

# Chapter 8

## Laboratories in the Earth Sciences

EDWARD CLOUTIS

University of Winnipeg

### **Introduction**

In reviewing and assessing the importance and role of laboratory exercises in earth sciences, we begin with defining the scope of this review. The ensuing discussion is limited to fields of study that have traditionally formed the core of studies of the solid earth, specifically geology, soil science, and geomatics (remote sensing and geographic information systems). Related subjects, such as meteorology and oceanography, have not been reviewed. It also seems reasonable to begin with some general observations which guide the ensuing discussion. Earth science as a discipline is extremely diverse and no consistent definition is available. A robust earth sciences curriculum includes aspects of more traditional disciplines, such as geology, geography, and environmental science. It also generally includes courses that are heavily oriented toward rigorous mathematical treatments (e.g., remote sensing, image processing, geographic information systems), courses with an emphasis on observational inputs (e.g., geomorphology), courses which benefit from hands-on exercises (e.g., mineralogy, petrology), and combinations of theory and observation (e.g., structural geology). In this sense, making the best use of laboratory components in earth science distance

education courses can benefit from studies in other disciplines, but earth science possesses some unique characteristics.

In a simplified sense, earth science is a blend of theory and observation. As traditionally practised, earth science attempts to bring scientific rigour to the messy reality of Mother Nature. The development of theories in earth science is normally driven by the desire to understand physical processes, and theories are constantly refined on the basis of observational inputs. The goal is to determine underlying mechanisms of geological processes and to develop predictive explanations. A good example of this is the field of seismology. The long-term goals of seismology are to move from observations (e.g., that earthquakes occur in discrete geographic regions) to understanding why this is so (borrowing observations from other disciplines, such as physics and chemistry), and if successful theoretical mechanisms can be developed, to use these predictive tools for earthquake forecasting, while also feeding back into refining the models of the causes of earthquakes. Earth science is necessarily grounded in a nearly ubiquitous requirement that observation is an essential component of the discipline.

As a result of the diversity in what is termed “earth sciences,” it is difficult to develop broadly applicable prescriptions or guidance in terms of optimum delivery methods for associated laboratory course components, or even their appropriateness. Perhaps as a result of the diversity of earth sciences, there is a general paucity of research on the use and effectiveness of earth science laboratories as a component of distance education (e.g., Shea, 1999). Consequently, the ensuing discussion blends reviews of relevant studies, results from affiliated disciplines, and anecdotal observations.

## **General observations**

The scattered literature on distance delivery as it relates to earth sciences, and in particular on associated laboratory components, either directly or indirectly recognizes the importance of laboratory

work in earth science education. Many distance education earth science courses have their laboratory/field components delivered by traditional face-to-face methods; this usually requires that the students be present at a central location for a specified period of time. Other earth science courses supplement multimedia/hypermedia course materials with physical objects, such as rock and mineral samples in geology courses (e.g., Andris, 1996; Mose & Maney, 1993), or periodic face-to-face visits or instruction (Butler & Gore, 1997; Mose & Maney, 1993). This seems to be driven by a number of imperatives: (1) that laboratory/field work is considered to be an essential component of earth science education; (2) that proper training in field-based earth science subdisciplines is driven by coupling “book-learning” to laboratory/field work; (3) that a “local perspective” is a useful teaching approach (i.e., enabling students to see how concepts learned in class are relevant to their local environment or immediate surroundings); and (4) that much earth science knowledge is observation-driven or -enabled. In addition, it appears that inclusion of distance-based visual components after exposure of students to hands-on laboratory exercises further facilitates learning and retention.

