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Book Review – Accessible Elements: Teaching Science Online and at a Distance

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See table of contents

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Book Review

Accessible Elements: Teaching Science Online and at a Distance

Editors: Dietmar Kennepohl and Lawton Shaw (2010). Accessible Elements: Teaching Science Online and at a Distance. Athabasca, Alberta: AU Press. 978-1-897425-48-0 (e-book).

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Introduction

Many have argued that the advancement of science and technology is the foundation upon which much of the economic development of the past century has been established. Although economic prosperity has clearly not been uniform across the world, it is still widely accepted that a fundamental key to progress in any region is education, and in particular, education in the science- and engineering-related fields. A recurring topic in the broader educational community, however, is how to provide education to an ever-increasing population with widely different economic and cultural backgrounds. Although societies have changed drastically, a face-to-face residential model is still generally accepted as the preferred or ideal approach to imparting knowledge, and more importantly, to developing creativity. However, this model is woefully inefficient, even elitist in many cases, and denies access to large parts of many populations. Perhaps contrary to popular belief, distance education (DE) has been around for more than a century. For many decades, DE programs were known as correspondence courses, but since the development of the Internet, DE has migrated online and is now often referred to as online education. Regardless of the name given, teaching at a distance has become much more widely accepted recently and is now a focus of educational research in order to better understand what works, what doesn't, and what can be improved.

Teaching science, either traditionally or at a distance, is unique when compared to other disciplines because in addition to theory and "paper and pencil" work, the subject requires a laboratory component. It is this laboratory component that has always been a challenge for DE and the subject is now receiving an increasing amount of attention. Because science is a laboratory discipline by nature, it is obvious that students need to learn laboratory and manipulative skills, but they must also experience a laboratory environment and develop the higher order cognitive skills that are necessary for laboratory work. It is this very subject that forms the core of *Accessible Elements, Teaching Science Online and at a Distance*. The editors attempt to provide a wide-ranging focus on the dominant issues of teaching science online, but the recurring theme throughout the book is the need to teach the practical or laboratory side of the discipline at a distance. This is a useful book that for the first time appears to provide a valuable starting point to discuss the theoretical, practical, and logistical issues involved in developing and delivering a quality online or DE science course. For all those involved in teaching science online it is worth reading, but I also found that the editors omitted a thoughtful and thorough discussion of the merits and place of virtual labs in a DE curriculum. No review is provided of what virtual labs are available, and a critique of their quality and utility is absent. Indeed, even the author of the foreword points out this deficiency. Of course, the editors and many of the chapter authors mention virtual labs, but in my opinion, the authors dismiss virtual labs out of hand. They focus instead on the obvious value of hands-on laboratory experiences, ignoring other cognitive skills that are just as important and likely better taught in a virtual laboratory environment.

The remainder of this review will first provide a synopsis of the book, followed by a discussion of virtual labs and how they can be used to enhance laboratory instruction either in a residential or online program.

Synopsis

The general purpose of *Accessible Elements* is to provide a broad perspective on the theoretical, practical, and logistical aspects of teaching science online and at a distance. The editors have divided the book into three sections reflecting these topics, which they call Learning, Laboratories, and Logistics. While there are obvious gaps in the topics they have chosen to study, mentioned previously, the information the editors have provided is meaningful and useful. I would certainly recommend this book to all those contemplating the development of or who are currently involved in online science education. One observation I must point out is that a quarter of the selected authors originate from Athabasca University, and thus my concern is that the perspectives included in the book are potentially limited. For example, it would be interesting to know the viewpoints of instructors teaching science at a distance from for-profit institutions as well as from public and private schools. Provided below is a brief synopsis of each of the sections in the book.

