% 24	53% 42	14% 11	3% 2	
Combining multimedia and web-based elements with in-class learning was beneficial to my learning	**0.61**	35% 28	51% 41	14% 11		
I could have learned the material equally effectively without the use of multimedia and web-based elements	0.59	1% 1	15% 12	40% 32	39% 31	7.5% 6
I did not find the forest floor website helpful in learning about the forest floor	0.52	3% 2	3% 2	9% 7	43% 35	45.7% 37
After completing the forest floor lab and assignment with the help of the website, the properties of different organic horizons are still not clear to me	0.52	7% 6	16% 13	21% 18	52% 44	7.1% 6
I found that the multimedia elements presented on the forest floor website reinforced what I learned during the forest floor lab	0.48	19% 15	65% 52	15% 12	1% 1	
I think having access to the information on the website outside of the classroom allowed me to effectively reinforce and expand my learning about the forest floor	0.48	25% 20	60% 48	15% 12		

Percentages represent the percent of students that selected that option; numbers below percentages represent the number of students that selected that option

Table 3.5– Factor One, satisfaction with website and videos as learning enhancement

Statement	Loading	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Graphics and images on the website and in videos helped me to visualize key elements of the forest floor	0.44	26% 21	59% 48	15% 12	1% 1	
Graphics and images on the website and in videos did not improve my understanding of the forest floor	0.43	4% 3	10% 8	12% 10	56% 46	19.5% 16
After completing the forest floor lab and assignment with the help of the website, I feel confident differentiating between the organic horizons (L, F, H and O)	0.43	17% 14	56% 47	24% 20	4% 3	
I thought too much information was presented in the forest floor videos	0.37	4% 3	9% 7	21% 17	51% 42	15.9% 13
Using the website to learn the material made me feel isolated from other students and/or my instructor	0.35		6% 5	6% 5	53% 42	32.9% 26

Percentages represent the percent of students that selected that option; numbers below percentages represent the number of students that selected that option

Table 3.6 - Factor Two, success of presentation of concepts using blended learning method

Statement	Loading	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Describing the forest floor samples in the laboratory was essential to my understanding of the properties of the different organic horizons	**0.74**	18% 14	62% 48	19% 15	3% 2	
I was able to relate the information in the videos and on the website to what we were seeing in our sample in the lab	**0.67**	21% 16	60% 47	17% 13	4% 3	
The forest floor lab and website taught me the differences between the decomposer communities in the different humus form orders	**0.63**	15% 12	57% 47	18% 15	6% 5	4.8% 4

Percentages represent the percent of students that selected that option; numbers below percentages represent the number of students that selected that option

Table 3.6 - Factor Two, success of presentation of concepts using blended learning method

Statement	Loading	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I found it difficult to make connections between the information presented in the forest floor videos and on the website with what we saw in our lab samples	**0.57**	3% 2	10% 8	12% 9	63% 49	12.8% 10
The forest floor lab and website effectively introduced me to the humus form orders (mor, moder and mull)	0.49	32% 27	54% 45	14% 12	5% 4	1.2% 1
After completing the forest floor lab and assignment with the help of the website, I understand the impacts of the forest floor on soil properties	0.46	13% 11	69% 57	17% 14	1% 1	
Describing and classifying the humus form in the laboratory was necessary for me to understand the properties of the different humus forms	0.45	13% 10	70% 54	16% 13	3% 2	
The forest floor lab and website effectively explained the chemical properties of different types of litter to me	0.44	12% 10	53% 44	29% 24	7% 6	
The forest floor lab and website effectively communicated the importance of the Forest Floor in forest ecosystems and soils	0.43	27% 22	62% 51	10% 8	2% 2	
I think that the forest floor videos did not provide enough information	0.31	1% 1	11% 9	29% 24	54% 44	7.3% 6

Percentages represent the percent of students that selected that option; numbers below percentages represent the number of students that selected that option

Table 3.7 – Factor Three, student self-assessment of learning

Statement	Loading	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
After completing the forest floor lab and assignment with the help of the website, I still feel unsure about the differences between the humus form orders	**0.66**	4% 3	21% 18	25% 21	43% 36	8.3% 7
After completing the forest floor lab and assignment with the help of the website, I feel confident differentiating between the organic horizons (L, F, H and O)	**0.59**	17% 14	56% 47	24% 20	4% 3	
After completing the forest floor lab and assignment with the help of the website, I do not feel comfortable explaining ways the forest floor influences soil properties or impacts the forest ecosystem	**0.58**	1% 1	16% 13	35% 29	40% 33	8.4% 7
I believe that what I learned from the forest floor lab and assignment is important knowledge for forest management	0.44	13% 10	63% 49	13% 10	10% 8	2.6% 2
The forest floor lab and website effectively introduced me to the properties of organic horizons (L, F, H, and O)	0.43	39% 30	51% 40	12% 9	1% 1	

Percentages represent the percent of students that selected that option; numbers below percentages represent the number of students that selected that option

Table 3.8 – Factor Four, student learning preferences in accessing materials

Statement	Loading	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I found the videos to be the most useful medium for learning about the forest floor	**0.63**	24% 20	42% 34	21% 17	15% 12	
While working on the forest floor lab and assignment, I preferred learning from reading text rather than watching video clips	**0.62**	5% 4	23% 19	33% 27	32% 26	9.8% 8
I found videos and graphics to be more effective than plain text in learning about the forest floor	**0.59**	35% 29	43% 35	22% 18	4% 3	
Learning with the aide of the website was preferable to using a textbook or lecture notes	0.31	23% 18	47% 37	26% 20	4% 3	1.3% 1

Percentages represent the percent of students that selected that option; numbers below percentages represent the number of students that selected that option

4 General Conclusions

4.1. Summary of Study Findings

As soils are receiving increasing recognition for the ecosystem services they provide – food, clean water, climate change mitigation – the question of how to position soil science within the purview of potential students arises. Current undergraduate students want collaborative, active experiences of the concepts they are learning (Bekerbrede et al. 2011) and access to multimedia and online resources (Mohanna 2007) that reflect how they access information outside of the classroom. A blended learning approach provides the opportunity to combine hands-on, collaborative experience on campus with online learning resources that give students, with their varied range of learning styles and backgrounds, greater control over how they access materials.