Previous researchers have found that earth science students have diverse learning styles (Andris, 1996; Healey et al., 2005), and that this affects student satisfaction, performance, and method of utilization of hypermedia-based course materials (Andris, 1996). This may actually be of benefit to earth science distance education, as many earth science subdisciplines are an amalgam of theories/concepts and observations, and hence lend themselves quite readily to delivery via different pedagogical approaches; the same learning outcomes can be accessed via different mechanisms and pathways (Bishop, Schroder & Moore, 1995; Andris, 1996; Healey et al., 2005; Reuter, 2007). This potential diversity in delivery styles comes with a price: learning outcomes and skills development must be clearly enunciated and considered in light of the proposed teaching strategies (Blowers, Sarre & Smith, 1992; Williams, 1992; de Caprariis,

2000; Reed & Mitchell, 2001; Harvey, 2002), and an estimate of expected time requirements on various aspects of a course should be provided to students (Blowers, Sarre & Smith, 1992). In addition, navigation through hypermedia-based materials should be straightforward (Bishop, Schroder & Moore, 1995; Lemke & Ritter, 2000). Course delivery mechanisms should be cognizant of the characteristics of the target audience (Buckley & Donert, 2004), which may differ from those of traditional undergraduate students (Dibiase, 2000; Solem et al., 2006). It also appears that a variety of learning and contact methodologies need to be employed to ensure effective learning (Tremblay, 2006). Related to this is a perception that multimedia and internet resources can serve as effective supplemental teaching tools (Warf, Vincent & Purcell, 1999; Schroder et al., 2002; Veal, Brantley & Zulli, 2004).

Distance delivery of earth science programs often involves some component of group work. While admirable in concept, for example by promoting a sense of community among geographically dispersed students, its record in terms of providing a satisfactory learning experience appears to be negative on balance. Common shortcomings include communication problems, scheduling conflicts, uneven levels of contribution from team members, and difficulties in assigning proper levels of credit to individual team members (e.g., Shea, 1995; Reed & Mitchell, 2001; Buckley & Donert, 2004; Vassala, 2006).

### *Essential need for field/laboratory/hands-on work*

Here we subdivide earth science courses into “technique” and “physical geography” categories. Technique courses are those that emphasize development of analytical skills for diverse earth science applications. Courses under this category include remote sensing/image processing, and geographic information systems (GIS). These tools are applicable to a wide range of earth science issues, such as environmental monitoring and geological exploration. For these courses, the emphasis is on the technique as opposed to the ultimate

end use. Image processing and geographic information systems are now almost exclusively computer-based techniques, and this migration from analogue to digital environments has transformed their utility to the point where they are considered core capabilities in an earth scientist's "tool kit" of skills.

To become proficient in utilizing image processing and geographic information systems, hands-on laboratory exercises provide two significant benefits: (1) understanding the essential capabilities and limitations of these techniques in a digital environment; and (2) providing an understanding of how image processing and GIS concepts are applied operationally (Bishop & Schroder, 1995). A third benefit is that students become proficient in digital data analysis utilizing a particular software package. Working with a different software package is likely facilitated by having had some exposure to some form of image processing/GIS software.

As mentioned earlier, one of the overarching objectives of the earth sciences is inherent in its title: applying scientific techniques to understanding the earth. In the physical geography subdisciplines, being able to relate scientific principles to direct observation is widely considered to be an essential element of earth sciences (e.g., Gober, 1998). Field work provides a "sense of place" (Gober, 1998) and is frequently cited as one of the most enjoyable aspects of earth science courses or programs of study (e.g., Kern & Carpenter, 1984, 1986; Moles, 1988; Camman, 1992; Gober, 1998; Vassala, 2006). There is also evidence that incorporating a field component into earth science courses results in higher overall program satisfaction (Kern & Carpenter, 1984).

Observation is an important component of physical geography. For this reason, laboratory work and field schools remain essential components of earth science education (e.g., Camman, 1992; Mose & Maney, 1993). Depending on resources and other factors, observation-based laboratory or field work can be undertaken in a traditional setting or via multimedia delivery (Schroder et al., 2002; Buckley & Donert, 2004). The proliferation of multimedia

educational resources for earth sciences allows for a much richer visual experience for students, reducing the traditional gap between merely seeing and experiencing (Lemke & Ritter, 2000; Schroder et al., 2002). Newer publicly available resources, such as Google Earth, whose utility in earth science distance education has not yet been assessed, and third party utilities built upon this resource, can also be used to greatly enrich the visual aspects of earth science education.