Learning

The focus of this section is the theoretical foundation that allows the teaching of science at a distance. The first chapter establishes the student–student and student–teacher interactions that are necessary for teaching and describes the methods for carrying out these interactions in a DE course. In chapter 2, the focus changes from student–teacher interactions to interactions that must occur at an institution in order to achieve the targeted learning outcomes. A key point made in this chapter is that the interactions in institutions required for good teaching are universal and not limited to DE. Chapter 3 focuses on the course development team and discusses the relationships between content, design, and the use of technology. Chapter 4 explores the need for flexibility in learning, that is, the need for institutions to investigate and understand different learning delivery modes (residential, online, traditional texts, etc.) and then to combine these modes in a consistent program that works for the demographics of the targeted student body. I found this chapter to be particularly useful because it encourages administrators, development teams, and instructors to look at all the tools that are available to them rather than limiting courses to a particular delivery mode.

Laboratories

In this section, the editors focus on the core elements of teaching at a distance and describe how the laboratory component can be taught to non-residential students. In chapter 5, the authors focus on home experiments or “kitchen chemistry,” describing how they have developed robust kits that can be mailed to students, allowing them to perform traditional introductory chemistry experiments. The authors also report research that supports the viability of using kits to teach the laboratory component at a distance when compared to a traditional model. These kits go well beyond stereotypical “kitchen chemistry” and are surprisingly effective. Chapter 6 repeats the same discussion but in the context of the biological sciences. The authors also make the point that advanced biological laboratories require a residential laboratory component because of the need for advanced equipment. Chapter 7 covers the discussion about physics experiments (which turn out to be easier than chemistry experiments), and chapter 8 focuses on the earth sciences. Chapter 9 is unique because it explores remote access laboratories, which provide a third option beyond home kits and residential laboratories for the various disciplines.

Logistics

The final section of the book covers the logistical concerns of delivering science content under various circumstances. In chapter 10, the authors use Athabasca University as an example and first discuss the personnel required to manage their online laboratory component. They then do a cost analysis to show that the use of home kits involves similar costs to those incurred by traditional methods to deliver the laboratory component. Chapter 11 presents a discussion of the logistical difficulties associated with providing science education in a third world country by showing how science is taught at a mega-university in Bangladesh. Chapter 12 continues with a similar discussion using the example of the University of South Pacific, describing the difficulties of covering an enormous geographical territory. Finally, chapter 13 provides an opinion on the future of DE in the context of the barriers currently faced by educators.

Virtual Laboratories

Computers are now ubiquitous in education and especially in DE. My personal perspective may provide a unique insight into the issues governing the implementation of a DE course and the use of virtual labs. Although I have been a chemistry professor for over 13 years, my family background is in computer science. My father was one of the pioneers working during the infancy of computers in the early 1950s and was involved in many large-scale space and military projects, including Gemini, Apollo, and several complex defense systems. He had a saying that we, as children, were constantly reminded of:

> Computers are just a tool. They are very useful for some things and essentially useless for others. If a computer does not make your life easier, or allow you to do things you would not normally be able to perform, then why use one?

I feel this perspective best illustrates a good approach to providing laboratory instruction at a distance. What are the tools at our disposal, what are the strengths and weaknesses of each, and how do we use them to complement each other? It is unlikely that any one tool will provide a complete solution. Within this context, I think it is appropriate to revisit how we can provide a laboratory component at a distance.