A pilot study was undertaken at Simon Fraser University (SFU) to identify and rectify issues with the Forest Floor website and videos, to gain initial insights into the students' reactions to the implementation of the blended learning method, and to conduct preliminary principal component analysis (PCA) of the survey instrument. The 19 participants in the pilot study were students in an upper-level soil science course focused on forest soils. Their laboratory involved an introduction that included viewing all of the forest floor videos. Five components were interpreted based on the survey responses: satisfaction with website and videos, negatively worded statements, success of presentation of concepts and self-assessment of learning, preferences in accessing materials, and perception of the importance of the forest floor. The primary themes in the interviews were the ability to repetitively view videos and the ability of the forest floor website to meet the learning needs of a variety of students.

The primary study included development and evaluation of a web-based, multimedia resources and campus-based laboratory activities. These blended learning activities were developed for a lower-level, undergraduate soil science course. Development of the website involved collaboration of a multidisciplinary team of soil, multimedia, web and education experts. The content of the Forest Floor resource includes: videos, tutorial, text, definitions, graphics, animations, photos and references. The forest floor laboratory consisted of an introduction to key forest floor concepts, viewing of supporting videos, an explanation of the laboratory tasks, hands-on descriptions of forest floor samples and a laboratory assignment to be completed with the assistance of the forest floor website.

The survey instrument used for the Introduction to Soil Science course was created to assess students' perception of their learning and learning experiences, rather than assessing how much students learned or comparing student learning within the blended learning approach to other teaching methods. Survey items (Appendix IV) were created to assess to what extent our approach met the learning and experiential objectives presented above.

The five factors selected accounted for a total of 46% of variability. Reliability was determined using Chronbach's Alpha, which was found to be 0.903 for the survey instrument as a whole and above 0.6 for all five of the individual factors. The factors were interpreted based on commonalities between the items that loaded in each, previous pedagogical research and participant comments in interviews. Factor 1 was interpreted to reflect respondents' satisfaction with the educational resource as a learning enhancement. Factor 2 was interpreted to reflect the success of presentation of concepts using the blended learning method. Factor 3 was interpreted to reflect student self-assessment of learning. Factor 4 was interpreted to reflect student learning preferences in accessing materials. Factor 5 was interpreted to reflect the usability of the educational resource.

Student responses suggest that the website was effective and the students appreciated being able to use the Forest Floor educational resource, with 95% of respondents selecting agree or strongly agree to the statement, "having access to the Forest Floor website while working on the lab assignment helped me to learn about the forest floor." Some respondents had difficulty with navigating the educational resource, as 23% of respondents selected agree or strongly agree to the statement, "I found it difficult to find the specific information I was searching for on the website." Students also found the in-class portion of the forest floor activities important and 79% selected agree or strongly agree to the statement, "describing the forest floor samples in the laboratory was essential to my understanding of the properties of the different organic horizons," and 81% selected agree or strongly agree to the statement, "I was able to relate the information in the videos and on the website to what we were seeing in our sample in the lab."

According to the survey responses the stated learning objectives of our study were met for the majority of students, with 90% of respondents selecting agree or strongly agree to the statement, "The forest floor lab and website effectively introduced me to the properties of organic horizons (L, F, H, and O)," and 86% of respondents selected agree or strongly agree to the statement, "The forest floor lab and website effectively introduced me to the humus form orders (mor, moder and mull." To the statement, "I believe that what I learned from the forest floor lab and assignment is important knowledge for forest management," 76% of respondents selected agree or strongly agree.

There was variation in the way students utilized the Forest Floor educational resource. To the statement, "I found the videos to be the most useful medium for learning about the forest floor," 66% selected agree or strongly agree, while 28% selected agree or strongly agree to the statement, "while working on the forest floor lab and assignment, I preferred learning from reading text rather than watching video clips."

4.2 Advantages and Limitations of Blended Learning Approach

4.2.1 Advantages

Using a blended learning model was effective in its provision of both the online component, reflecting students increasing use of the Internet and associated technologies (Jones et al. 2010), and a collaborative, hands-on classroom experience that reflects the learning preferences of many contemporary students (Bekerbrede et al. 2011). Compared to classroom-based learning or online learning alone, a blended learning approach can improve student satisfaction and grades (Castle and McGuire 2010; Cavanagh 2011). Participants in our group interviews noted how it was necessary to use the forest floor vocabulary and build consensus through discussion within their groups and make connections between what they saw in the videos and their own samples that they have examined in the campus-based activity. Discussion between peers gives students deeper insights into the material they are learning (Udovic 1998) and a sense of engagement with one another (Collopy and Arnold 2009). The importance of the hands-on aspect of the in-class activities was noted by interview participants in our study. One student said, "Once you pull stuff apart you kind of realize, that's what the definition means," and another explained that learning hands-on was "more fun."

The blended learning model allows students to connect what they are learning in and out of the classroom as they apply their learning (Collopy and Anrold 2009). According to student responses during the interviews, the Forest Floor videos were appreciated for giving students a more visual experience compared to traditional lectures, providing the opportunity for repetitive reviewing of material and catering to different learning styles. Students value the ability to choose between different learning mechanisms to best suit their learning needs, and appreciate the flexibility in time and place allowed with online learning (Mitchell and Forer 2010). Drawing on constructivist learning theory, blended learning gives students more control over what material they access and at what pace they review material – allowing them to concentrate on material they find difficult and move quickly through material they understand easily (Cook 2007). The Forest Floor educational resource allowed students to expand upon what they learned in the laboratory at their own pace and in their own way, search for information, make discoveries and build their knowledge (Chumley-Jones et al. 2002).