Some aspects of earth science education are more sensory in nature than mere observation. The best example would be the laboratory component normally associated with mineralogy and petrology. Training in these areas normally includes working with rock and mineral hand specimens, and other more visual techniques, such as examining thin sections with petrographic microscopes. The latter could be delivered reasonably effectively via appropriate multimedia; for example, virtual thin sections and how individual minerals display different interference figures under plane polarized light as the sample stage is rotated could be presented in a video or still picture mode with, likely, little negative impact on comprehension.

In the case of hand specimen examination, rock and mineral identification is often based on a number of identifying characteristics. Concepts such as colour, cleavage, and crystal habit could be presented using visuals in distance delivery mode, but other key mineral identification properties such as specific gravity, hardness, taste, and lustre are more amenable to direct sensation. It is difficult to convey the lustrous feel and softness of talc, the greasy feel of graphite, the bitter taste of sylvite, the surprising heaviness of barite, or the iridescent nature of labradorite through means other than providing actual mineral specimens to students. This also allows students to see how multiple properties are often necessary for proper mineral identification. Multiple properties often “go together” to enable mineral identification. This is one of the main reasons that introductory level geology courses at Athabasca

University include a rock and mineral specimen kit as part of the course materials.

A similar rationale can be applied to historical geology courses. An important aspect of these courses is fossil identification, which serves a number of purposes: to illustrate principles of extinction (clearly unfamiliar species once existed on the earth) and evolution/succession (how body plans and species have changed over time), and to show how the process of fossilization can radically alter (or preserve) once-living organisms. While images can convey much of what is important concerning fossils, an opportunity to physically handle remains of long-dead organisms is both satisfying and compatible with almost any form of distance delivery.

Some courses within an earth science curriculum require mastering certain mathematical/geometric concepts. The most apparent of these are structural geology and some aspects of cartography. Becoming proficient in structural geological analysis requires mastering, or at least understanding, the basic principles of a stereonet or Wulff net. Essential concepts such as small and great circles are difficult to understand initially. However, the use of analogies has proven to be useful for student understanding of stereonets and basic types of map projections. The basic analogy which is used to aid in student comprehension of stereonets and map projections is to imagine (or actually construct) a hemisphere or sphere with a light bulb in the centre (a bowl can be used for this purpose with line of latitude and longitude drawn on its surface). A piece of paper placed outside but in close proximity to the sphere/hemisphere/bowl then allows students to visualize how lines of latitude and longitude appear in projection. This follows from the principle that projection is required to represent a three-dimensional curved surface (e.g., the earth's surface) on a two-dimensional (flat) surface. Students can also use the sphere/hemisphere-piece of paper analogy to understand how essential properties of features on, or properties of, the earth's surface (direction, distance, shape, area) may be distorted depending on the particular type of projection

that is used. Cylindrical projection and its inherent distortions can be visualized by observing how lines of latitude and longitude may be distorted when the piece of paper used for the projection is formed into a cylinder and placed around the sphere/hemisphere. Similarly, the piece of paper can be formed into a cone (for conical projection) or laid flat (for planar projection) and the resulting distortions observed.

## **Review of previous studies**

In this section we review the available literature on distance delivery of earth science laboratories. Once again, because of the diversity of what constitutes earth sciences, the relevance of most of these studies is likely limited to only some aspects of earth science. Appendix provides a more detailed review of previous studies on an individual basis.

The review of previous studies has found that there are few studies that critically assess the outcomes of distance education in the earth sciences: the bulk of the studies discuss anecdotal data. A further shortcoming of many of the previous studies is that they often deal with selected components of earth sciences courses; many of the studies involve assessment of courses in which only selected components are delivered via distance education, most commonly the laboratory or field-study component.

