The Effectiveness of Internet-based Instruction: an experiment in physical geography

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Abstract

Geographers increasingly use the Internet as an instructional tool in higher education. The effect of Internet-based instruction on learning, however, is essentially unknown. This research involves a matched-pairs experiment that assesses the differences in student performance between a group of students taking an Internet-based lesson in introductory physical geography, and another group learning the same material via traditional classroom methods. Both groups were subject to the same knowledge assessment post-test, and scores were statistically analysed to determine whether one instructional method led to better student performance over the other. Results show that the Internet can be a viable alternative instructional tool compared with traditional classroom methods.

Keywords

Internet-based instruction, matched pairs, physical geography.

Introduction

Distance learning is a term increasingly being used to describe a situation in which students, almost always at the post-secondary level, take courses or some portion of a course remote from the classroom. Students have participated in distance learning for decades through correspondence education and tele-courses. The continuing development of the Internet coupled with the explosive growth of the World Wide Web, however, adds an entirely new dimension to distance learning. In fact, many universities in the United States and abroad are offering courses online, and there are a number of ‘virtual’ universities that exist entirely on the Internet.

The Internet is a powerful communication tool in education whether it is used in a distance-learning environment or within the classroom. Lessons can be posted on a web page for students to access at their convenience, chat rooms may be set up so that those
students can communicate with each other and the instructor and, unlike textbooks, online materials are easily updated. Additionally, multimedia such as high-resolution graphics, maps, videos and animated images can be made readily accessible to students. Many college and university departments, including geography departments, recognise the Internet as an instructional tool and currently offer online lessons and supplementary course materials to their students. The acquisition of spatial knowledge in geography courses is a highly visual process and the Internet can be a useful tool to deliver visual representations of both the physical and cultural environment.

The ability to display animated graphics makes the Internet a particularly intriguing instructional tool for explaining complex phenomena in physical geography. For instance, fundamental concepts such as differential heating and cooling, pressure gradients, the Coriolis effect and Hadley circulation must be learned before a student can be expected to understand global atmospheric circulation. Although spatio-temporal in nature, these fundamental concepts have traditionally been taught using static images such as those found in introductory physical geography textbooks or their complementary overhead transparencies. On the other hand, the Internet can be used to display animated graphics, allowing students to view moving simulations of these concepts.

Although the method is developing rapidly, it remains unknown how online instruction affects student learning in physical geography. While a few studies have assessed student opinion of online instruction versus traditional classroom instruction in geography (Krygier et al., 1997; Chrisman & Harvey, 1998), little empirical research has been conducted to determine how online instruction compares with traditional classroom instruction in terms of student performance. Quantifying the effectiveness of Internet-based instruction in physical geography is critical to teachers, educational researchers, university administrators and others who are involved with this revolutionary instructional method. If Internet-based instruction is effective, distance learning could become the new methodology of post-secondary education.

The question of whether Internet-based instruction is effective is a complex one with a multitude of contributing factors. Most of the research addressing this question has assessed the effects of Internet-based instruction on student motivation. While student motivation and opinion are significant in the overall assessment of the effectiveness of Internet-based instruction, new research should focus on quantifying the effectiveness of Internet-based instruction on student learning. The purpose of this research is to assess the differences in student performance between similar Internet-based and lecture-based lessons in introductory physical geography. It is intended to be the first of what it is hoped will be a number of studies assessing how well students learn geographical concepts from the Internet compared with traditional instructional methods.

This paper is divided into four sections following this introduction. The next section consists of a review of the relevant literature concerning the effectiveness of Internet-based instruction. The third section discusses the methodology employed in the research. The fourth section presents the results and analysis of a controlled experiment conducted with students of physical geography to assess the differences in student performance between Internet-based and lecture-based instruction. Finally, we summarise the findings and recommend directions for future research.

The Distance-learning Literature

The review of the relevant literature is conducted to meet two objectives. The first is to assess the results of previous research on the effectiveness of multimedia and Internet-
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Based instruction. The second is to assess the efficacy of visual representations of the environment in spatial knowledge acquisition. Insights from the literature are necessary to determine the most appropriate lessons in physical geography to be used in a controlled experiment comparing Internet-based and lecture-based instruction.

