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Development of a web-enabled learning platform for geospatial laboratories: improving the undergraduate learning experience

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ABSTRACT

This paper describes a web-enabled learning platform providing remote access to geospatial software that extends the learning experience outside of the laboratory setting. The platform was piloted in two undergraduate courses, and includes a software server, a data server, and remote student users. The platform was designed to improve the quality of the learning experience and to increase student confidence and proficiency with software-based geospatial skills. Laboratory grades of students using the platform were significantly higher than those of students who did not use the platform, and survey responses reported that students overwhelmingly liked the convenience of the platform, which allowed them to work from any location.

Keywords: web-enabled learning platform; experiential learning; geospatial; remote laboratory

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Introduction

The increasing connectedness of our world has paved the way for the development of new educational technology being able to enhance traditional models of teaching and learning. Blended approaches to course instruction integrate a combination of traditional in-class lectures and online activities, thus blending two distinct learning modalities.[5] Other approaches utilize educational technology such as web-enabled assessments or teaching tools to enhance learning objectives. Geospatial course topics such as remote sensing, geographic information systems (GIS), and spatial analysis are intrinsically computer-based disciplines, and thus especially appropriate for adaptation to online modes of delivery. Already, an identified trend has been the replacement of traditional computer laboratories and local networks with alternate web-enabled arrangements in order to reflect the expansion of GIS and technology from single laboratories to multiple departments, schools, and colleges within a single institution (Sinton, 2012).

Online resources and tools have been demonstrated to facilitate the use of technology for students, and to enable collaborative and multidisciplinary research for faculty (Baker et al., 2015). Evidence-based research has shown that the use of technology in pedagogy has an overall positive impact on student learning (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011), while blended learning approaches, specifically, have been found to support meaningful student learning outcomes (Garrison & Kanuka, 2004), outperform traditional classroom instruction (Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014; Means, Toyama, Murphy, Bakia, & Jones, 2010), and increase overall student performance (Kamruzzaman, 2014). While lecture components are most frequently adapted to blended instructional methods (e.g., Clark, Monk, & Yool, 2007; Joyce, Boitshwarelo, Phinn, Hill, & Kelly, 2014), those courses with a laboratory component may also benefit from web- enabled enhancements. Traditional laboratory tutorials or practicums in the geospatial domain typically involve students working on software such as ArcGIS or ERDAS within the settings of a physical computer laboratory housed at the academic institution. Completion of graded laboratory assignments provides a quantitative measure of a student’s success and their ability to execute guided instructions; however, a deeper proficiency with these specialized programs is often lacking.

While students can easily reinforce lecture content by going over notes outside of class, and exploring concepts in further detail through extended reading or research, there is no such equivalent for furthering application-based proficiency when access to proprietary programs are limited. However, the ability of web-enabled technology to link students to remote laboratories outside of formal class time could potentially provide an avenue for deeper experiential learning by providing an adaptively flexible method of extending the learning process beyond the laboratory. Kolb's (1984) theory on experiential learning describes four stages of learning as concrete experience (doing), reflective observation (observing), abstract conceptualization (thinking), and active experimentation (planning or testing), each reflecting different learning styles of individual students. As an enhancement to traditional practicums, remote laboratories may offer a means for students not only to improve upon their laboratory grades, but also to address different components of the learning cycle, satisfy individual styles of learning, and build practical and lasting skills in geospatial analysis.

In this paper, we describe the development and assess the effectiveness of a web-enabled learning platform (WLP) designed to improve the quality of the learning experience for undergraduate students. The platform provides students with remote access to geospatial software from any location with Internet access and was developed to encourage self- directed exploration and to improve upon the traditional computer laboratory approach.

Background and objectives

The virtual laboratory platform we created targets students across the tri-campuses of the University of Toronto (UofT), Ontario, Canada. This project reflects our effort to respond to the growing demand for GIS education and to use technology to achieve academic excellence. The proposed platform provides students in GIS programs with unlimited access to costly software packages, large spatial datasets, and public workspace (files and folders). It enables students to conveniently and actively explore geospatial programs from anywhere using the Internet and their student account to log in. The platform is especially targeted for: (i) large geospatial courses for which current laboratory facilities cannot satisfy the demand; (ii) students who commute to campus and distance learners; and (iii) learners who are more comfortable working at a slower pace, or whose schedules do not fit with computer laboratory hours. Students with health issues or disabilities may also find this platform more attractive, as it can reduce some of the difficulties associated with traveling to, and working in, traditional learning environments (e.g., crowded space, distracting environment, time pressures, or social discomfort).