Nevertheless, as this review shows, there is much anecdotal evidence that earth science courses can be effectively delivered via distance education, provided that such offerings are well designed and take into account the needs of the students. Hands-on components, either in the form of laboratory exercises or field work, are also generally well received. Group assignments generally fare less well with students, although there are significant variations in student satisfaction, and this seems to be a function of the students' backgrounds and expectations.

## Lessons learned

Some common themes emerge from the studies available on distance delivery of earth science courses, and many of these themes transcend political boundaries and specific courses. One of the most consistent observations is that some level of face-to-face contact with course instructors or tutors is beneficial (Camman, 1992; Butler & Gore, 1997; Warf, Vincent & Purcell, 1999; Buckley & Donert, 2004). Related to this is the consistent positive feedback from students concerning field trips and related group activities (Kern & Carpenter, 1984, 1986; Camman, 1992; Finstick, 1997; Gober, 1998; Vassala, 2006).

An additional common theme is that careful consideration needs to be given to the interrelationships between learning objectives, skills development, mode of delivery, and support services (Blowers, Sarre & Smith, 1992; Gerber & Lundin, 1992; Williams, 1992; Reed & Mitchell, 2001; Harvey, 2002; Lieblein et al., 2005; Reuter, 2007). Continuous or periodic assessment of learning progress, through self-testing or other mechanisms, is also a useful aspect of distance delivery (Camman, 1992).

An additional theme that commonly arose was the need to keep course materials “fresh” and engaging, and this can commonly be achieved by including course materials that are of local or direct relevance to students or are current (Camman, 1992; Lieblein et al., 2005). In earth sciences, this is probably easier than other disciplines, as many natural phenomena have an earth science origin (e.g., volcanic eruptions, earthquakes, tsunamis) and such stories appear frequently in the media.

Much of the past research on distance delivery of earth sciences is anecdotal. Many potentially valuable earth science distance education programs seem to suffer from a lack of systematic evaluation and follow-up (e.g., Camman, 1992; McDowell & Yockney, 1992; Neal, 2007). Due, probably in part, to the lack of systematic evaluations of distance-delivered earth science courses, their effectiveness is still somewhat uncertain (e.g., Warf, Vincent & Purcell, 1999; Reed & Mitchell, 2001).

At a more anecdotal level, certain approaches have been found to be very effective at enhancing student comprehension of certain concepts or course materials. In the case of structural geology, having students physically construct a globe and experiment with it to understand concepts of projections and stereonet appears to be particularly effective. It has also been found that some sort of field geology component can be undertaken by students regardless of their location. This could involve analysis of stratigraphy in areas with appropriate geological environments, or something as simple as examining rock types used to make headstones in a cemetery or a visit to a local museum, for students located in areas of “bland” geology. Appropriate exercises can be constructed that allow for some level of field observation in nearly any environment. An ability to conduct field observations in a locally relevant context is found to be advantageous to students and builds on the more rigorous studies cited above that demonstrate the benefits of local relevance in earth science courses.

The type of laboratory exercises that are incorporated into an earth science curriculum or course must of course be driven by the learning objectives. Some courses lend themselves well to the use of physical “props,” in particular mineralogy and petrology. There appears to be no effective substitute for students being given the opportunity to physically handle geological samples. In the larger context, and as discussed above, laboratory/field-based activities are felt to be particularly important in the earth sciences because of the essential coupling between theory, observation, and understanding that underpins much of the earth sciences.

Some earth science programs, such as that at Athabasca University, permit students to begin a particular course at the start of any month of the year. As a result, group projects are not feasible in this setting. However, effective group work has been found to be difficult to implement in a number of cases (Shea, 1995; Reed & Mitchell, 2001; Vassala, 2006), and thus a lack of group interaction is not considered to be an impediment to effective earth science education.

Returning momentarily to the issue of distance versus face-to-face instruction, the success or satisfaction level of a particular student will depend on their particular circumstances, and a number of studies have shown that some types of students perform better in a distance education environment than they would in a traditional setting (Camman, 1992; Mose & Maney, 1993; Warf, Vincent & Purcell, 1999; Dibiase, 2000).