Research in Multimedia and Internet-based Instruction

Rieber (1994, p. 251) defines multimedia instruction as “integrated instructional systems that deliver a wide range of visual and verbal stimuli, usually through or in tandem with computer-based technologies”. Multimedia instruction includes text, images, maps, diagrams, sound, animation and video (Krygier et al., 1997). A web page, stored on a computer server and accessible via the Internet, can deliver information using one or all types of multimedia instruction. We call this Internet-based instruction.

There are a number of studies on Internet-based instruction and its usage and effectiveness. Kearsley et al. (1995) found that some benefits of online courses include increased student satisfaction, better examination scores and a higher level of critical thinking. Other cited benefits of Internet-based instruction are user-friendliness, self-paced learning and 24-hour access (Freundschuh & Hellevik, 1999). In a case study of an online course, researchers found that the electronic discussion generated between students was stimulating and included interactive debate (Lewis et al., 1997). With regard to information retention, Barth (1990) found that interactive multimedia computer lessons resulted in an 80 per cent retention rate, while lecture and associated visuals resulted in a mere 20 per cent retention rate in a sample of students. Other studies have found that computer-assisted instruction allows teachers to deliver the same material in a shorter period of time (Rooze & Northrup, 1989).

Some researchers counter these results, maintaining that instructional media have no impact on student learning, but that instructional method is the critical element to student success (Kulik, 1985; Clark, 1994). In Kulik’s (1985) meta-analysis of multimedia research, he concludes that a computer program can be erroneously perceived to affect student knowledge acquisition, when in fact it is the instructional method built into the program that affects knowledge acquisition. It is important to note, however, that this research preceded the advent of the Internet as an instructional tool in education. Still, critics maintain that studies showing an increase in student learning from multimedia instruction have not been controlled for other conditions that may have caused student success (Lookatch, 1997). After comparing integrated media versus lecture, text and lab exercises, Havice (1998) concluded that the group receiving instruction via the traditional methods of lecture, text and lab exercises recorded higher gains. However, Havice acknowledged that environmental, preparatory, and set-up factors could have influenced the results. Finally, other critics target distance learning as creating an artificial learning environment and destroying the importance of physical presence and ‘sense of place’ (Meyrowitz, 1985; Streibel, 1997).

Despite these conflicting results, a number of proponents view Internet-based instruction as an excellent means to reach multiple learning styles. Multiple Intelligence Theory developed in response to the traditional and narrowly focused emphasis on linguistic and logical-mathematical abilities. It asserts that humans actually learn through many different cognitive styles (Gardner, 1983). The theory consists of seven types of intelligence: bodily-kinesthetic, interpersonal, intrapersonal, linguistic, logical-mathematical, musical and spatial (Gardner, 1983). If humans learn through multiple types of intelligence, then the most effective instructional media would appeal to many or all of
them. From this it follows that Internet-based instruction might represent a better way to correspond to these learning styles than the printed and static images of traditional instruction (Freundschuh & Hellevik, 1999).

Computer technology plays a critical role in the discipline of geography. For instance, many studies tout a variety of different benefits stemming from the development of GIS, including its use as an educational tool (Bartier & Keller, 1992; Walsh, 1992; Dobson, 1993; White & Simms, 1993). The complexity and sheer volume of data required in geographic analysis and map generation necessitates the use of computers. While the body of literature surrounding GIS technology is large and multi-faceted, literature regarding the effectiveness of Internet-based instruction in geography is small but growing. At the Association of American Geographers 1999 annual meeting in Honolulu, more than a dozen papers dealt specifically with multimedia and Internet-based instruction in geography education. Additionally, a handful of studies have focused on student motivation and have demonstrated that students prefer Internet-based instruction versus traditional methods of instruction. Students questioned in one such study responded positively to the clarity of presentation, multiple examples of concepts and interesting displays provided by an online lesson in Geographic Information Systems (Chrisman & Harvey, 1998). Another study, in which students learned about changing agricultural patterns using multimedia and animated maps, reported that the students found multimedia to be more interesting and fun to use than traditional text-based learning (Freundschuh & Hellevik, 1999).