We piloted this WLP in two separate courses in the Department of Geography at the UofT Mississauga (UTM) campus across different learning environments and levels of complexity of material: GGR276, Spatial Data Analysis and Mapping, a second year course with an enrolment of 142 students; and GGR337, Environmental Remote Sensing, a third year course with an enrolment of 40 students. These courses were also selected because they are core courses and therefore a requirement in completing the GIS major program. Typically, at least half of the students in the second year GGR276 course enroll with some experience in GIS program usage. Students from the third year GGR337 course often have greater GIS experience, having completed earlier GIS program prerequisites, but less experience with remote sensing software.

Both of the selected courses were structured with two hours of lecture and one hour of computer laboratory per week. However, it has become increasingly evident that the course model is not effective for application-based learning and limits access to software resources. To provide further context, the Department has witnessed increased student demand for courses in GIS and remote sensing over the past 6 years. Specifically, our GIS Major and Minor program enrolments increased by 108% and 88%, respectively, between Fall 2008 and Fall 2013. Unfortunately, the Department has only one computer laboratory with a seating capacity of only 40 students at a time. The availability of the physical laboratory outside of scheduled laboratory hours is limited due to usage by other courses in the department, resulting in a full capacity almost every day of the week from September to April. This is a situation reported in other institutions and has been suggested as a deterrent to instructors for introducing GIS in their teaching (Şeremet & Chalkley, 2014). Furthermore, our campus is mainly a commuter-based campus and students report challenges in traveling to UTM just to access the computer facilities during evening and weekend hours for extra work time.

In addition to the physical constraints students face in accessing the laboratory for additional work time, to efficiently build lasting skills and familiarity with these complex programs, the “doing” (i.e., concrete experience) is the key. Yet from an experiential learning perspective, we had hoped that the WLP would encourage progression through the other stages of learning, including reflective observation (e.g., after leaving the physical laboratory), abstract conceptualization (thinking about what they did, and why), and then active experimentation through use of the WLP. The platform provides the opportunity for active, and self-directed exploration, in a comfortable environment with minimal pressure or time constraints to facilitate this deeper learning. Since the programs used in our laboratories are new to many students, we wanted to allow them to take the necessary time to actively experiment on their own, have an opportunity to reach all stages of the learning cycle, and improve the quality of their experience. By offering an opportunity to access the virtual laboratory at any time of the day, we hoped that the platform would also encourage independent learning. Studies at the university level require a higher level of self-governed learning, which is a skill that many undergraduates lack as they transition from a secondary education that is more dependent upon their teachers (Thompson, Pilgrim, & Oliver, 2005). In using a web-enabled platform for accessing geospatial data and programs, students have control over when and where they do their work and are able to self-monitor their progress because access to data and software is no longer constrained. Research has shown that self-monitoring of academic progress is important for promoting self-efficacy in learning, which is linked with better quality learning strategies, better skill acquisition, more effective studying, and higher academic achievement (Lemke & Ritter, 2000; Zimmerman & Risemberg, 1997).

Practicums (or tutorials) in these courses generally are comprised of four laboratory- based assignments per course, where students are provided with geospatial datasets and must follow instructions demonstrating how to complete a particular type of analysis, and then answer questions regarding the assignment. Answers can include generating map or analysis outputs, interpreting visual or quantitative data, or answering questions that link concepts discussed in lectures to laboratory-based outcomes. The general expectation is that students will spend between 6 to 10 hours working on each assignment, depending on individual skill level, and only a portion of that time requires access to GIS and remote sensing programs. Skill-based learning objectives in these laboratories inherently require more self-directed and self-paced exploration by the student in lieu of lecture-style teaching, and the advantages of technology that supports instruction, but does not directly teach, are supported by previous studies (Tamim et al., 2011). Remote learning laboratories are not a new idea and have been successfully implemented in other disciplines such as Engineering (e.g., Garrison & Kanuka, 2004; Stefanovic, Cvijetkovic, Matijevic, & Simic, 2011) and Chemistry (e.g., Carnevale, 2003), yet the distinction should be made that what we propose here is not a replacement of the physical laboratory, but rather a supplement to it, to support greater skill development and independent learning by students.

From a practical standpoint, the WLP also provides a secure and streamlined method of delivering laboratory data that may be extremely large in size, sensitive, or proprietary in nature. The platform allows these data to be maintained within the institution's server while students work remotely. The WLP also addresses incompatible software and operating system issues by allowing an Internet-based avenue that overcomes this conflict. Another advantage is that the platform ensures that all students are working with the same programs and program versions in the same work environment, which makes it easier for staff to troubleshoot and provide technical support. Free limited-term student licenses are available for some programs (e.g., ArcMap), but this alternative does not address the advantages stated earlier, nor does it provide students with access to the laboratory data, or the full suite of programs required to complete laboratory assignments.