## **Conclusions**

With such a wide-ranging topic as earth sciences, it is difficult to draw universally applicable conclusions. This difficulty is coupled to the general lack of rigorous evaluations of the effectiveness of distance-delivered earth science courses. However, some general observations can be made from the preceding overview:

- field-based study of some sort appears to be beneficial for earth science students
- geology courses should include “hands-on” exercises for students involving the use of rock/mineral/fossil samples
- techniques-based courses, such as structural geology, remote sensing/image processing, and geographic information systems, should include a laboratory component, as this provides a number of simultaneous benefits
- courses should be subdivided into discrete modules which, while allowing for a logical flow, facilitate updating and revision
- all aspects of an earth science laboratory (e.g., learning outcomes, time requirements, student expectations, course materials) need to be well integrated to ensure student satisfaction and skills development

There appear to be no major impediments to distance delivery of effective earth science laboratories. It is, however, imperative that

earth science laboratory courses be well designed prior to delivery, and constantly evaluated in terms of effectiveness and student satisfaction.

## REFERENCES

- Andris, J.F. (1996). The relationship of indices of student navigational patterns in a hypermedia geology lab simulation to two measures of learning style. *Journal of Educational Multimedia and Hypermedia*, 5, 303–315.
- Bishop, M.P., Schroder Jr., J.F., & Moore, T.K. (1995). Integration of computer technology and interactive learning in geographic education. *Journal of Geography in Higher Education*, 19, 97–110.
- Blowers, A., Sarre, P., & Smith, D. (1992) Exploring interdisciplinary issues at a distance: Teaching environment at the Open University. In R. Gerber & M. Williams (Eds.), *Distance education and geography teaching*, (pp. 26–33). Swansea, Wales, United Kingdom: Department of Education, University College of Swansea.
- Buckley, C., & Donert, K. (2004). Evaluating e-learning courses for continuing professional development using the Conversational Model: A review of UNIGIS. *European Journal of Open, Distance and E-Learning*, 2004. Retrieved February 24, 2009 from: [http://www.eurodl.org/materials/contrib/2004/Buckley\\_Donert.html](http://www.eurodl.org/materials/contrib/2004/Buckley_Donert.html)
- Butler, J.C., & Gore, P. (1997). Another node on the internet. *Computers & Geosciences*, 23, 607–608.
- Camman, M. (1992) Telelearning project. In R. Gerber & M. Williams (Eds.), *Distance education and geography teaching*, (pp. 71–93). Swansea, Wales, United Kingdom: Department of Education, University College of Swansea.
- de Caprariis, P.P. (2000). Creating or adapting courses for on-line presentation. *Journal of Geoscience Education*, 48, 673–678. Retrieved February 24, 2009 from: <http://www.nagt.org/files/nagt/jge/abstracts/v48n5p673.pdf>
- Dibiase, D. (2000). Is distance education a Faustian bargain? *Journal of Geography in Higher Education*, 24, 130–135.
- Finstick, S.A. (2002). Field trips — their importance in an undergraduate general education distance learning geology course. Presented at: 54th Annual Meeting of the Geological