While student opinion of Internet-based instruction is critical to assessing motivation, there are very few studies that assess student performance in online geography courses. Those studies that have been conducted provide mixed results. One of these studies produced interesting results from a sample of 39 cartography students and their ability to respond correctly to test questions using both static and animated maps (Koussoulakou & Kraak, 1992). While there was no significant difference in the number of questions answered correctly from the maps, students answered the questions more quickly when asked about the animated maps, suggesting that animated maps lead to more rapid cognition than static maps (Koussoulakou & Kraak, 1992). Others agree that computers can both quicken and enrich geography instruction (Fitzpatrick, 1990). Fitzpatrick (1993) also asserts that multimedia is particularly appropriate for geographic education since geographic concepts should be learned through text, maps, pictures and sound to achieve the fullest learning experience. However, another pilot study involving 16 adult students showed no significant difference in performance between students who answered questions after taking an Internet-based lesson and those who gleaned the information from a textbook (Freundschuh & Hellevik, 1999).

Finally, there is a paucity of research on the effect of Internet-based instruction on student performance in physical geography. While Krygier et al. (1997) refer frequently to physical geography lessons developed for the online Gaia course at The Pennsylvania State University, they assessed the impact of those lessons through such methods as focus groups and questionnaires and not by testing student knowledge. Another study of computer-based instruction in physical science also assessed student motivation and not student performance (Podell et al., 1993). The lack of research in this area certainly justifies this research endeavour.

Visualisation and Spatial Knowledge Acquisition

McCormick et al. (1987, as cited by Couclelis, 1998) state that human beings have a
natural ability to process visual information quickly and efficiently. Their capacity to readily understand spatial relationships facilitates interpretation of images that simulate geographic space (Couclelis, 1998). Visualisation is an increasingly used term in geography that refers to both the ability to process visual information and the design of concrete visual representations meant to assist such processing (MacEachren & Ganter, 1990). Both must be understood to evaluate the relative importance of visual representation in geographic education. While most of the research in visualisation has been performed by psychologists, many cartographers are synthesising this information and expanding on it in the context of geography instruction and spatial analysis (MacEachren, 1991). Cartographers, it is argued, are especially adept at geography visualisation owing to their long history of work in graphic symbolisation, feature generalisation and the interpretation of graphic images (DiBiase et al., 1992).

Cognitive Learning Theory postulates that an individual learns based on the ability to select, perceive, process and encode information, and to retrieve it from memory (DiVesta, 1987). According to this theory, a key component to learning is the transfer of information from short-term to long-term memory, a process that requires coding (Rieber, 1994). According to Paivio’s theory (1971, 1986) of dual coding, long-term memory consists of separate verbal (language) and non-verbal (imagery) codes. He states further that an individual who successfully codes both verbal and non-verbal information regarding the same concept into long-term memory will be twice as likely to retrieve that information as a person who codes the information via one or the other (Paivio, 1971, 1986). Since its introduction, the dual-coding theory has formed the basis for the majority of imagery research performed by psychologists (DeVega & Marschark, 1996), and cartographers have also reflected on the dual-coding approach in their recent emphasis on narrative maps (MacEachren & Monmonier, 1992; Monmonier, 1992).

The concept of cognitive coding also forms the basis for what Downs and Stea (1973, p. 9) termed cognitive mapping, defined as “a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment”. Cognitive mapping is especially salient to research in human navigation in unfamiliar environments, where cognitively stored and recalled information is heavily relied on (Golledge, 1999). A commonly held conclusion is that more experience within an environment leads to better cognitive mapping (Golledge & Rushton, 1976; Thorndyke, 1981). This conclusion suggests that whether geographic education occurs within the classroom or an Internet-based environment, students with real-world experience within the environment discussed will be better able to cognitively map that information.

Golledge and Stimson (1987) devised a system of spatial knowledge categorised into three types of knowledge: declarative, procedural and configurational. MacEachren (1991), in his simplified explanation of the system, defines declarative knowledge as the ability to recognise and characterise objects and places, and in geography it is essential to the study of regional geography (MacEachren, 1991). Procedural knowledge enables an individual to navigate from one place to another and represents a higher cognitive level than declarative knowledge (MacEachren, 1991). The majority of research in spatial knowledge acquisition focuses on both declarative and procedural knowledge, particularly as they pertain to the coding of spatial information from maps and direct experience in order to navigate (Garling et al., 1983). Configurational knowledge, however, is the highest level of spatial cognition and, according to MacEachren (1991, p. 154) “allows geographic patterns to be identified, relationships between patterns to be noticed, and hypotheses about spatial association to be developed”. Configurational
knowledge, therefore, is most critical of the three to understanding spatial processes in physical geography. Unfortunately, research in configurational knowledge and its relationship to understanding physical geography does not exist.

