Introduction

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We've arranged a civilization in which most crucial elements profoundly depend on science and technology.
• Carl Sagan

The importance of science education and science literacy is rising rapidly. As a society and as individuals, having access to it has become absolutely vital. Established educational routes of the past have served us well, but their limitations are becoming more apparent. There is very real and growing demand by students for more flexible approaches to learning science. Online and distance delivery offers practical alternatives to traditional on-campus education for students facing barriers such as classroom scheduling, physical location, and financial status, as well as job and family commitments. In short, it is becoming a viable and popular option for many on- and off-campus students in meeting their educational goals.

As educators in science and science-related disciplines, we recognize that pursuing online and distance delivery not only provides equal access for students, but also gives us several more teaching options that can lead to quality learning. This book embodies the experience of educators around the globe and presents approaches that have been successful in teaching science online and at a distance. We hope it will inspire a positive change in science and science-related education.

The challenge

Teaching science online and at a distance is more demanding than and certainly not as common as in many other disciplines. There are a variety of reasons why this might be the case. First of all, the concepts and skills that a student must master are numerous, complex, and often build on each other. Crafting an effective learning environment for a science student is not trivial for any mode of delivery. Secondly, science teachers do not necessarily always have sufficient technological savvy or logistical support to create their courses. The myth of free multimedia resources that can be created out of thin air is alive and well. To make matters worse, many teachers still want to go it alone with a sort of 'lone ranger' attitude. While this might be okay for a chalk talk in the classroom, many modern courses with multimedia resources really do require a team approach to develop. Thirdly, the literature available specific to online and distance delivery of science courses (especially the laboratory component) has appeared in widely scattered sources. There is frankly little organized pragmatic information readily available in the sciences for distance educators. The fourth reason is primarily found at the post-secondary level. Science educators, who bring with them very strong disciplinary and research backgrounds, often do not have any formal pedagogical training. To develop their teaching skills faculty rely on their own learning experiences, model colleagues, and research the literature. This self-taught and learning-on-the-job approach brings variable results at best. Finally, there is the very real problem surrounding the practical or laboratory component. A strong laboratory component is at the heart of many science courses, but it is also one of the more difficult components to deliver effectively at a distance.

The challenge of teaching science online and at a distance is very real. There are no simple answers or silver bullets for any of these concerns. However, as you go through this book you will quickly see you are not alone and many problems will sound familiar. You will also discover some interesting approaches and clever solutions that might be adapted to your own science courses.

Who is this for?

This book is aimed at teachers and administrators in the natural and physical sciences who are working with new teaching technologies, multimedia, delivering courses at a distance, or exploring blended and flexible learning to complement traditional lecture settings. This would include schoolteachers, college instructors, university professors, and senior administrators.

It was our intention to include elements of both theory and applied information in an effort to set context and be of practical use. This book is not meant to be either a rigorous distance education theory book or a step-by-step "how-to" guide of educational technology. However, it does present a survey of current practices and offers a solid foundation for anyone involved in teaching science online or at a distance. We feel it also provides some ideas and guidance for related disciplines in the health sciences, computing sciences, and engineering, which share many of the same challenges.

Opening the gate

We are taking an open approach in this book. What do we mean by open? We have certainly tried to be broad and representative in our approach in assembling the chapters. Our educational experts, the authors and reviewers of this book, are both scientist and non-scientist, they come from diverse parts of the world, and they are from various types of institutions (traditional, as well as open and distance learning). Although our selection is not exhaustive, we have also tried to find examples from different disciplines among the natural and physical sciences, and in some cases discussions within the chapters have touched slightly on other fields such as health sciences, computing sciences, and engineering. While this is arguably academically open in theory, there is also a very practical component to our interpretation of openness.

Consistent with promoting a collegial atmosphere and in the spirit of sharing knowledge, we also want to freely share our work. It is being published by an open university and we are delighted that it is an open-source licence format. We agree with many of the ideals and observations on open access set out in Athabasca University's first open book *Theory and Practice of Online Learning* (Anderson & Elloumi, 2004). We have also seen the positive results of open publications in terms of access, catalyzing ideas, and dramatically advancing research. Our hope is that this book will not only disseminate the collective efforts of its authors, but will strongly encourage further discussions and other open works to help bring about a positive change in science and science-related education.

So, knowing that an open gate can let things in as well as out, we choose to open it wide — enjoy!

Major themes

We have organized this book into three major sections or themes, entitled simply Learning, Laboratories, and Logistics. They are the building blocks meant to address common interests and concerns in delivering science online and at a distance. It is important to remember that these three themes are not totally independent of each other. In fact, they are very much interrelated and often build on each other. However, each one represents and emphasizes an aspect worthy of serious consideration in most fundamental undergraduate science courses.