Providing materials online can help to reinforce learning by allowing students to repeatedly review content (Hoffman and Ritchie, 1997; Moore and Gerrard, 2002; Polsani 2003), and learning soil classification requires such repetitive review (Krzic et al. 2013). This was supported by student comments in group interviews conducted in our study; one student said, "I watched the videos again while I was doing the lab report. It really helped seeing it before, then doing [the sample description], then [seeing it] after." Variety in the presentation of information, including video, tutorials, text, definitions, graphics, animations photographs and references, can help maintain student interest and cater to a variety of learning styles as students choose how they access materials (Hoffman and Ritchie, 1997; Moore and Gerrard, 2002; Polsani, 2003; Cox and Su, 2004). Most students utilized some combination of the videos and text on the Forest Floor educational resource, as one student explained, “The reading was more in depth than the videos, so after I watched the videos, if that wasn’t enough then I could read to supplement that.” Many students in group interviews noted the advantages of having videos compared to plain text. One student spoke about the videos providing more relevance by relating the samples back to the forest and how they were a more efficient use of time compared to traditional lectures. Another described the importance of visuals in learning the topic, “Often I find when I read things, I have to read it at least a few times for me to be able to come up with a visualization… When it’s a video, you can see that first hand.” A final advantage of the blended learning model is that, with declining resources in postsecondary education, supporting course content with online technologies has the potential to reduce pressure on instructors and institutions (Bates 2000) while providing a platform to incrementally build on over time.

4.2.2 Limitations

Development of the Forest Floor educational resource and campus-based activities took a significant investment of time and cost $64,000 to create, $44,000 was funded through UBC’s Flexible Learning Fund with an additional $20,000 as in-kind contributions. It took 1,400 person hours over 18 months to conceptualize, develop and beta test.

While students generally regarded learning collaboratively within groups positively, there were some negative comments regarding group sizes, dominance of particular group members during discussions and a lack of participation on the part of other group members. Students were encouraged to work in groups of five, however, one participant in the focus group discussions stated that their initial group of five was too large, “when there are five hands in one sample it doesn’t really work. Afterwards, we split up and it was a lot easier.” Other participants described their group of four as the “perfect” number. Navigation of the educational resource was an issue for some students. To the statement, “I found navigation of the website to be self-explanatory,” 9% of students selected disagree. We also received comments that the menus on the Forest Floor educational resource were not easy to use, that it was difficult to find things on the website and that some information was not where a student expected it to be. Although these complaints are important to consider, it has been shown that complexity in the layout of a website is important in encouraging students to explore and build their own knowledge and improves learning outcomes. Furthermore, it has been shown that students who struggled solving problems in the absence of direct support of educators did better solving complex problems in post-tests (Kapur and Bielaczyz 2012).

Another issue brought up by students was our decision to have students watch the Forest Floor videos at the beginning of their campus-based activities, rather than ask them to review the videos prior to the laboratory. If students were required to review the material beforehand, they could potentially be more prepared for the campus-based activities as well as having more time to complete their forest floor descriptions and classifications.

4.3 Potential Uses of the Study in the Future

The Forest Floor educational resource can be used by instructors of soil science, forestry, or other natural resource courses to introduce students to the organic horizons, humus forms and their properties. It also serves as an example for science instructors wishing to develop learning materials online or produce videos. The ubiquity of the Internet makes it ever easier to present information using varied media online. Virtual field trips provide the opportunity, not only to connect students visually to the entities and environments they are learning about, but to preserve the knowledge of experts in the field. The ease of updating online material, the possibility to adapt websites to emerging technologies, and the ability to create mobile experiences such as the forest floor quest, make moving into the future with educational websites possible.

Through exploratory factor analysis (EFA), we interpreted five factors within students' responses to our survey instrument. This constituted a blend of qualitative and quantitative data used to inform the interpretations of the factors. These factors have the potential to be verified through confirmatory factor analysis (CFA) in similar studies using blended learning in hands on laboratories. Our survey instrument, having a high reliability, can serve as an example to be adapted for such studies. Essentially, items regarding desired learning outcomes could be changed to reflect the desired learning outcomes of other laboratories. The highest loading items are most relevant to that factor and should be selected preferentially for any future research. Furthermore, it is necessary to keep in mind that smaller sample sizes require fewer items.

To those wishing to develop online and multimedia resources and implement blended learning activities, the following suggestions might be relevant.

- Identify learning outcomes to ensure that the methodology is compatible with the material being taught and research contemporary pedagogical theory to understand student learning preferences.

- Include experts in the field of study, multimedia and web development and education. This will ensure that multimedia and online components are of high quality and that the pedagogical foundation is sound. An added benefit to including a variety of people in the development process is that their different perspectives will better represent the varied knowledge and learning preferences of the desired audience.

- Expect to invest a significant amount of time to complete the project. Conceptualization, development and testing multimedia educational resources and conducting and evaluating blended learning activities each take time, involving meeting with everyone involved, reviewing and editing material, and troubleshooting, etc.

- Keep videos short and to the point, and break up and reduce text as much as possible to help to maintain student interest and improve ease of information retrieval.

- Ensure student collaboration and active learning through small peer groups and encouraging discussion during campus-based activities.

- Determine the best time for students to explore the online and multimedia components of the blended learning activities. Depending on the topic and the in-class activities, consider exposing students to the material either before, during or after the activities, or repeatedly to reinforce what they are learning.

For those wishing to create a survey instrument to be used in factor analysis and conduct EFA or CFA of responses to a blended learning experience, the following suggestions should be considered.

- Consider potential factors in advance and develop survey items (questions) based on those factors. Factors may include student motivations, meeting learning outcomes, student learning preferences, etc. Alternatively, if performing confirmatory factor analysis, factors should be based on those interpreted through previous, similar research.

- Create at least three items based on each potential factor, as an acceptable factor should have at least three items loading. A strong factor will have at least five items loading. The number of factors should be balanced by the number of respondents, with a suggested ratio often being 5:1, depending on the data (McCallum et al. 1999; Costello and Osborne 2005).