**Research in Static and Animated Image Cognition and Implications for Physical Geography Education**

Some of the important research in the cognition of static visuals among young adults comes from the work of Francis Dwyer. He found that pictures help young adults learn when they are optimally realistic, when sufficient time is given to interpret them and, in the case of instructional books, when text alone would not be as effective (Dwyer, 1978). It has also been suggested that adults rely less heavily on pictures than children, since maturation leads to a better ability to form mental images (Guttmann *et al*., 1977). Other research has shown that being able to remember a picture depends on the contrast between foreground and background, colour, complexity, movement and the relationship between components (Levie, 1987).

Although the theory of dual coding of both language and image is well supported (Bahrick & Bahrick, 1971; Levie & Levie, 1975; Kobayashi, 1986; Rieber, 1990), only recently have researchers focused on the difference between the cognition of static versus animated images. Animated images are actually a sequence of static images viewed so closely together in time that the brain perceives them as one fluid motion (Ramachandran & Anstis, 1986). An example would be how a person perceives motion pictures and filmstrips. Klein (1987), in comparing animated images with static images, finds that animation is distinguished in the ability to demonstrate changes in both movement and direction. Therefore, animation can reduce abstraction in temporal concepts and better display changes over time (Rieber, 1994). Additionally, while one must fill in the gaps when viewing static images of temporal processes, animation frees those cognitive resources, thereby reducing the demands on short-term memory and raising the success rate of accurate encoding (Rieber, 1994).

One salient research effort found that the presentation of animated images and narration concurrently, as opposed to separately or in succession, benefited students who had little background in the subject matter (Mayer & Gallini, 1990). Mayer and Gallini (1990), basing their conclusions in dual-coding theory, state that the concurrent presentation of verbal and visual information allows students to build connections between the two. However, this effect is stronger for high-spatial ability learners than low-spatial ability learners, since the latter must spend more cognitive resources on the process of visual encoding, leaving fewer resources to build connections between the two (Mayer & Sims, 1994). In another study using adult subjects, response times on the post-test were significantly faster among those who viewed animated images versus those viewing static graphics or no graphics (Rieber *et al*., 1990). While the body of research is small, MacEachren and Monmonier (1992) predict that geographic visualisation research will continue to expand in the direction of animation.

The evidence suggests that animated imagery may play an important role in physical geography education. The majority of processes studied in introductory physical geography involve changes over space and time. A sampling of chapter headings from a popular physical geography textbook reveals the spatio-temporal nature of the discipline. Topics such as ‘Seasons and Time’, ‘Winds and the Global Circulation’, ‘Air Masses and Cyclonic Storms’, ‘Runoff and Water Resources’ and ‘Weathering and Mass Wasting’ all involve processes that change the earth’s surface (Strahler & Strahler, 1987). A physical geographer should consider the earth in terms of “flow systems of
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matter and energy,” each consisting of “… connected pathways through which matter, or energy, or both move continuously” (Strahler & Strahler, 1987, p. 1). Accordingly, continuous movement over space and time is better illustrated by animated rather than static images. Furthermore, computer programs that produce animated simulations are considered ideal in demonstrating physical processes such as sediment transport and deposition and other concepts (Gold et al., 1991). It has also been predicted that the simultaneous visual exploration of spatial and temporal change will have a significant impact on the insights of earth scientists and, presumably, students of earth science (MacEachren & Monmonier, 1992). Finally, students taking introductory physical geography are not likely to have a high degree of previous knowledge in the subject. According to Mayer and Anderson (1991), these are the students that would most greatly benefit from the presentation of material via both verbal and animated visual methods.

Summary
The research on whether Internet-based instruction is better than traditional instruction has produced mixed results, and none has provided evidence of the impact on student learning in physical geography education. Geography involves the study of spatial relationships and interactions, and, in order to capitalise on the innate human capacity to understand spatial representations of the environment, visual learning should be used in geography instruction. Preliminary evidence shows that animated images are preferred over static images to effect visualisation of spatio-temporal processes. It remains unknown, however, whether animated images of spatio-temporal processes in physical geography will lead to better knowledge retention than static images.