LEARNING

It is no accident that we start here. The aim of this section is to identify, introduce, and discuss key theoretical concepts that inform teaching online and at distance. Laying the foundation for discussions in later chapters, it takes a generalist approach and is aimed primarily at scientists who are now teaching. It is not meant to be an advanced theory course in education by any means. On the contrary, the chapters under the Learning theme, which are written in the context of current issues, are intended to give the reader an appreciation of the challenges involved and the pedagogical underpinnings of the approaches used to meet them.

Chapter 1: *Interactions Affording Distance Science Education*

The role of the various interactions students encounter in their learning process is analyzed and the challenges of enhancing this in the distributed and mediated learning environment are explored. A good understanding of interactions is vital to any distance educator and becomes even more important when considering the science laboratory. Epistemological assumptions usually place a high value on the role of human interaction. While this can and does lead to both formal and informal learning, other forms of interaction can also lead to learning. How those interactions are ultimately supported and encouraged through strategies offered by new technologies and application of social software is of great interest and importance.

Chapter 2: *Learning Science at a Distance: Instructional Dialogues and Resources*

The theme of interactions is continued in this chapter from the perspective of the role of instructional dialogues and resources. A theoretical framework is provided within which questions about the factors that influence amount of dialogue or the correlation of dialogue and learning outcomes can be explored. To this end, the authors summarize a series of their own studies on chemistry and physics students to illustrate and examine the framework. One key point, emphasized throughout the chapter, is that this is a universal approach to all modes of educational delivery, where online and distance education are included.

Chapter 3: *Leadership Strategies for Coordinating Distance Education Instructional Development Teams*

The elements of good instructional design are introduced through a brief historical review followed up by a case study discussion on leading a DE instructional team. The lone ranger myth of the teaching professor is quickly dispelled, as one recognizes how complex components of content, design, and technology are skilfully woven together by a group of experts. One also realizes that this parallels the world of scientific research, where the shift from the lone genius to a team approach has not only become preferred, but very necessary.

Chapter 4: *Toward New Models of Flexible Education to Enhance Quality in Australian Higher Education*

Although presented as a case study of teaching engineering and technology at a major Australian university, many of the goals, challenges, and applications of a flexible delivery model are universal. In addition to providing an excellent review of the considerations around flexible learning, this chapter raises two important points. First, the boundaries between the traditional silos of distance, open, online, and face-to-face education are being blurred. There is gravitation to a more blended approach. Secondly, driven by external considerations, the flexible delivery model is a student-centred approach that is not limited to open universities and their ilk, but is also seriously being contemplated at more traditional institutions worldwide.

LABORATORIES

Although this section is entitled 'laboratories,' the ideas presented are equally applicable to other forms of applied learning components such as clinical or field work. The design of any laboratory component is often undertaken to meet a variety of aims. The most general aim is the reinforcement of course concepts through illustration and making it real for the student. A number of different means have been employed by science educators to deliver an effective laboratory component at a distance. These include laboratory simulations (virtual laboratory), remote controlled laboratories, and home-study laboratory kits, as well as concentrated regional and on-campus supervised laboratory sessions or fieldwork. Without a doubt the most researched, discussed, and presented area of education among science teachers, in general, is the practical component. This is only amplified when that activity has to be delivered online or at a distance. Given the difficulty in providing effective and credible laboratory experiences, it is certainly no surprise. This section is meant to provide practical approaches used by educators around the globe.

Chapter 5: *Taking the Chemistry Experience Home — Home Experiments or "Kitchen Chemistry"*

The home-study laboratory enables students to carry out real experiments in the home environment offering them tremendous flexibility. However, considering (1) that there is a wide range in quality and sophistication of kits that have been employed by different institutions, (2) the popularity of science kits for children in the toy market, and (3) that the experiments carried out at home are done alone and unsupervised, there is the very real question of whether the home-study laboratory experience is equivalent to the traditional on-campus experience. This chapter summarizes the experiences of two institutions that have provided what could be best described as higher level home experiment kits for first year university chemistry. Experiences in the actual development of the higher level kit, including some student evaluation experiences, are described.

Chapter 6: *Acquisition of Laboratory Skills by On-Campus and Distance Education Students*

This chapter presents a study in which off-campus students in a biological sciences program complete some parts of their first year laboratory work using home-study kits. To investigate whether there is an equivalent experience between on- and off-campus cohorts, the students' level of confidence in their laboratory skills was compared at various stages in the program. Student confidence levels have been linked to some aspects of student performance, such as grade point average and retention.