Attracting students to soil science is increasingly important in the face of global environmental challenges. It is up to educators to make curriculum relevant and exciting, while creating a learning environment that suits today's students. A blended learning approach has the potential to achieve this. Students participating in group interviews in our study appreciated the Forest Floor videos as a window into the forest ecosystem and for providing the opportunity for repetitive review. Regarding the in-class activities, they considered that group discussion, using the forest floor vocabulary with their peers, making connections between the videos and their hands-on experience with the samples were all beneficial to their learning. During the interviews many of the students were aware of their different learning preferences and valued having exposure to the material in a variety of formats. In response to the written comments portion of the online survey, one student wrote, "I think I enjoyed this lab the most. It was not only educational but fun. It was also easy to understand and straightforward." Hopefully, this student and any others sharing similar sentiments will be encouraged to continue learning about soil and look forward to doing so with enthusiasm. I hope that other instructors will contemplate adapting their curriculum to better suit the current learning climate in which their students are living, one of greater connectivity and unlimited information through web-based educational resources, by embracing teaching methods that support more active ways of learning. I also encourage those educators who decide to blend multimedia into their teaching methods to adapt the factors we have interpreted here, in order to assess the experiences of their students.

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APPENDIX I: Humus Form Description Sheet Pilot Study

HUMUS FORM PROFILE DESCRIPTION
(B.C. Ministry of Forests, 1980)

Project I.D. ______ **Plot No.** ______
Surveyor ______ **Page** ____ **of** ____

Horizon Designation	Lab. No.	Depth	Thickness Min. / Boundary Dist.	Thickness Max. / Boundary Form	Moisture Status	Colour Aspect	Colour Mun. Not.	Structure	Consistence	Character	Texture	Roots Ab.	Roots Size	Roots Or.	Roots Distr.

Horizon Designation	Non-conforming Materials Kind	Non-conforming Materials Distr.	Non-conforming Materials Size	Non-conforming Materials Ab.	Soil Biota Flora	Soil Biota Fauna	Origin of Material	Reaction (pH)	Bulk Density	Notes	Cross-section Drawing

Humus Form Taxon

R.D. PENHALL LTD MADE IN VANCOUVER CANADA DUKSBAK WATERPROOF

APPENDIX II: Primary Study Data Collection Sheet

Horizon	Depth (cm)	Forest Floor Structure	Forest Floor Consistence	Roots		
				Abundance	Size	Orientation

Flora Observed:	Fauna Observed:	Diagnostic Horizon:	Humus Form Order:

Notes:

APPENDIX III: Forest Floor Lab Assignment

1. Review your Data sheet to answer the following:
   a. Explain how you determined the diagnostic horizon and humus form order of your sample. What do your findings tell you about the type of decomposition that is occurring in the forest floor? (What type(s) of decomposers are dominant?)

   b. What type of vegetation was the primary source of organic matter in your sample? Identify some properties of this litter compared to other types of litter (C:N ratio, pH, lignin content – See "***In the Ecosystem***" video)

[4 points]

2. Watch the "***How to Sample***" video clip posted on the Description page (under Classification) of the "Forest Floor" website.
   a. What soil property can be determined by drying and weighing a forest floor sample in an oven?

   b. What can be estimated about a landscape by measuring this property? What else needs to be measured to determine this?

[3 points]

3. On the Description page of the "Forest Floor" website, you can also learn what is meant by **Non-Conforming Materials**. Often a large percentage of the forest floor can be made up of non-conforming materials. What are some examples of these?

[1 point]

4. On the Humus Forms page (under Definitions) "Forest Floor" website, watch "***In the Ecosystem***" video clip. What is unusual about the second site mentioned in the video, given the coniferous trees? What has likely caused this?

[2 points]

5. Under what conditions would you expect to find the following horizons:
   a. O
   b. Fa
   c. Thick Ah

   Briefly explain your answers

[3 points]

6. Explain the difference between the Forest Floor and a Humus Form. Under what conditions and forest types would you expect the thickest forest floors to form? The thinnest? Briefly Explain.

[3 points]

7. Identify the organic horizon according to the following descriptions:
   a. Dark colour, few mineral particles apparent, greasy.
   b. The organic matter is held together strongly, roots are apparent in the horizon, some yellow fuzzy stuff is visible.
   c. Brownish needles from a tree.
   d. Dark colour, mineral grains apparent, granular structure.

[2 points]

Attachment:
Data Collection Sheet

[3 points]

Total for lab 6 assignment [21 points]

BONUS: Complete the Forest Floor Quest at the UBC Farm!

[up to 5 points]

2 bonus points for completing the quest and getting a mark between 1 and 46
3 points for quest mark of 47-62
5 points for quest mark of 63-79

You may attempt the quest as many times as you like in order to get full number of points.

APPENDIX IV: INITIAL FOREST FLOOR SURVEY ITEMS

The forest floor lab and website effectively introduced me to the properties of organic horizons (L, F, H, and O).

After completing the forest floor lab and assignment with the help of the website, I feel confident differentiating between the organic horizons (L, F, H and O).

After completing the forest floor lab and assignment with the help of the website, the properties of different organic horizons are still not clear to me.

The forest floor lab and website effectively introduced me to the humus form orders (mor, moder and mull).

After completing the forest floor lab and assignment with the help of the website, I can tell the difference between the humus form orders (mor, moder and mull).

The forest floor lab and website taught me the differences between the decomposer communities in the different humus form orders.

After completing the forest floor lab and assignment with the help of the website, I still feel unsure about the differences between the humus form orders.

The forest floor lab and website did not help me to feel confident in differentiating between the humus form orders.

The forest floor lab and website effectively communicated the importance of the Forest Floor in forest ecosystems and soils.

After completing the forest floor lab and assignment with the help of the website, I understand the impacts of the forest floor on soil properties.

The forest floor lab and website effectively explained the chemical properties of different types of litter to me.

After completing the forest floor lab and assignment with the help of the website, I do not feel comfortable explaining ways the forest floor influences soil properties or impacts the forest ecosystem.

I found the videos to be the most useful medium for learning about the forest floor.

I found videos and graphics to be more effective than plain text in learning about the forest floor.

While working on the forest floor lab and assignment, I preferred learning from reading text rather than watching video clips.

I liked having access to the forest floor website while working on the lab assignment.

Having access to the forest floor website while working on the lab assignment helped me to learn about the forest floor.

I did not find the forest floor website helpful in learning about the forest floor.

I found having access to skeleton notes while reviewing the videos helped me to identify important points.

Graphics and images on the website and in videos did not improve my understanding of the forest floor.

I thought too much information was presented in the forest floor videos.

I think that the forest floor videos did not provide enough information.