Methodology
The design of this research is a variation of the design entitled pre-test–post-test comparison group by McMillan and Schumacher (1989). In the present study, 88 students participated in an experiment in which half of the students took an Internet-based lesson in introductory physical geography while the other half learned the same material via traditional classroom methods. All students were then subject to the same knowledge assessment post-test and the scores were statistically tested for significance using a matched pairs t-test.

Selection of Research Participants
At San Diego State University in the spring of 2000, there were eight sections of the course entitled Physical Geography Laboratory (GEOG 101L). Five sections with 20 students each of this course were chosen for this research. The sections were chosen for a number of reasons. First, the class period for these sections was two hours and 40 minutes, allowing enough time to conduct the experiment. Attendance was required and monitored in all sections thereby reducing the risk that students would be absent during the experiment. The instructors of the five sections were willing to cooperate.

Subject Matter
The lesson presented to students was on fluvial processes and how they shape the physical landscape over time and space [1]. Specifically, the following concepts were incorporated into the lesson:
stream gradient, erosion, transportation of stream load, and deposition;
how to calculate the discharge of a stream;
the relationship of Strahler’s stream order to stream gradient and discharge;
the concept of a graded stream, aggradation and degradation;
meandering of a stream and the formation of floodplains, cut-offs and oxbows.

Design of the Lessons

The traditional lesson involved the instructor presenting concepts in fluvial processes and landforms in lecture format accompanied by overhead transparencies and/or slides of static images. The Internet-based lesson emphasised the same concepts that the course instructor presented, and was verified and approved by each instructor. The Internet-based lesson, however, presented the material using animated video images such as Apple Quicktime movies and animated graphic image files (gifs), static gifs, and text files programmed in hyper-text mark-up language (HTML) displayed on a series of web pages. The student determined the length of time each graphic and text box was viewed, and was able to return to previously viewed material at any point during the lesson.

At issue in this experimental design was matching the quality of the Internet-based lesson with the traditional lesson. This experiment was designed to emulate a real-world situation in order to accurately compare two instructional methods. As students may not have the opportunity to ask questions of the instructor while taking an Internet-based lesson, it is very important that the lesson be thorough, complete and as free from error or ambiguity as is possible. On the other hand, a lecturer may not have to spend as much time preparing the lesson since he or she is present in the classroom to interact with students, answer questions and clarify points during the lesson. It is therefore realistically expected that more time will be given to the development of Internet-based lessons than traditional lessons. The Internet-based lesson for this research effort was no exception. The 13-page web lesson took approximately 20 hours to complete (after becoming competent in HTML programming and graphics creation using Macromedia Freehand). The instructors have stated that they spent no more than three or four hours preparing their lecture on the same topic. Of course, in a traditional academic structure the Internet-based lesson could be used repeatedly with little (for updating) or no preparation time involved. Clearly there are long-term efficiencies in using Internet-based lessons.

Pre-test and Assignment of Groups

The process of matching followed by randomisation is an effective alternative to purely random assignment for the purpose of assuring equivalency between groups and preserving internal validity (Campbell & Stanley, 1963; McMillan & Schumacher, 1989). The first and second examinations of the semester, taken at their regularly scheduled time, served as the pre-test for this research. The scores were averaged for each student and the students were then ranked according to their score from highest to lowest within their own section. The scores on both tests allowed us to quantitatively identify pairs of students who most closely matched each other in achievement. The matching was based on the absolute difference in scores on the first exam combined with the absolute difference in scores on the second exam. Pairs of students were identified by minimising differences in scores. One member of each pair was randomly assigned to either a group slated to take the Internet-based lesson or a group slated to take the traditional lesson.
The most common purpose of a pre-test in educational research is to compare the results of the pre-test with the post-test in order to calculate differences attributable to the given treatment, usually through the analysis of score gains (Campbell & Stanley, 1963; McMillan & Schumacher, 1989). In this research design, however, the pre-test was an entirely different instrument from the post-test, and was employed only to assure statistical equivalency among the pairs of students to be tested. Additionally, pre-tests in the traditional sense can be a threat to internal validity when they familiarise a student with the post-test material (McMillan & Schumacher, 1989). In this research, the pre-test was composed of different material from the post-test, avoiding complications with regard to internal validity.