In developing the WLP, we provided students with the ability to work in the convenience of their own homes (or anywhere of their choice), allowing physical laboratory times to be devoted to more directed teaching and focused questions. This WLP was developed with the goals of:

- motivating self-directed experiential learning and exploration;
- increasing the geospatial skills and confidence levels of undergraduate students;
- improving accessibility by providing a web-enabled option for laboratory work;

- improving the overall performance of laboratory modules by reducing the load on servers during scheduled laboratory periods; and
- accommodating diverse styles of learning.

With an increasing trajectory of undergraduate enrollment and a consistent demand for geospatial courses, this approach was piloted as a means of improving the education offered to students while meeting their needs for access to specialized geospatial software and instruction.

WLP: design and development

The web-enabled platform involved three main components (Figure 1). The first is *a Citrix system* that hosts XenApp, a virtualizing service that enables students to use geospatial software through the Internet and operates under a standard licensing agreement with the institution. Specifically, XenApp handles a frontend web interface server and a backend server. The frontend web interface server provides services including a user interface for login and software graphics, while the backend server hosts a series of geospatial software programs including ArcGIS 10.2 and ERDAS (2013) and facilities data processing. The geospatial software packages are installed only on this system, eliminating the need for multiple individual licenses for each student or workstation. This infrastructure allows up to 75 students to use the system at a time. Differing from fully web-based applications, this is a web-enabled system in which the Citrix program allows the end-user to view another computer remotely (i.e., the XenApp server hosted in the institutions computer space). The second component is *a data server* that hosts geospatial data (e.g., satellite imagery, numeric spatial databases). The data on this server can be read and processed by students using the geospatial software through XenApp. The final component is *the external users* (i.e., students' personal computers). Students are provided with instructions on how to install the XenApp service on their own devices. Once the XenApp service is installed onto a student's computer, the student only needs a stable Internet connection and their university login credential to access the Citrix system, from any remote location. The student then simply opens an Internet browser, types in the url of the xenweb site, inputs their student credentials to login, and a virtual desktop appears from within the browser displaying the suite of GIS and remote sensing program icons available. Once access is gained, the virtual laboratory and laboratory data are available for use on his/her own computer providing complete independence from a geographic location. Once the program icons are clicked on, they open as if they are running from each student's hard drive, but are in actuality operating through the web. Aside from a minor difference in initial login and access steps, the web-enabled infrastructure operates in a parallel manner to the laboratory-based network.

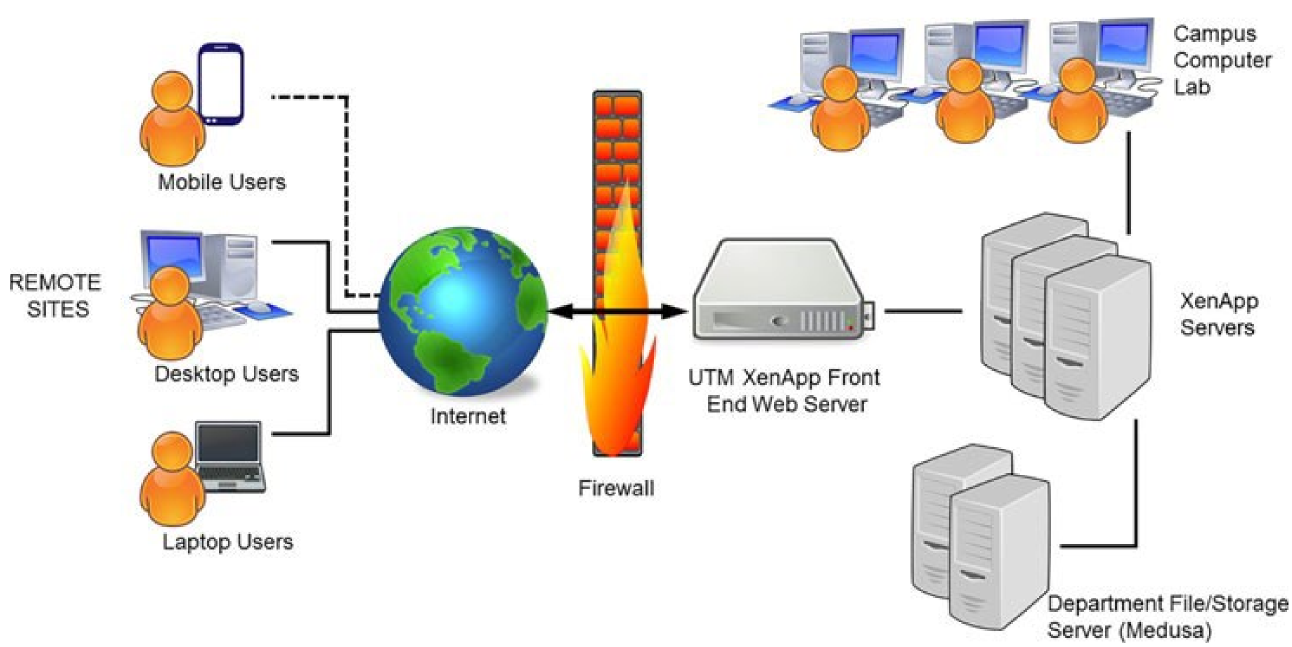

Figure 1. Conceptual representation of the WLP infrastructure.