- Society of America; Cedar City, IO, USA, May 7–9, 2002. Abstract 34015.
- Foote, K.E. (1999). Building disciplinary collaborations on the World Wide Web: Strategies and barriers. *Journal of Geography*, 98, 108–117.
- Gerber, R., & Lundin, R. (1992). Strategies for distance education in geography. In R. Gerber & M. Williams (Eds.), *Distance education and geography teaching*, (pp. 108–127). Swansea, Wales, United Kingdom: Department of Education, University College of Swansea.
- Gerber, R., & Williams, M. (Eds.) (1992). *Distance education and geography teaching*. Swansea, Wales, United Kingdom: Department of Education, University College of Swansea.
- Gober, P. (1998). Distance learning and geography's soul. *AAG Newsletter*, 33(5), 1–2.
- Harvey, L. (2002). The end of quality?. *Quality in Higher Education*, 8, 5–22.
- Healey, M., Kneale, P., Bradbeer, J., with other members of the INTL Learning Styles and Concepts Group (2005). Learning styles among geography undergraduates: An international comparison. *Area*, 37, 30–42.
- Kern, E.L., & Carpenter, J.R. (1984). Enhancement of student values, interests and attitudes in earth science through a field-oriented approach. *Journal of Geological Education*, 32, 299–305.
- Kern, E.L., & Carpenter, J.R. (1986). Effect of field activities on student learning. *Journal of Geological Education*, 34, 180–183.
- Lemke, K.A., & Ritter, M.E. (2000) Virtual geographies and the use of the internet for learning and teaching geography in higher education. *Journal of Geography in Higher Education*, 24, 87–91.
- Lieblein, G., Moulton, M., Sriskandarajah, N., Christensen, D., Waalen, W., Breland, T.A., Francis, S., Salomonsson, L., & Langer, V. (2005). A Nordic Net-based course in agroecology — integrating student learning and teacher collaboration. *European Journal of Open, Distance and E-Learning*. Retrieved February 24, 2009 from: <http://www.eurodl.org/materials/contrib/2005/Lieblein.htm>
- McDowell, W., & Yockney, J. (1992). Distance learning: Great Britain's Royal Navy and the study of geography. In R. Gerber & M. Williams (Eds.), *Distance education and geography teaching*, (pp. 57–70). Swansea, Wales, United Kingdom: Department of Education, University College of Swansea.

- Moles, J.A. (1988). The classroom and the field: A necessary unity. *Journal of Experiential Education*, 11(2), 14–20.
- Mose, D., & Maney, T. (1993). An experiment in distance learning of geology. *Journal of Computers in Mathematics and Science Teaching*, 12, 5–18.
- Neal, E. (2007). A critical response to Jerald G. Schutte’s virtual teaching in higher education: The new intellectual superhighway of just another traffic jam? Retrieved February 24, 2009 from: <http://www.informatikdidaktik.de/HyFISCH/Teleteaching/VirtualTeachingCritics.html>
- Reed, M., & Mitchell, B. (2001). Using information technologies for collaborative learning in geography: a case study from Canada. *Journal of Geography in Higher Education*, 25, 321–339.
- Reuter, R. (2007) Introductory soils online: An effective way to get online students in the field. *Journal of Natural Resources and Life Sciences Education*, 36, 139–146.
- Schroder Jr., J.F., Bishop, M.P., Olsenholler, J., & Craiger, J.P. (2002). Geomorphology and the World Wide Web. *Geomorphology*, 47, 343–363.
- Shea, J.H. (1995). Problems with collaborative learning. *Journal of Geological Education*, 43, 306–308.
- Shea, J. (1999). Education “research” at the annual meeting. *Journal of Geoscience Education*, 47, 110.
- Solem, M., Chalmers, L., Dibiasse, D., Donert, K., & Hardwick, S. (2006). Internationalizing professional development in geography through distance education. *Journal of Geography in Higher Education*, 30, 147–160.
- Tremblay, R. (2006). Technical evaluation report. 55. Best practices and collaborative software in online teaching. *International Review of Research in Open and Distance Learning*, 7(1). Retrieved February 24, 2009 from: <http://www.irrodl.org/index.php/irrodl/article/view/309/513>
- Vassala, P. (2006). The field study as an educational technique in open and distance learning. *Turkish Online Journal of Distance Education*, 7(4), 10–17. Retrieved February 24, 2009 from: [http://tojde.anadolu.edu.tr/tojde24/articles/article\\_1.htm](http://tojde.anadolu.edu.tr/tojde24/articles/article_1.htm)
- Veal, W., Brantley, J., & Zulli, R. (2004). Developing an online geology course for preservice and inservice teachers: Enhancements for online learning. *Contemporary Issues in Technology and Science Teacher Education*, 3, 382–411. Retrieved February 24, 2009 from: <http://www.citejournal.org/vol3/iss4/science/article1.cfm>

- Warf, B., Vincent, P., & Purcell, D. (1999). International collaborative learning on the World Wide Web. *Journal of Geography*, 98, 141–148.
- Williams, M. (1992) Distance learning and geographical education: Introduction. In R. Gerber & M. Williams (Eds.), *Distance education and geography teaching*, (pp. 1–8). Swansea, Wales, United Kingdom: Department of Education, University College of Swansea.