To test whether the matched pairs were indeed good matches, a Pearson’s correlation was performed between the pre-test score of each student with that of his or her assigned matching student. The results of this test revealed an \( r \)-value of \( +0.887 \), which is statistically significant at the 0.05 level \( (n = 44 \text{ pairs}) \). This means that there was a strong correlation between an individual’s pre-test score and that of his or her match. Clearly, this lends credence to any test where differences between the members of a pair are suspected.

At the regularly scheduled time in which the group’s instructor intended to present the lesson in fluvial processes, the students took either the Internet-based lesson or the traditional lesson depending on the outcome of the random assignment. The instructor began the class period by explaining the research project. The students were told that they would be tested on the material learned and that their score on the test would count towards their final grade in the class. They were also told that they would have no time to review their notes between the end of the lesson and the taking of the post-test. The period of time between treatment and measurement can be a threat to internal validity, because other factors can be introduced over time and possibly affect the results of an experiment (McMillan & Schumacher, 1989). Administering the post-test immediately following the lessons minimised these unwanted effects.

Those students selected to take the Internet-based lesson were escorted to a computer laboratory while the other students remained for the lecture-based lesson in their regular classroom with the course instructor. In the classroom the post-test was administered to the students immediately following the end of the approximately 45-minute lecture. Students who took the Internet-based lesson, however, took the test individually when they said that they were finished with the lesson.

Exactly the same post-test was conducted using paper and pencil for both sets of students in order to eliminate any differences in performance that could be attributed to different test media. It consisted of 20 questions relevant to the lesson that had been used by the instructors in past semesters for this course. The purpose of using these questions was to ensure content validity. The post-test comprised entirely multiple-choice items, consisting of a question or partial statement followed by four or five plausible answers, only one of which was correct. The multiple-choice test was used to avoid subjectivity in the grading of the tests and to assess the widest breadth of knowledge possible in the limited amount of time available.

Analysis of Post-test Results

The primary goal of the analysis in this research is to determine whether Internet-based lessons lead to better student performance than traditional lessons. A paired samples \( t \)-test is used to determine whether the means on the post-test differ significantly between
the two groups. The null hypothesis is that there is no difference between the test scores of the matched-paired students. Since the groups in the experiment are not independent samples but matched samples, the dependent samples $t$-test is used. The null hypothesis is that the population means between those taking Internet-based lessons and those taking traditional lessons do not differ, or $H_0: \mu_1 - \mu_2 = \mu_0 = 0$. The final step is to accept or reject the null hypothesis in a two-tailed test. At the 95 per cent confidence level, $H_0$ can be rejected if $t > t_{0.05}$ or if $-t < -t_{0.05}$ where $t_{0.05}$ is based on the number of pairs or $(n-1)$ degrees of freedom.

A secondary goal of the analysis is to test whether the Internet-based lesson had a greater impact on lower-achieving students. It is reasonable to assume that some students who are performing poorly in the class may benefit from an Internet-based lesson since it allows for as much time as necessary reviewing each aspect of the lesson. The poorer students could conceivably have difficulty keeping up with the pace of the traditional lecture. Sometimes the problem is associated with students’ difficulty in understanding English. At other times, some students simply become distracted and are not focused, thereby missing some lecture material. The Internet-based lesson allows students to pace themselves.

Pearson’s product moment coefficient of correlation is used to measure the correlation between a pair’s overall rank in the class with the difference in post-test scores between the two students. The null hypothesis is that there is no correlation between the benefits of the Internet-lesson and student achievement level. One variable is the difference between the Internet post-test score and the traditional post-test score per pair and the other variable is the pair rank in the class.

**Results and Discussion**

The two hypothesis tests were augmented with further tests to ensure that the methodology was sound and that certain external variables did not interfere with the results of the experiment.

**Primary Test Results**

The first hypothesis questioned whether Internet-based instruction led to better post-test scores than traditional instruction. Tests were performed for each of the five course sections (referred to as Sections A–E) as well as an overall test for all participating students. The results are given in Table I.