Graphics and images on the website and in videos helped me to visualize key elements of the forest floor.

Combining multimedia and web-based elements with in-class learning was beneficial to my learning.

I could have learned the material equally effectively from the multimedia and web-based elements alone.

I could have learned the material equally effectively without the use of multimedia and web-based elements.

I found that the multimedia elements presented on the forest floor website reinforced what I learned during the forest floor lab.

I think having access to the information on the website outside of the classroom allowed me to effectively reinforce and expand my learning about the forest floor.

I found navigation of the website to be self-explanatory.

I found it difficult to fine the specific information I was searching for on the website.

I thought that the website was esthetically pleasing overall.

Having access to the website at any time and place was helpful for learning forest floor concepts.

Using the website to learn the material made me feel isolated from other students and/or my instructor.

Learning with the aide of the website was preferable to using a textbook or lecture notes.

I thought that the in-class portion of the lab was complemented by the addition of the forest floor website.

Describing the forest floor samples in the laboratory was essential to my understanding of the properties of the different organic horizons.

Describing and classifying the humus form in the laboratory was necessary for me to understand the properties of the different humus forms.

I was able to relate the information in the videos and on the website to what we were seeing in our sample in the lab.

I found it difficult to make connections between the information presented in the forest floor videos and on the website to what we saw in our lab samples.

I believe that what I learned from the forest floor lab and assignment is important knowledge for forest management.

APPENDIX V: Recruitment Document for Pilot Study

Forest Floor Tool Survey and Focus Group Recruitment

Dear GEOG 417 students,

You are invited to participate in an online survey and focus groups to evaluate an educational web-based tool entitled “Forest Floor Tool”. You are being invited to take part in this research study because our records indicate that you are currently registered in GEOG 417 for 2014/15 academic year. We want to learn more about how to make engaging educational tools that immerse students in systems that are typically hard-to-see, such as the soil environment. We are inviting people like you who are taking GEOG 417 this term to help us improve the educational elements of web-based tools.

The upcoming forest floor description and humus form classification laboratory section of the GOEG 417 – Advanced Soil Science course is part of Darrell Hoffman’s MSc research project that is supervised by Dr. Maja Krzic. We will greatly appreciate your feedback on the upcoming Forest Floor Lab. During the lab we will ask you to review material from a website (“The Forest Floor Tool”) designed specifically to help students in completing the lab. The tool provides relevant information (supplementary to the lab manual) needed to complete the lab assignment.

After you complete the Forest Floor lab and receive mark and feedback on your lab assignment, we will ask you to complete an online survey about your experiences with the “Forest Floor Tool”. Your feedback will be collected anonymously and will be used to evaluate the effectiveness of the tool in communicating the learning objectives of the Forest Floor lab . Your participation in the online survey will be essential for Forest Floor lab and tool improvements and refinements

You will be asked to provide your consent before you will be able to access the online survey. The participation in the online survey is voluntary. All students who take part in the online survey will be entered into a random draw for a $20 gift card to Starbucks. Each student will receive a random code upon completion of the survey. The student with a winning code will receive their gift card from their course instructor. This will further maintain your anonymity as a participant in the research study.

In addition to the online survey, we will also carry out 20-minute focus groups to discuss students responses to the online survey regarding effectiveness of the Forest Floor Tool.

At the end of the online survey you will be asked if you wish to participate in a focus group discussion. You will be able to forward your name and email to Darrell Hoffman (Note: this will not be linked to your survey responses), and he will follow up with you to arrange times for the focus group discussion sessions.

It will be necessary to sign a consent form prior to participating in focus group discussions. There will be another random draw for a $20 gift card to Starbucks. The draw will again occur anonymously.

If you are interested in participating in this study, please contact Darrell for more information. A brief description of the study, including time to ask questions or express concerns, will be provided in the GEOG 417 class. Your decision whether or not to participate in this study will remain confidential and have no effect on individual assessment or grading.

Thank you for taking the time to participate in this study.
Best regards,

Darrell Hoffman
MSc. Candidate in Soil Science
University of British Columbia

APPENDIX VI: Recruitment Document for Primary Study

Forest Floor Tool Survey and Focus Group Recruitment

Dear APBI 200 students,

You are invited to participate in an online survey and focus groups to evaluate an educational web-based tool entitled "Forest Floor Tool". You are being invited to take part in this research study because our records indicate that you are currently registered in APBI 200 for 2014/15 academic year. We want to learn more about how to make engaging educational tools that immerse students in systems that are typically hard-to-see, such as the soil environment. We are inviting people like you who are taking APBI 200 this term to help us improve the educational elements of web-based tools.

The upcoming forest floor description and humus form classification laboratory section of the APBI 200 – Introduction to Soil Science course is part of Darrell Hoffman's MSc research project that is supervised by Dr. Maja Krzic. We will greatly appreciate your feedback on the upcoming Forest Floor Lab. During the lab we will ask you to review material from a website ("The Forest Floor Tool") designed specifically to help students in completing the lab. The tool provides relevant information (supplementary to the lab manual) needed to complete the lab assignment.

After you complete the Forest Floor lab and receive mark and feedback on your lab assignment, we will ask you to complete an online survey about your experiences with the "Forest Floor Tool". Your feedback will be collected anonymously and will be used to evaluate the effectiveness of the tool in communicating the learning objectives of the Forest Floor lab. Your participation in the online survey will be essential for Forest Floor lab and tool improvements and refinements

You will be asked to provide your consent before you will be able to access the online survey. The participation in the online survey is voluntary. All students who take part in the online survey will be entered into a random draw for ten $20 gift cards to Starbucks. Each student will receive a random code upon completion of the survey, 10 codes will be randomly selected and sent to all APBI 200 students by email. Any student with a winning code will be able to pick up their gift card from student services (MCML 344). This will further maintain your anonymity as a participant in the research study.

In addition to the online survey, we will also carry out 20-minute focus groups to discuss students responses to the online survey regarding effectiveness of the Forest Floor Tool. At the end of the online survey you will be asked if you wish to participate in a focus group discussion. You will be able to forward your name and email to Darrell Hoffman (Note: this will not be linked to your survey responses), and he will follow up with you to arrange times for the focus group discussion sessions.