Implementation

The WLP was first offered to the third-year Remote Sensing course (GGR337), in the Fall semester of 2013. Followed by the second-year GIS course (GGR276) in the Winter of 2014. Students in GGR337 were given four laboratory assignments to complete worth 40% of their final grade. Laboratory time was devoted to understanding the capabilities of image processing software (ERDAS) and understanding, implementing, and interpreting results of available tools. In the GGR276 course, students were also required to complete four assignments worth 32% of their final grade. The WLP was presented to students during the first laboratory practicum of each course and offered as a supplement to attendance at scheduled physical laboratory practicums.

A survey that was developed to test the students' reactions to the WLP was administered at the end of each course. The survey included 21 questions that addressed student academic background, location and access, installation, use of the WLP, and assistance. Response scales varied: seven questions asked for specific information about how students accessed the WLP (for example, which Internet browser they used); six questions offered a four- or five-point scale evaluating their experiences using the WLP; and the rest were open-ended questions (Table 1). The survey was administered through an online survey website (www.surveymonkey.com). Examples of specific questions are provided in Table 1.

Performance evaluation

Laboratory-based grade results

In GGR337, 32 out of 40 students (80%) chose to use the platform. Those who used the platform earned an average laboratory grade of 78.5%, which was significantly higher (p , 0.01) than that earned by those students who did not use the platform (i.e., those who elected to complete work solely using the physical laboratories) (62.6%) (Figure 2). In GGR276, 112 out of 142 students (79%) elected to use the platform, and achieved an average laboratory grade of 72.5%, which was significantly higher (p , 0.01) than that achieved by the 30 students who did not (64.9%) (Figure 2).

Survey results

An evaluation survey was administered to students at the end of their courses in the fall term (December 2013) and the winter term (April 2014), with a total of 130 respondents (32 responses from GGR337 and 98 from GGR276). In some cases, respondents did not complete all the questions in the evaluation survey.

Table 1. Sample questions from WLP student evaluation survey

Question
How easy did you find it to learn to use the WLP on your computer?
(a) Very easy
(b) Somewhat easy
(c) Somewhat difficult
(d) Very difficult
Compared to using software in a computer lab, how easy did you find to use the WLP?
(a) Much easier
(b) Somewhat easier
(c) The same
(d) Somewhat more difficult
(e) Much more difficult
How easy did you find it to access lab data for use in the WLP?
(a) Very easy
(b) Somewhat easy
(c) Somewhat difficult
(d) Very difficult
Compared to using the same software in a computer lab, how efficient do you find the WLP?
(a) Much more efficient
(b) Somewhat more efficient
(c) The same
(d) Somewhat less efficient
(e) Much less efficient
Describe one or more problems that you had with using the WLP:
Describe one or more things that you liked with using the WLP:
Do you have any suggestions for how to improve this WLP?