First, note that the number of matched pairs varied from 10 (or 20 students) to seven. There were one, two and three students absent for sections C, D and E, respectively. Objectivity required that no attempt be made to match the ‘unmatched’ students. Overall, there were 44 pairs, or 88 students participating in the experiment. Second, the post-test scores for those assigned to the Internet were higher than the traditional in four out of five classes. Overall, 21 Internet students scored higher than their counterpart and 20 traditional students scored higher, with three pairs the same. Finally, none of the $t$-test scores was considered to be statistically significant at the 0.05 level, although the overall tendency is to favour the Internet.

While the null hypothesis cannot be rejected, the results are nonetheless revealing. If the mean scores between the two groups are not statistically different, then neither traditional-based learning nor Internet-based learning will have an advantage over the other in similar situations. In this instance we conclude that one method of instruction
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TABLE I. Dependent samples $t$-tests based on 20 questions (one point each).

<table>
<thead>
<tr>
<th>Section</th>
<th>$n$</th>
<th>Internet Mean</th>
<th>Traditional Mean</th>
<th>Difference</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>14.30</td>
<td>14.10</td>
<td>0.20</td>
<td>0.196</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>16.10</td>
<td>14.00</td>
<td>2.10</td>
<td>1.655</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>14.78</td>
<td>15.44</td>
<td>-0.66</td>
<td>-0.894</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
<td>16.75</td>
<td>15.25</td>
<td>1.50</td>
<td>0.992</td>
</tr>
<tr>
<td>E</td>
<td>7</td>
<td>14.58</td>
<td>14.58</td>
<td>0.00</td>
<td>0.000</td>
</tr>
<tr>
<td>Overall</td>
<td>44</td>
<td>15.23</td>
<td>14.64</td>
<td>0.59</td>
<td>1.232</td>
</tr>
</tbody>
</table>

could be substituted for the other to achieve similar results in student performance. The ramification of this is that the Internet can be a viable alternative to traditional classroom-based learning in fluvial processes, and probably other lessons in introductory physical geography.

The second hypothesis stated that lower-achieving students would benefit more from Internet-based instruction than higher-achieving students. If the hypothesis were to be supported, the difference in post-test scores would have become increasingly positive (favouring the Internet) as the class rank decreased; thus, we expect a positive correlation. The correlation coefficient for $n = 44$ is $+0.163$, which is not significant at the 0.05 level. The weak positive correlation is too low for any claim of statistical significance. Thus, although there is a tendency in the expected direction, we conclude that students who were performing poorly in the class prior to the experiment did not realise a greater benefit from Internet-based learning than traditional-based learning.

Secondary Test Results

It is conceivable that students in the group who took the Internet-based lesson were not at ease because of their unfamiliarity with the pedagogical tool. They may have scored more poorly on the post-test than students in the same group who felt comfortable with Internet use. At the time of the post-test, all students participating in the experiment were asked to rank their comfort level when using the Internet on a scale of 1 to 5, 1 being most comfortable and 5 being least comfortable. If the level of discomfort were high, post-test results would become suspect. A correlation was calculated on the relationship between level of comfort and post-test score for the Internet users. The correlation was $-0.092$ for the 44 students. These results show that a student’s comfort level when using the Internet had no significant effect on that student’s post-test score.

Participating students were also asked whether they had completed a previous course in physical geography prior to the current semester. If the student answered ‘yes’ it was assumed that he/she had been exposed to material on fluvial processes. This variable could have affected the post-test results. Specifically, a student’s score on the post-test could have depended on whether or not that student had had previous exposure to the material in another geography course. Two participating students did not respond to this question, leaving 86 out of 88 possible responses. Of the 86 responses, 61, or 71 per cent, claimed no prior exposure to the material in a geography course. A point biserial correlation was performed to determine whether there was a relationship between a student’s earlier exposure to material on fluvial processes and the post-test score. The correlation coefficient was $+0.025$, or no relationship. Whether or not a student had
prior exposure to the lesson material was not a predictor of the post-test score. These results are interesting because they suggest that students who have learned this material in the near or distant past are not retaining the material well enough to perform better than those who are new to it. Conversely, it is possible that the material is relatively easy to comprehend and therefore those students who have not been exposed to it in the past have little trouble catching up to the same level of knowledge as those who have previously been exposed to the material.