It will be necessary to sign a consent form prior to participating in focus group discussions. There will be another random draw for ten $20 gift cards to Starbucks. The draw will again occur anonymously through a third party.

If you are interested in participating in this study, please contact Darrell for more information. A brief description of the study, including time to ask questions or express concerns, will be provided in the APBI 200 class. Your decision whether or not to participate in this study will remain confidential and have no effect on individual assessment or grading.

Thank you for taking the time to consider improving education at UBC by participating in this study.
Best regards,

Darrell Hoffman
MSc. Candidate in Soil Science
University of British Columbia

APPENDIX VII: Consent Form for Pilot Study

Evaluation of the web-based Forest Floor Tool
Consent form for GEOG 417 students

Dear GEOG 417 students,

We are arranging 20-minute focus groups to discuss your experiences using the Forest Floor Tool. We will greatly appreciate your participation in these discussions, so that we can make improvements to the tool, as well as make recommendations for future projects.

If you have any questions about this research study before signing this consent form, please read the information presented below. If you have further questions, email

Objective:
To determine how useful was the Forest Floor Tool in helping students complete a forest floor description and humus form classification and learn about the importance of the forest floor in forest ecosystems.

Researchers:
Data will be collected by Dr. Maja Krzic and Darrell Hoffman, who will include the results in his Masters thesis.

Purpose:
This study aims to understand the experiences of students in a soil science using the Forest Floor online educational tool. You are being invited to participate in this study as a student in GEOG 417 in term 2 of 2014/15 academic year. This research will be used in a Masters thesis report, as part of a graduate degree at the University of British Columbia. The final thesis report will be a public document. An abridged version of the thesis will be developed into a manuscript that will be submitted to an academic journal for publication.

Study Procedures:
The study will consist of online survey and additional focus group discussion. The focus groups will take place after the completion of the lab on forest floor and after you have received your marks for that lab's assignment. The focus groups will address the following topics:

- Expectations for the forest floor laboratory section

- Impressions and experiences with Forest Floor online educational tool
- Efficacy in addressing forest floor laboratory section learning outcome.

During the focus group, participants may be asked about experiences with teaching and learning methods, soil science, as well as evaluation. Statements and discussions that arise from these discussions may be included in the co-investigator's final thesis report or related materials (e.g. conference presentations, manuscripts).

Maintaining Anonymity:
Your name will not be linked to your responses. The purpose of the focus group interviews is to get more insight into your experiences with the tool; we will not be linking the data to any information that could identify you as a participant. Only Darrell Hoffman and Dr. Maja Krzic will have access to the data.

Audio Recording:
Darrell Hoffman will be recording audio of focus group sessions on his computer. He will make transcripts of discussions from the audio files. All data will be contained in password-protected files and stored in safe locations accessible only to the researchers.

Choosing NOT to Participate:
You are free to choose not to participate in a focus group session at any time. Even if you sign this consent form, you are not compelled to participate. It is important to know that we can not remove your data once it is collected as it will not be linked to anything that can identify you.

Risks:
Participation in this study process poses minimal risk. While none of the questions address sensitive subject area, it is possible that discussing classroom experiences may be unpleasant for some students. If you are uncomfortable with any of the questions, please let the researchers know and keep in mind that you do not have to answer any questions if you do not want to.

Anonymized student statements may be used for publications, reports or conference presentations. The risk associated with the focus group will be similar to what students experience in group-work throughout the semester in GEOG 417. Participants who elect to participate in the focus group risk being exposed to the opinions of their peers in a face-to-face environment. Focus group participants may choose to refrain from comment on any topic they are uncomfortable discussing.

Benefits:
Participation in this study has the potential to improve the quality of the soil science curriculum for future students by facilitating new knowledge about student experiences in a modified learning environment. The results of this study may also benefit the greater academic community for other science instructors. In addition, participants may benefit

from the reflective process involved in interviews. Knowing more about how you learn can be beneficial. Talking about how you used the Forest Floor Tool, what aspects of it you liked or did not like, can help you to understand more about how you like to learn.

Measures to maintain confidentiality:

The identities of all participants in this study will remain confidential. A password protected coding system will be used to identify all participants in the focus groups. All data, including information connected to participants' names or other identifying characteristics, will be encrypted and password protected on the co-investigator's personal computer that is kept in a locked office at the University of British Columbia. Focus group participants are requested to observe confidentiality with respect to their group member's responses; however, we cannot control what participants do with the information discussed.

The final thesis and manuscript may contain statements obtained during the course. Participant's names will not be disclosed in relation to any statements in association with the course for the final thesis report, presentations, or related materials.

Contact for information about the study:
If you have any questions or would like further information with respect to this study, please contact Darrell Hoffman (co-investigator) at or Dr. Maja Krzic (principal investigator) at

Contact for concerns about the rights of research subjects:
If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at or if long distance e-mail or call toll free.

Participant consent and signature:
We greatly appreciate your help with this research. By signing this consent form, you are agreeing to have anything said during focus group interviews recorded and used for research into the effectiveness of the Forest Floor Tool. Thank you!

By signing this consent form, I ______________________________________ agree to have my responses recorded and used for research into the effectiveness of the Forest Floor Tool.

Signature: ______________________________ Date: __________________________

____
Printed Name of the Participant signing above

APPENDIX VIII: Consent Form for Primary Study

Evaluation of the web-based Forest Floor Tool
Consent form for APBI 200 students

Dear APBI 200 students,

We are arranging 20-minute focus groups to discuss your experiences using the Forest Floor Tool. We will greatly appreciate your participation in these discussions, so that we can make improvements to the tool, as well as make recommendations for future projects.

If you have any questions about this research study before signing this consent form, please read the information presented below. If you have further questions, email.

Objective:
To determine how useful was the Forest Floor Tool in helping students complete a forest floor description and humus form classification and learn about the importance of the forest floor in forest ecosystems.

Researchers:
Data will be collected by Dr. Maja Krzic and Darrell Hoffman, who will include the results in his Masters thesis.