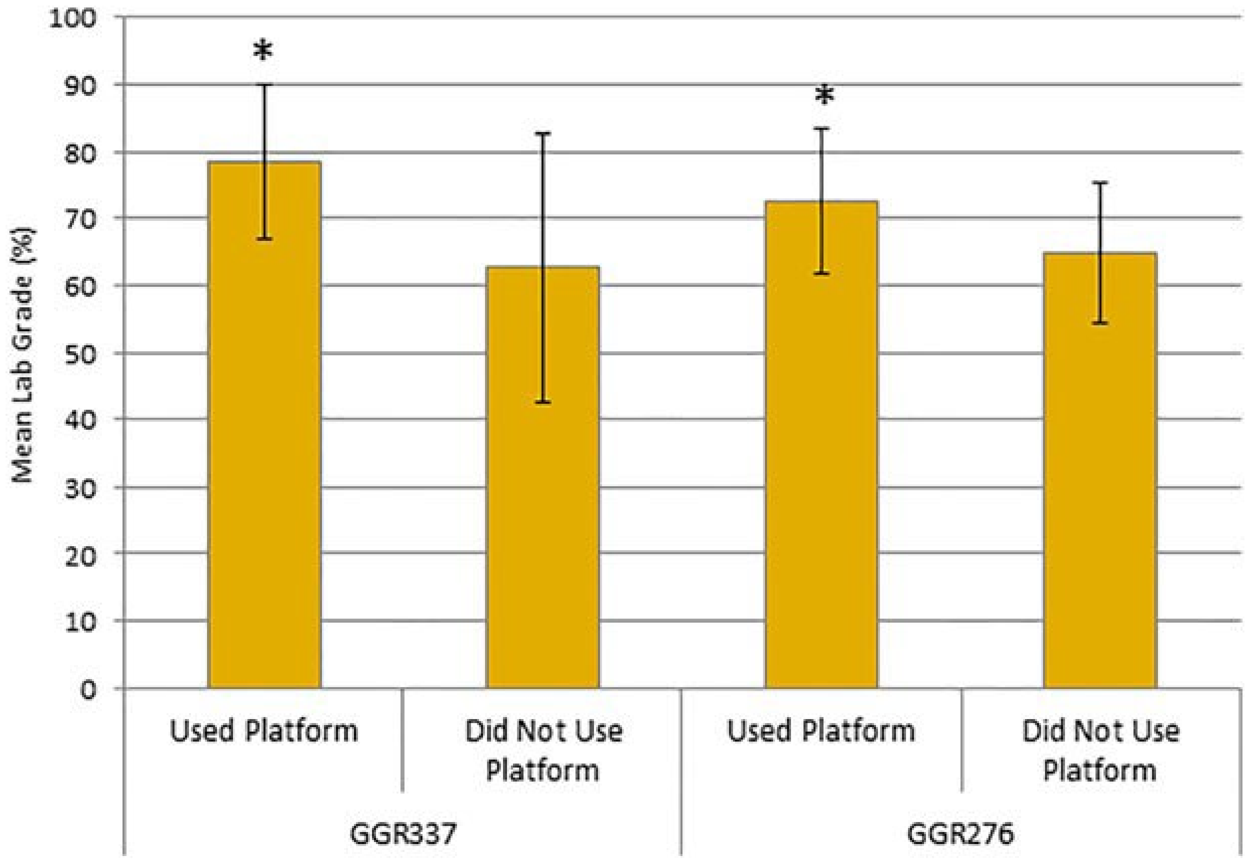

Figure 2. Comparison of means (*t*-test) between laboratory grades achieved by students using the WLP versus those that opted out. *p , 0.01.

Survey results are pooled for both courses in order to underscore general perceptions and opinions regarding the WLP. According to the results obtained, 90% of students (117 of 130) found the installation instructions helpful, 81% of students (105 of 130) found it easy to learn how to use the platform, and 9% of students (12 of 130) found it difficult (Figure 3). One respondent reported being unable to use the platform at all. Results of the survey also demonstrated that 48% of students (62 of 130) found the web-enabled platform just as easy to use as software in a computer laboratory, while 32% of students found it easier to use (41 of 130), and 18% reported that the WLP was more difficult to use (24 of 130) than software in a computer laboratory (Figure 4).

Out of 130 students, 74 (57%) had previous experience using geospatial software. Of these, four students had used geospatial software as part of an internship or other type of placement; the rest had used software as part of the requirements of a course.

The accessibility and convenience of the platform, especially being able to work from home, was by far the most common aspect of the platform that students reported they liked. Forty-seven percent of students (61 of 130), when asked to comment on what they liked about the platform, mentioned its convenience and were very enthusiastic about not having to work in a crowded computer laboratory that was often taken up by other classes, and about not having to travel to campus to do assignments. As one student stated, “It was very convenient to work on an assignment from home over the weekend instead of commuting to the university.” Another student commented that the WLP “allowed me the freedom to do the assignments on my own time. When having to go to the lab you often encounter loud distributive behaviour, i.e – talking [or] classes.” Twenty-five percent of students (32 of 130) commented that laboratory data and the programs were easy to access, or that the program was efficient and easy to use. For example, one student said that the platform was “easy to use and [has a] very comfortable interface.” A very high proportion of students who filled out the survey lived off campus and therefore had to commute to school: of all students who answered the survey question about place of residence, only 2% (3 of 130) of students responded that they live on campus at the UTM.

Other responses included positive comments on the clarity of the instructions, the security of data, the ability of instructors to easily update files, and the cost savings of being able to use the programs without having to pay for them. Students commented that the platform was interesting and provided a new way to “learn more about [geography].” In response to a question about problems with using the software, 30% of respondents stated that the program was slow, froze, and had to be restarted, or “lagged” (39 of 130 respondents). It is possible from students’ responses to the survey that a number of simultaneous logins were responsible for the reported slow speed of operation of the platform; however, there is no conclusive evidence of this. The highest number of confirmed simultaneous uses of the platform was 5. Inclusion of students who specified a day but not a time of access raises this number to 9. Given that the platform has 75 licenses, it seems unlikely that nine students using it simultaneously would cause it to slow down. Further, several of the students who accessed the platform at the same time as several others mentioned that it was slow; however, not all of them mentioned this, nor was the complaint of slow speed restricted to students who accessed the platform at a time when other students were using it as well.