## APPENDIX — REVIEW OF PREVIOUS STUDIES

Andris (1996) conducted a hypermedia geology lab simulation which utilized actual rock and mineral samples as part of the laboratory. He found that students' learning style affected how students utilized the accompanying hypermedia resources.

Bishop, Schroder & Moore (1995) provide a discussion of integrating internet-based resources into earth science teaching. They concluded that such materials are proliferating rapidly and provide new opportunities for distance education beyond those available through more traditional media, as well as being applicable to a wide range of pedagogical tasks.

Blowers, Sarre & Smith (1992) reviewed the development of interdisciplinary courses in environment science at the Open University in the United Kingdom. They found that well-developed objectives and time requirements are essential elements for such courses.

Buckley & Donert (2004) conducted a review of the UNIGIS program from the perspective of continuing professional development and student interaction. They found that the program delivers many benefits but that some shortcomings remain.

Butler & Gore (1997) briefly reviews his delivery of introductory-level geology courses via distance delivery. He found that periodic face-to-face visits were beneficial from a number of perspectives. These courses were also supplemented by traditional face-to-face laboratories.

Camman (1992) provides an overview of a telelearning project in geography at the secondary school level. She found that well-planned and delivered course materials were essential to student satisfaction and that group projects and field excursions were well received by the students.

De Caprariis (2000) discusses the general lack of research on distance

education in earth sciences. He has determined that various modes of feedback should be included in course design. Course design should also include careful consideration of objectives, skills, and teaching strategies.

Dibiase (2000) discusses some of the larger issues surrounding geography distance education. He contends that educators have an obligation to serve as wide a constituency as possible. He also finds that distance learners are qualitatively different from traditional undergraduate students and that they can be properly served by distance delivery.

Finstick (2002) discusses the use of field trips in the context of an undergraduate distance learning course. The field work component of the course was consistently rated as one of the most enjoyable parts of the course.

Foote (1999) presents a discussion of how the Internet can be used to develop collaborative distance offerings in geography. He has found that the multiplicity of resources allows for the development of high-quality courses and laboratory modules that can be widely adopted.

Gerber & Lundin (1992) reviewed the findings of a committee on distance education. It was found that important elements in distance delivery of geography programs include carefully developed materials, small modules of study, the availability of counselling, and credit transferability. In addition, the particular needs and learning styles of students need to be considered during course development.

Gerber & Williams (1992) provided a compendium of studies and presentations conducted by the IGU Commission on Geographical Education. Many of the contributions discuss specific examples of distance delivery of geographic courses. While some of the findings, particularly as they relate to the impact and use of computer resources for distance delivery, are now somewhat dated, it is an excellent overview of some of the early efforts in this area.

Gober (1998) presents an impassioned case for including field work as a component of earth science education. Such work provides a number of perceived benefits, including developing a “sense of place” among geography students.

Harvey (2002) provides a summary of discussions and presentations of papers presented at a seminar entitled “The End of Quality,” held in 2001. One of the themes that emerged from this meeting is the need to

pay close attention to course organization and clarity in the design of distance education courses.

Healey, Kneale & Bradbeer (2005) conducted a study of learning styles among geography undergraduate students. They found that students in this group possess different learning styles, as expected, and that the proportion of different learning styles varies among different countries.

Kern & Carpenter (1984) describe results of an experimental introductory level earth science course delivery study where students took an essentially identical course, with or without a fieldwork component. Students who participated in the fieldwork-enhanced course reported greater levels of enjoyment and interest.