Purpose:
This study aims to understand the experiences of students in APBI 200 course in using the Forest Floor online educational tool. You are being invited to participate in this study as a student in this course in term 2 of 2014/15 academic year. This research will be used in a Masters thesis report, as part of a graduate degree at the University of British Columbia. The final thesis report will be a public document. An abridged version of the thesis will be developed into a manuscript that will be submitted to an academic journal for publication.

Study Procedures:
The study will consist of online survey and additional focus group discussion. The focus groups will take place after the completion of the lab on forest floor and after you have received your marks for that lab's assignment. The focus groups will address the following topics:

- Expectations for the forest floor laboratory section

- Impressions and experiences with Forest Floor online educational tool
- Efficacy in addressing forest floor laboratory section learning outcome.

During the focus group, participants may be asked about experiences with teaching and learning methods, soil science, as well as evaluation. Statements and discussions that arise from these discussions may be included in the co-investigator's final thesis report or related materials (e.g. conference presentations, manuscripts).

Maintaining Anonymity:
Your name will not be linked to your responses. The purpose of the focus group interviews is to get more insight into your experiences with the tool; we will not be linking the data to any information that could identify you as a participant. Only Darrell Hoffman and Dr. Maja Krzic will have access to the data.

Audio Recording:
Darrell Hoffman will be recording audio of focus group sessions on his computer. He will make transcripts of discussions from the audio files. All data will be contained in password-protected files and stored in safe locations accessible only to the researchers.

Choosing NOT to Participate:
You are free to choose not to participate in a focus group session at any time. Even if you sign this consent form, you are not compelled to participate. It is important to know that we can not remove your data once it is collected as it will not be linked to anything that can identify you.

Risks:
Darrell Hoffman, a Teaching Assistant (TA) in the APBI 200 course will be leading focus group discussions. Participation in this study process poses minimal risk. While none of the questions address sensitive subject area, it is possible that discussing classroom experiences may be unpleasant for some students. If you are uncomfortable with any of the questions, please let the researchers know and keep in mind that you do not have to answer any questions if you do not want to.

Anonymized student statements may be used for publications, reports or conference presentations. The risk associated with the focus group will be similar to what students experience in group work throughout the semester in APBI 200. Participants who elect to participate in the focus group risk being exposed to the opinions of their peers in a face-to-face environment. Focus group participants may choose to refrain from comment on any topic they are uncomfortable discussing.

Benefits:
Participation in this study has the potential to improve the quality of the APBI 200 course for future students by facilitating new knowledge about student experiences in a modified learning environment. The results of this study may also benefit the greater academic community for other science instructors. In addition, participants may benefit from the

reflective process involved in interviews. Knowing more about how you learn can be beneficial. Talking about how you used the Forest Floor Tool, what aspects of it you liked or did not like, can help you to understand more about how you like to learn.

Measures to maintain confidentiality:

The identities of all participants in this study will remain confidential. A password protected coding system will be used to identify all participants in the focus groups. All data, including information connected to participants' names or other identifying characteristics, will be encrypted and password protected on the co-investigator's personal computer that is kept in a locked office at the University of British Columbia. Focus group participants are requested to observe confidentiality with respect to their group member's responses; however, we cannot control what participants do with the information discussed.

The final thesis and manuscript may contain statements obtained during the course. Participant's names will not be disclosed in relation to any statements in association with the course for the final thesis report, presentations, or related materials.

Contact for information about the study:
If you have any questions or would like further information with respect to this study, please contact Darrell Hoffman (co-investigator) at or Dr. Maja Krzic (principal investigator) at .

Contact for concerns about the rights of research subjects:
If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at or if long distance e-mail or call toll free

Participant consent and signature:
We greatly appreciate your help with this research. By signing this consent form, you are agreeing to have anything said during focus group interviews recorded and used for research into the effectiveness of the Forest Floor Tool. Thank you!

By signing this consent form, I ____ agree to have my responses recorded and used for research into the effectiveness of the Forest Floor Tool.

Signature: _______________________________ Date: ___________________________

____
Printed Name of the Participant signing above

APPENDIX IX: Components from Pilot Study

Component 1

Statement	*Loading*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Combining multimedia and web-based elements with in-class learning was beneficial to my learning	*.870*	*47.4%* *9*	*31.6%* *6*	*10.5%* *2*	*10.5%* *2*	
Having access to the website at any time and place was helpful for learning forest floor concepts	*.853*	*63.2%* *12*	*26.3%* *5*		*10.5%* *2*	
Graphics and images on the website and in videos helped me to visualize key elements of the forest floor	*.817*	*52.6%* *10*	*36.8%* *7*		*10.5%* *2*	
I think having access to the information on the website outside of the classroom allowed me to effectively reinforce and expand my learning about the forest floor	*.798*	*52.6%* *10*	*36.8%* *7*	*5.3%* *1*	*5.3%* *1*	
I found that the multimedia elements presented on the forest floor website reinforced what I learned during the forest floor lab	*.769*	*42.1%* *8*	*42.1%* *9*	*10.5%* *2*		
Having access to the forest floor website while working on the lab assignment helped me to learn about the forest floor	*.739*	*52.6%* *10*	*31.6%* *6*	*5.3%* *1*	*5.3%* *1*	*5.3%* *1*
The forest floor lab and website effectively introduced me to the properties of organic horizons (L, F, H, and O)	*.733*	*42.1%* *8*	*52.6%* *10*		*5.3%* *1*	
Learning with the aide of the website was preferable to using a textbook or lecture notes	*.730*	*31.6%* *6*	*21.1%* *4*	*36.8%* *7*	*5.3%* *1*	*5.3%* *1*
I liked having access to the forest floor website while working on the lab assignment	*.728*	*63.2%* *12*	*15.5%* *4*	*10.5%* *2*	*5.3%* *1*	
I did not find the forest floor website helpful in learning about the forest floor	*.727*	*5.3%* *1*	*5.3%* *1*	*5.3%* *1*	*31.6%* *6*	*52.6%* *10*