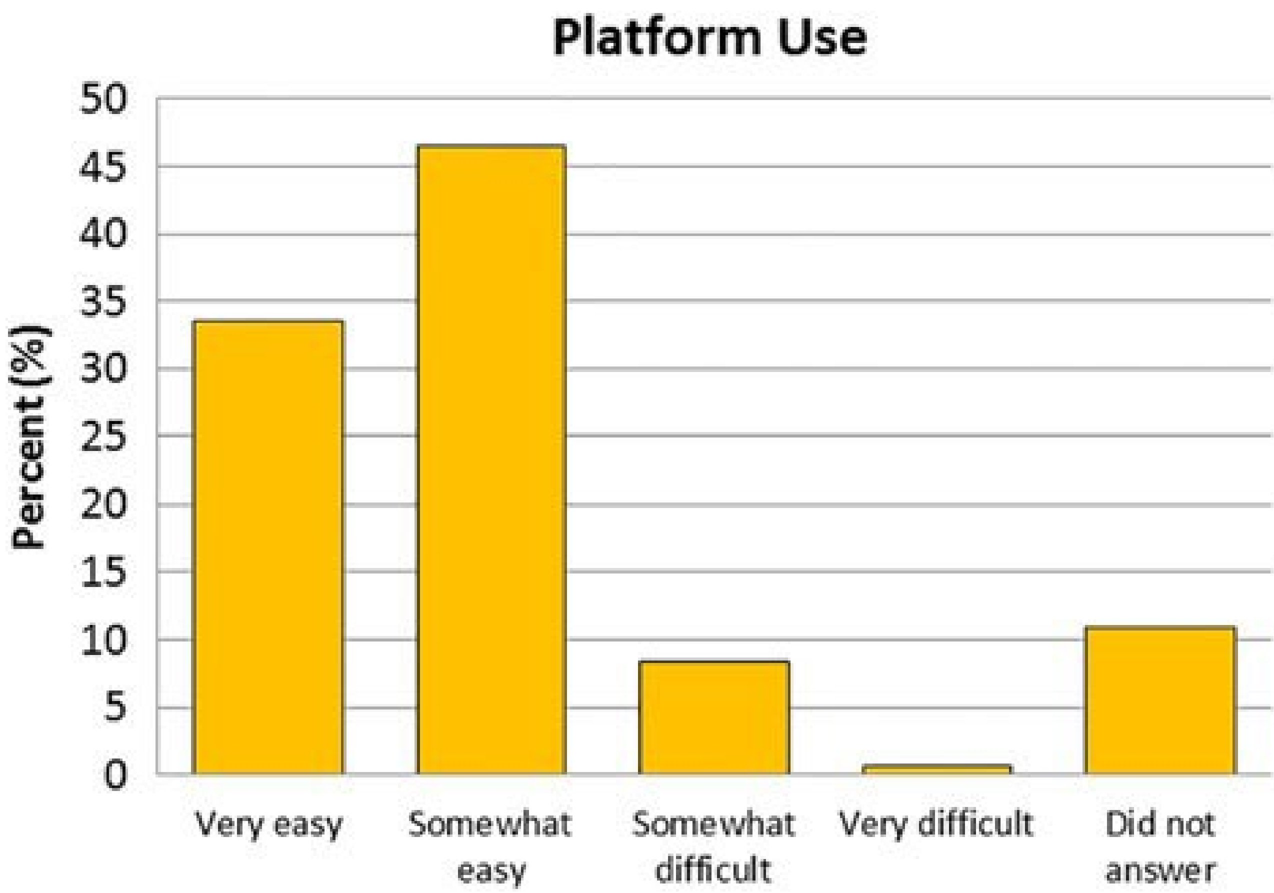

Figure 3. Survey results on ease of platform use.

Another problem that students reported was with accessing laboratory data through the WLP. Fourteen percent of respondents (18 of 130) reported difficulties with accessing or saving personal data within the WLP. As only 57% of survey respondents had previous experience with geospatial software, some of these difficulties might be attributed to the fact that they were encountering the software interface for the first time. Students who reported having problems almost universally described having initial difficulties, but were able to overcome the problems on their own once they acquired a greater familiarity with the platform.