Kern & Carpenter (1986) report results from a study similar to that reported in their 1984 paper. In their 1986 study both groups of students had identical levels of lower-order learning, while the group enrolled in the section with a fieldwork component demonstrated significantly higher levels of comprehension, application, analysis, and synthesis of knowledge.

Lemke & Ritter (2000) discuss the use of the Internet for distance education in geography. They found that this is a potentially valuable educational resource, but that instructors must pay careful attention to ensure that it is used as an effective teaching tool.

Lieblein et al. (2005) conducted an evaluation of a Net-based ecology course offered through Nordic Net. This study involved students from a number of countries and diverse backgrounds. Among their findings was that providing a local perspective to the course (in this case farming practices), even if the local perspective was used for comparison with the case study used in the course, was beneficial to the learning experience of the students. They also emphasized the importance of designing the course starting from clearly defined learning objectives.

McDowell & Yockney (1992) reported on distance delivery of geography courses for the British Royal Navy. They concluded that effective geography teaching can be provided for students in a wide variety of geographic and operational settings.

Moles (1988) offers personal perspectives on the values to be derived from experiential teaching (i.e., field work). He found that the inclusion of a field-based component to his agricultural courses added immeasurably to the students' educational experiences.

Mose & Maney (1993) provide a discussion of an introductory level geology course offered via distance learning. They found that students who utilized computers for communications showed improvements in their grades over the first (non-computer) semester.

Neal (2007) provides a brief critique of an earlier unpublished study by J.G. Schutte concerning serious errors in evaluating distance versus direct learning courses. He found that the distance and direct learning courses were very different and hence meaningful comparisons could not be made.

Reed & Mitchell (2001) report on their experiences in designing and delivering a distance collaborative learning course in geography. They found that a number of challenges arose in this exercise, with a major issue being the need to clearly define objectives and expectations.

Reuter (2007) discusses the success in offering hands-on/distance delivered lab components of an introductory level soil science course. They found no significant differences between the distance delivered and face-to-face versions of this course. The distance education laboratory component was designed to ensure that students could perform the necessary experiments through simplified experiments.

Schroder et al. (2002) discuss resources available on the World Wide Web that are relevant to teaching geomorphology, either by direct or distance delivery. They find that the use of such resources can enhance a student's learning experience, but that they must be used judiciously.

Shea (1995) described anecdotal evidence gathered over many years of teaching, documenting a number of shortcomings associated with collaborative learning in the earth sciences. These shortcomings include scheduling constraints and unequal levels of participation by team members.

Shea (1999) bemoans the general lack of rigorous education research in the earth sciences. While the volume of such work has increased its usefulness has not.

Solem et al. (2006) discuss the issues behind international professional development in geography through distance education. They examine the potential of distance learning and conclude that it can be used to reach non-traditional learners and other underserved constituencies. They also identify a number of challenges, including quality assurance and inter-institutional certification.

Tremblay (2006) provides an overview of collaborative software available for distance delivery. He believes that a number of tools should be available or used to ensure that a rewarding learning experience is provided to all students.

Vassala (2006) provides some lessons learned from the use of field work in open and distance learning in geology. She finds that field study was enthusiastically embraced by her students, but that special care must be taken to effectively undertake field studies given the external demands on students' time.

Veal, Brantley & Zulli (2004) provide a discussion of techniques for developing and delivering an online geology course. They found that interpersonal interactions were perceived by the students as being influential to their learning. As with other distance delivery courses, a number of procedural hurdles needed to be overcome.

Warf, Vincent & Purcell (1999) discuss the use of the Internet for international collaborative learning in geography. Among their conclusions, they believe that Web-based interactive learning is an "imperfect substitute" for traditional face-to-face interaction.

Williams (1992), in his introduction to the volume by Gerber & Williams (1992), discusses some of the essential elements that need to be considered during course development for distance education in geography. He concludes that geography distance education can be adapted for in-service teacher education, provided that learning objectives are identified initially, followed by needs analysis and determination of appropriate delivery methods and support services.