I thought that the in-class portion of the lab was complemented by the addition of the forest floor website	*.718*	*26.3% 5*	*47.4% 9*	*10.5% 2*	*15.8% 3*	
I thought that the website was esthetically pleasing overall	*.706*	*36.8 7*	*42.1% 8*	*15.5% 4*		
I could have learned the material equally effectively without the use of multimedia and web-based elements	*-.705*	*5.3% 1*	*15.8% 3*	*10.5% 2*	*57.9% 11*	*10.5% 2*
I found it difficult to find the specific information I was searching for on the website	*.697*	*5.3% 1*	*15.8% 3*	*15.8% 3*	*47.4% 9*	*15.8% 3*
Graphics and images on the website and in videos did not improve my understanding of the forest floor	*.554*		*10.5% 2*	*5.3% 1*	*31.6% 6*	*52.6% 10*
I could have learned the material equally effectively from the multimedia and web-based elements alone	*.544*	*15.8% 3*	*26.3% 5*	*26.3% 5*	*21.1% 4*	*10.5% 2*

Component 2

Statement	*Loading*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
After completing the forest floor lab and assignment with the help of the website, I still feel unsure about the differences between the humus form orders	*.796*		*5.3% 1*	*15.8% 3*	*47.4% 9*	*31.6% 6*
After completing the forest floor lab and assignment with the help of the website, the properties of different organic horizons are still not clear to me	*.784*		*10.5% 2*		*26.3% 5*	*63.2% 12*
Using the website to learn the material made me feel isolated from other students and/or my instructor	*.765*			*26.3% 5*	*42.1% 8*	*31.6% 6*
Describing the forest floor samples in the laboratory was essential to my understanding of the properties of the different organic horizons	*.654*	*42.1% 8*	*57.9% 11*			
I believe that what I learned from the forest floor lab and assignment is important knowledge for forest management	*.582*	*26.3% 5*	*73.7% 14*			

I think that the forest floor videos did not provide enough information	*.527*		*15.8%* *3*	*21.1%* *4*	*52.6%* *10*	*10.5%* *2*

Component 3

Statement	*Loading*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
After completing the forest floor lab and assignment with the help of the website, I feel confident differentiating between the organic horizons (L, F, H and O).	*.751*	*47.4%* *9*	*21.1%* *4*	*31.6%* *6*		
Describing and classifying the humus form in the laboratory was necessary for me to understand the properties of the different humus forms	*.683*	*47.4%* *9*	*47.4%* *9*	*5.3%* *1*		
I thought too much information was presented in the forest floor videos	*-.670*	*5.3%* *1*	*10.5%* *2*		*73.7%* *14*	*10.5%* *2*
I was able to relate the information in the videos and on the website to what we were seeing in our sample in the lab	*.617*	*26.3%* *5*	*57.9%* *11*	*15.8%* *3*		
The forest floor lab and website effectively explained the chemical properties of different types of litter to me	*.615*	*15.8%* *3*	*36.8%* *7*	*21.1%* *4*	*26.3%* *5*	
The forest floor lab and website taught me the differences between the decomposer communities in the different humus form orders	*.586*	*15.8%* *3*	*52.6%* *10*	*26.3%* *5*	*5.3%* *1*	
After completing the forest floor lab and assignment with the help of the website, I can tell the difference between the humus form orders (mor, moder and mull)	*.517*	*31.6%* *6*	*57.9%* *11*	*5.3%* *1*	*5.3%* *1*	

Component 4

Statement	*Loading*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
I found videos and graphics to be more effective than plain text in learning about the forest floor	*.830*	*47.4%* *9*	*21.1%* *4*	*15.8%* *3*	*15.8%* *3*	

I found the videos to be the most useful medium for learning about the forest floor	.804	36.8% 7	21.1% 4	26.3% 5	15.8% 3	
While working on the forest floor lab and assignment, I preferred learning from reading text rather than watching video clips	-.801	5.3% 1	31.6% 6	31.6% 6	26.3% 5	5.3% 1
I found it difficult to make connections between the information presented in the forest floor videos and on the website, and what we saw in our lab samples	.656		5.5% 1	15.8% 3	57.9% 11	21.1% 4

Component 5

Statement	*Loading*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
After completing the forest floor lab and assignment with the help of the website, I do not feel comfortable explaining ways the forest floor influences soil properties or impacts the forest ecosystem	*.800*	*47.4%* *9*	*21.1%* *4*	*31.6%* *6*		
I found navigation of the website to be straight-forward	*-.560*	*47.4%* *9*	*31.6%* *6*	*5.3%* *1*	*15.8%* *3*	
The forest floor lab and website effectively introduced me to the humus form orders (mor, moder and mull)	*.540*	*55.6%* *10*	*38.9%* *7*	*10.5%* *2*		
After completing the forest floor lab and assignment with the help of the website, I understand the impacts of the forest floor on soil properties	*.445*	*26.3%* *5*	*52.6%* *10*	*15.8%* *3*	*5.3%* *1*	
The forest floor lab and website effectively communicated the importance of the Forest Floor in forest ecosystems and soils	*.430*	*31.6%%* *6*	*42.1%* *8*	*15.8%* *3*	*10.5%* *2*	
I found having access to skeleton notes while reviewing the videos helped me to identify important points	*.419*	*21.1%* *4*	*52.6%* *10*	*15.8%* *3*	*5.3%* *1*	*5.3%* *1*

APPENDIX X: ANOVA and Tukey's HSD Tables

ANOVA Comparison of 1st Year and Remaining Year Mean Response

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.117	1	0.117	0.820	0.368
Within Groups	10.963	77	0.142		
Total	11.080	78			

ANOVA Comparing Course Lecture Section Mean Response

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.075	1	0.075	0.526	0.470
Within Groups	11.004	77	0.143		
Total	11.080	78			

ANOVA Comparing Laboratory Section Means

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.211	7	0.316	2.528	**.022**
Within Groups	8.869	71	0.125		
Total	11.080	78			

Tukey's HSD Comparing Laboratory Sections (Against Section 5)

Lab Section	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
1	-0.141	0.138	0.970	-0.573	0.291
2	-0.443	0.151	0.080	-0.914	0.028
3	-0.531	0.171	0.052	-1.065	0.003
4	-0.171	0.140	0.924	-0.609	0.267
6	-0.221	0.164	0.878	-0.734	0.292
7	-0.215	0.191	0.948	-0.811	0.380
8	0.017	0.179	1.000	-0.543	0.577