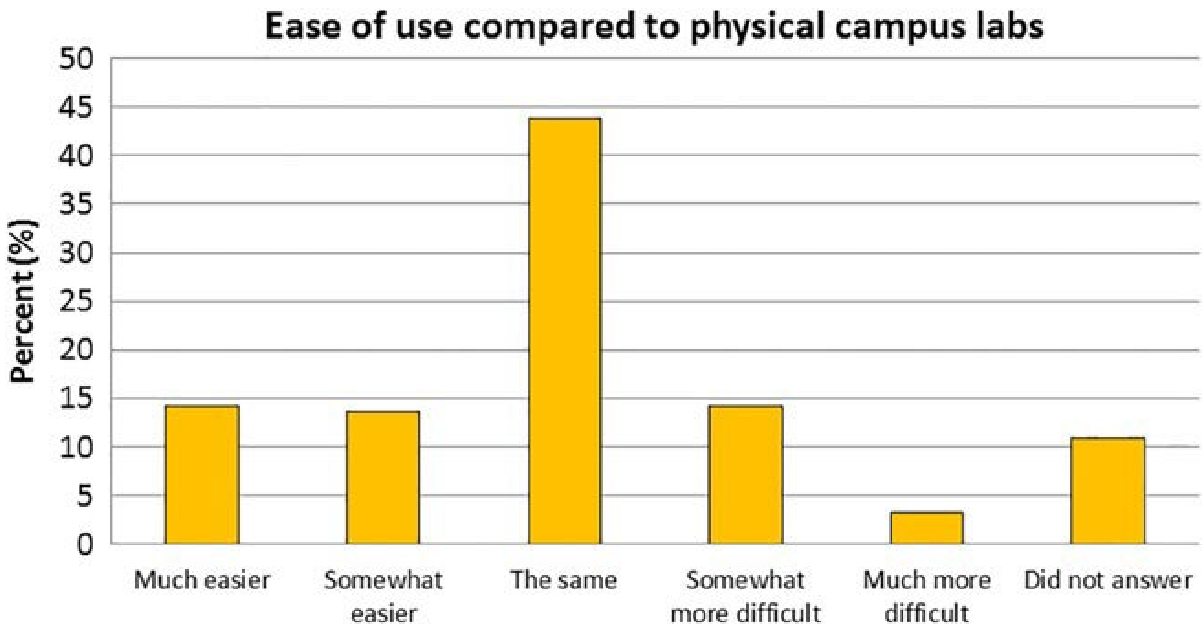

Figure 4. Survey results on comparative ease of platform use versus physical laboratories.

Out of all 130 respondents, only three students stated that they did not like anything about the platform and one of these was a student who reported that the platform did not work at all for them. As they did not seek out assistance, we do not have any further information available as to why they experienced this issue. Twenty-two percent of students stated that they had no problems with using the platform (29 of 130).

Future platform improvements

Since a small number of students were not able to access the platform at all, yet did not utilize the support system provided, we are implementing a live chat forum where students can post their questions or difficulties with the virtual laboratory, or questions about laboratory assignments. Although students did not report any sense of isolation or lack of interaction between peers while using the WLP, we believe that it would provide an overall benefit to offer a common forum for students to engage with each other. From this forum, other students can offer assistance to their peers, while faculty-level assistance can be provided at set times of the day. It is also the hope that this forum will create a sense of community among remote WLP users, thus encouraging interaction between students and faculty, and developing reciprocity and cooperation among students as a means of promoting effective undergraduate education (Chickering & Gamson, 1991).

From survey results, almost a third of respondents reported that the geospatial platform was slow at times or froze. This issue could be a result of limited server capacity to hold many student accounts active at the same time, or the Internet speed originating from the end-user. Currently, the Citrix server capacity has a limit of 25 simultaneous users and future improvements will work on increasing the number of simultaneous client licenses, and using higher capacity servers to hold the software and the data. Any Internet bottleneck from the end-user, in terms of individual household Internet speed, will remain so unless upgrades are made. We encouraged students to use a wired Internet connection, as they tend to offer higher speeds than wireless connections. Related to this issue, we have proposed to add a function to track user statistics, a tool that currently does not exist. Information such as number of concurrent users, time of access, and duration of use would help to pinpoint if slower speeds are a result of user overload versus other technical issues. To ensure that the WLP continues to meet student needs, we will keep collecting feedback from students.

Discussion and conclusions

Given the increasing demand for geospatial knowledge and skills, the ability to apply web- enabled enhancements to student learning is both timely and relevant to current needs. In this paper, we presented a WLP for enhancing laboratory practicums through creation of a virtual laboratory accessible to students anytime and anywhere with an Internet connection. We based this platform upon the philosophy of experiential learning, and addressing individuality in learning styles to improve both the student experience and academic achievement. This platform was developed in response to students reporting the need for greater access to specialized geospatial software identified through student communication and through consistent and increasing enrollment in geospatial courses. The platform included a software server (the Citrix System), a data server containing geospatial laboratory data, and the external student users.