With regard to the Internet-based lesson, students were permitted to take as much time as they felt necessary to learn the material. There was great variability in the amount of time taken on the lesson. The quickest student finished viewing the lesson in 21 minutes while the student taking the greatest amount of time took 91 minutes. The mean time taken for all 44 students who took the Internet-based lesson was 52 minutes. The purpose for collecting these data was to determine whether or not the amount of time taken learning the Internet-based lesson was a predictor of post-test score. Again, a Pearson’s correlation was performed to identify a correlation between the two variables. The r-value was –0.042. These results show that, by and large, the relationship is only slightly negative and not statistically significant. Therefore, the amount of time spent on the lesson did not affect the post-test scores for the Internet-based group.

Conclusions
The central objective of this research was to determine whether Internet-based instruction led to higher student achievement than traditional classroom learning. This experiment was the first to test the effectiveness of Internet-based instruction in introductory physical geography. While prior research shows that students prefer learning on the Internet to traditional classroom learning, there is no evidence that one of the two instructional methods is more successful in achieving student knowledge retention. As a pioneering effort in the field, the results of this research should be accepted with the knowledge that additional experiments of a similar or more rigorous nature must be performed before a great deal of confidence can be placed on their implications.

The results of the experiment show that there was no significant difference in post-test scores between students who learned material on fluvial processes from their classroom instructor, in lecture format, and those who learned the material from an Internet-based lesson. The raw data from the experiment showed a slight tendency for scores to be higher among the group taking the Internet-based lesson.

The implications of these results are of great interest to the future of post-secondary education in geography. First, while not statistically significant, the tendency for post-test scores to favour the Internet must be explored further. Future research in this area may consistently show that Internet-based instruction leads to better student knowledge retention. Should these results be realised, then the Internet could replace traditional instruction in similar types of courses. Based on the results of this research, however, the Internet should nonetheless be considered a viable alternative to traditional classroom instruction in introductory physical geography. Should future research reveal similar results for courses such as this, colleges and universities can be confident that Internet-based instruction does not impede student learning. With that knowledge the number of online courses will undoubtedly increase, particularly if they are not as costly to the university and can enrol more students than a traditional course that requires both an instructor and a classroom. Indeed the results of this and similar research may assist in changing the way geography is offered in post-secondary education. Clearly, start-up
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costs are high for Internet-based instruction, but both economies of scale and spreading costs over the long term point strongly in the direction of Internet-based courses.

The results of this experiment also indicate that the Internet as an instructional tool does not benefit one type of student over another. Specifically, lower-achieving students did not realise a significantly greater benefit from the Internet-based lesson than higher-achieving students. The Internet, therefore, can be an alternative instructional tool to the traditional classroom for students representing a wide variety of academic levels, and can be applied to a geography course as a whole and not just as an instructional aid for students requiring extra assistance in learning.

There are many different possibilities for future research stemming from this experiment. This experiment would benefit from more students, more instructors and different physical geography lessons to further test the Internet as a viable alternative instructional tool in introductory physical geography. The question of long-term knowledge retention is an issue not broached in this paper. To discover whether the Internet is effective in post-secondary education as a whole, researchers in other disciplines must perform similar experiments with their own curricula. Clearly, researchers must take great care, as we have, to assure readers that results are as objective as is possible.

If a body of literature finally supports the Internet as an effective instructional tool, research should turn in the direction of identifying specific variables that are responsible for its success. What is it about the Internet that leads to student learning? Is it self-pacing, graphic animation, interaction with a computer or some other variable? Will the novelty of the Internet wear off at some point? The answer to these questions will help developers of educational technology produce more effective learning tools.

Other research might focus specifically on the effectiveness of distance learning. While the Internet may prove to be a good instructional tool, researchers must look at it in the context of a distance-learning environment. The experiment described in this paper required students to take part in a one-day assignment and tested them while they were together in a computer laboratory on campus. What would the results have been if the exercise was optional and the students were isolated from each other at home? Also, would distance-learning courses prove effective over the course of an entire semester? How many students would simply drop out? What types of courses are most likely to benefit from an Internet approach? These questions must be addressed to understand whether distance-learning courses lead to the same or better student performance than traditional courses. The small sample research presented here shows that Internet-based instruction may be a viable alternative—a parallel approach—that would work as well as conventional instruction.

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NOTE

[1] All materials relevant to this study (lesson, matched pairs determination procedures, post-test, data) are available from the authors upon request.
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