Chapter 7: *Low-Cost Physics Home Laboratory*

The availability of modern hand-held calculators that possess remarkable computing power has allowed the development of sophisticated, yet low-cost, home-study experiments for first year physics. The dramatic increase in student participation rates by using this more accessible mode of delivery are noted here (a more general home-study kit discussion follows later in the book in Chapter 10). The authors go on to describe the home-study kits through three concrete examples of experiments. It is important to note that while most introductory science experiments tend to be expository or recipe-style, the experiments illustrated use an Investigative Science Learning Environment, which is a more problem-based form of instruction. The authors also strongly argue that not only is this home-study kit a cost-effective way to flexibly deliver an entire first year physics laboratory experience, it also emphasizes to the student that experiments and natural phenomena can exist outside the campus laboratory.

Chapter 8: *Laboratories in the Earth Sciences*

Without a doubt, the earth sciences have the smallest amount of readily available literature on DE laboratory delivery amoung the natural and physical sciences. This is surprising because (1) laboratory and field work is vital in many earth science courses, and (2) there are a lot of active distance courses in this area. The author provides a broad overview of what is being done for the practical components in geology, soil science, and geomatics. The type of activity certainly varies greatly with the nature of a particular course, and there is no one correct solution in delivering laboratories for distance students.

Chapter 9: *Remote Control Teaching Laboratories and Practicals*

Although remote control has been with us for some time, remote control over the Internet for teaching experiments is relatively new. Remote laboratories are increasingly appearing in a variety of disciplines and quickly becoming a viable part of a science educator's teaching arsenal. This chapter provides a review of how remote laboratories are employed, the connection to learning, design considerations, and an analysis of advantages and disadvantages.

LOGISTICS

This section addresses a very important and too often neglected aspect of teaching science online and at a distance. Most courses do not live up to their conceived potential or in some cases completely fail simply because the infrastructure is not in place to support the learning. Like the air around us, infrastructure is never given much thought unless it is taken away. We have adopted a dual approach here by providing both a big picture view and the nitty-gritty of the details that make it all work. Again, because of the challenges involved, it is no accident that substantial portions of the discussion focus on laboratory delivery.

Chapter 10: *Needs, Costs, and Accessibility of* DE *Science Lab Programs*

Most laboratory experiences require the effective and safe coordination of personnel, equipment, chemicals, samples, and biological specimens in space and time by skilled staff. It becomes an even more complex matter to offer students increased access and flexibility when the number of degrees of freedom is increased. The expression "the devil is in the details" can be all too true. The authors begin by outlining the fundamental structures that need to be in place to deliver DE science laboratories and go on to do a costing analysis in comparison with more traditional laboratory delivery. The chapter concludes with an examination of the impact on student participation of introducing home-study laboratory kits into a science course.

Chapter 11: *Challenges and Opportunities for Teaching Laboratory Sciences at a Distance in a Developing Country*

The wholesale importation of someone else's solution is not always the right solution. This chapter explores how laboratory and field components are delivered to large numbers of students at a mega-university in a resource-poor environment. It is noteworthy that in a very short time frame this university (founded in 1992) has scaled up its operation to over 700,000 students. The author outlines what needs to be considered in this setting and provides an analysis of the current system, identifying problems and proposing solutions to mitigate them.

Chapter 12: *Distance and Flexible Learning at University of the South Pacific*

Working in a resource-poor environment is reminiscent of the discussion on delivering laboratories in a developing country that we saw in Chapter 11. However, here we do not have large numbers of students at a mega-university, but rather 20,000 students spread out across the 12 founding countries of USP in the vastness of the Pacific Ocean. This case study provides both a general overview of distance and flexible delivery options within this environment and a focus on support needs for science courses. Issues of cost, lack of infrastructure, geographical isolation, technical considerations, language of instruction, and cultural differences are discussed in the context of trying to provide equal quality and service to students from all participating countries.

Chapter 13: *Institutional Considerations: A Vision for Distance Education*

In this final chapter we step back from the immediate particulars of delivering science online and at a distance to examine the bigger picture. The author gives us perspectives from the point of view of the institution, the academy, and even society. This chapter not only identifies larger organizational concerns, but also underscores why we are doing this in the first place. The assumption is that increased education and particularly science education, along with science literacy, are beneficial and necessary goals for the individual and society. Through a discussion of barriers and opportunities, we are ultimately taken to a vision of universal access to science education with a high level of freedom and individual choice. Along the way we see both what is already in place and what still needs to be put in place institutionally. The underlying and most pressing theme here is change — not just changes in the details of technology and teaching methodologies, but a more profound change in attitudes toward education itself.

REFERENCES

Anderson, T., & Elloumni, F. (Eds.) (2004). Theory and Practice of Online Learning. Athabasca: Athabasca University Press. Available: http://cde.athabascau.ca/online_book