Assessment of this platform was conducted through an evaluation of student survey responses and a comparison of laboratory grades achieved by students who used the platform and by those who did not. The large number of students who opted to use the platform, higher laboratory grades achieved by students utilizing the platform, and an overwhelmingly positive response on evaluation survey questions all suggest that this virtual laboratory is a positive addition to the educational experience and promotes key learning objectives. In a previous endeavor to integrate web-enabled modes of GIS learning into classrooms by Kamruzzaman (2014), student's access to ArcGIS on their own computers was identified as a key factor that improved the learning experience and was reinforced by student's comments stating that the best aspect of the course was the opportunity to work at home and apply learned concepts outside of the university environment. While these results demonstrate the benefits of the WLP, it is important to note that we have no way of controlling for student aptitude. In Canada, university students are not required to take standardized aptitude tests or entrance examinations. Thus, we are unable to determine whether the WLP users represent a self-selecting group of better performing students. However, given that over 50% of students used the WLP in both the second- and third-year courses, we do not believe that the higher grades earned by users can be explained by self-selection alone.

What is clear is that the WLP appeals to certain types of learners. A key to effective teaching is the recognition of differences in the abilities and preferred learning styles of students. For example, some students may perform better when they are allowed to work at their own pace, or their own schedule (e.g., people who perform better early in the morning or late in the evening) or when they are not distracted by their classmates. Other learners may perform best in environments where they are most comfortable (e.g., in a student's home, or in the library), which may also help facilitate deeper learning. Individuals differ in their preferred style of learning, and helping students to recognize this, is the first stage in raising their awareness of alternative approaches to learning and helping them to be more flexible in meeting the demands of an undergraduate education (Gibbs, 1988). Regardless of individual learning styles, students who are actively engaged in a task tend to understand more, learn and retain more as well as appreciate the relevance of what they are learning (Park, 2003). Experiential learning (Kolb, 1984) has already been applied in numerous ways to the discipline of Geography in higher education (Healey & Jenkins, 2000) and the more opportunities that we can give students to explore this active learning, the greater the benefit.

The WLP we developed also has an economic benefit. A budget breakdown from our institution's Information and Technology Division estimated that for the cost of establishing a physical computer laboratory with 50 seats, only 10% of this budget is required to develop and implement the WLP for the same number of "seats". The readers have to keep in mind that the budgets we mention here are only applicable to our campus (UTM) and could vary at different places and over time. In the long term, however, with increased student enrollment in GIS courses as we have been experiencing, it is not a realistic approach to keep adding seats to in-house geospatial laboratories. Instead, the WLP provides an attractive alternative to meeting the increasing demand for geospatial learning, while also enhancing the learning experience. Technological interventions need not always come with a hefty financial investment, and sometimes a simple technological intervention can have a monumental effect on enhancing learning outcomes (Kamruzzaman, 2014).

Other institutions may benefit from utilizing this same approach, given similar constraints of increased enrolment without a concurrent increase in computer laboratory space. Even without increased enrolment, we believe that the benefits of a remotely accessed virtual laboratory, such as the one we have described earlier, would enhance any geospatial laboratory through increased self-directed student learning opportunities. As the WLP approach is not exclusive to Geography, other departments wanting to offer students access to specialized software could also utilize the same platform, thus making it an attractive and multi-disciplinary investment that would save universities money in the long run while improving access to and enhancing educational opportunities. With any supporting IT department, this approach can be easily implemented. Considering the rapid and ongoing developments in technology, higher education must take advantage of opportunities that locate learning in space and place to ensure that geographic education is attractive and accessible to all (Lynch et al., 2008). The WLP described here is a relatively simple and straightforward approach to implement with clear benefits to student learning and to mitigate the physical constraints of laboratory space.

In summary, this geospatial WLP provides many benefits to students and addresses the need that initially drove its development. We wanted to create a learning environment for students that allowed them to experiment, explore, learn from mistakes, and figure out how to trouble-shoot problems without constraining this important cognitive growth to the one- hour per-week limitation of most computer laboratories. With future iterations, we expect to further improve this platform by strengthening pedagogical objectives, facilitating a higher learning experience, and fully harnessing the transformative potential of this learning technology.

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Disclosure statement

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Notes

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5. Following Bernard et al. (2014), we define *blended learning* as the combination of traditional class instruction and online learning outside of class, where the latter does not exceed 50% of the course time; and *educational technology* as any use of technology for teaching and learning as opposed to technology that may serve administrative and/or managerial purposes.

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