To begin the discussion, I must return to the purpose of having students perform laboratory assignments. The authors of chapter 5 provide as good a description as any when they summarize that the aims of laboratory work are to teach (a) manipulation, (b) observation and recording, (c) processing and interpreting data, and (d) planning experiments (p. 87). In my experience as a research chemist I would also add a fifth aim, decision-making and deductive reasoning skills, although this could fall within the general "processing and interpreting data" aim given by the authors. If these are the goals of instructional laboratory work, the question is: Do residential and kit-based laboratories achieve all of these aims? While I fully agree with the various authors in the book that hands-on laboratories are necessary and even vital, in my experience not all of the goals are met when placing students exclusively in "real" instructional laboratory settings. Because of time, safety, liability, and cost constraints, students in an actual laboratory setting are often reduced to a cookbook mentality where they blindly follow instructions for both procedures and data analysis (Woodfield et al., 2004; Woodfield et al., 2005; Swan, 2008). Certainly there are exceptions to this observation, and some students are able to enjoy real, open-ended environments, but many others are not afforded such opportunities and can only perform experiments in narrowly constrained environments. In such environments, students certainly experience (a) basic laboratory skills and (b) observation and recording, but it is questionable whether they are able to independently process and analyze data (without significant guidance from instructors), and in particular, to plan and design experiments. In addition, the scope of experiments that students can perform is, for the most part, extremely limited when compared to the breadth of scientific research.

Another way of looking at the aims of laboratory instruction is that lab work should provide students with a glimpse of what real science is. That is, it should show them what scientists do, what they experience in the laboratory, and how they think. Scientists manipulate lab equipment, record and analyze data, and design experiments, but they do this in an open-ended environment where what they observe is new, where the interpretation and understanding of these data require creativity and the application of diverse concepts and skills, and where the answer is not known. While not all students are going to be scientists, skills for coping with an open-ended environment without knowing the "correct" answer are useful in every walk of life. Actual or real-world laboratory environments, whether they are conducted at school or created at home with kits, are just one tool for educators to teach students these important skills.

Students must physically experience and feel how experiments are done in the laboratory as a part of learning these skills, but an appropriately designed and constructed virtual environment can complement real-world laboratories by providing a safe, open-ended, and accessible environment for students to design experiments, to make decisions, and to suffer consequences without the constraints of time, safety, liability, and costs (Woodfield et al., 2004; Woodfield et al., 2005; Swan, 2008). Yes, virtual laboratories do a poor job of teaching manipulatives, but when appropriately designed they are, in many cases, superior for teaching students how to cope with science in an unstructured environment. I am not talking about replacing real-world labs entirely, but rather about enhancing them with virtual reproductions or extensions.

There have been many attempts to produce simulations of a wide variety of scientific concepts, and it is well beyond the scope of this review to provide a lengthy description of each, but I will make the observation that most attempts at simulations are very limited in concept and are designed primarily to target specific lessons in a prescriptive manner. Indeed, this is the primary reason why most experts in the educational community dismiss virtual laboratories out of hand. For the most part, simulations available online are narrowly focused within a simple 2D interface, and students have essentially no freedom to design and construct experiments, make choices, and experience real-world consequences. The number of highly realistic and sophisticated 3D virtual environments is quite small, primarily due to the effort and cost associated with the production of the art and simulation engine necessary to support such an environment. Some of those that I am familiar with include Geology Explorer and Virtual Cell from the North Dakota State University, Late Nite Labs (a chemistry laboratory) produced in Israel, and Model ChemLab. There are other virtual laboratories, some conceived and produced by commercial publishers and others that are no longer supported and are now obsolete.

In the interest of transparency, I am the author and project director for a set of virtual laboratories called Y Science Laboratories, which have been produced at Brigham Young University since 1998 and are licensed to and distributed by Pearson Education. These laboratories currently include the general products Virtual ChemLab, Virtual Physics, Virtual Physical Science, and now Virtual Biology. Within these programs, lab benches have been created for inorganic qualitative analysis, calorimetry, titrations, gas properties, experiments in quantum chemistry, mechanics, density, circuits, optics, microscopy, genetics, molecular biology, ecology, and systematics. These simulations are built around a realistic 3D interface that allows students to move about in a laboratory and to perform a wide variety of experiments with a nearly unlimited number of outcomes. The focus of the labs is not necessarily laboratory technique (although that is certainly included whenever possible), but rather experiment design, data gathering and recording, data interpretation and analysis, and, most importantly, dealing with an unstructured laboratory environment. If experiments are not set up properly, students can experience explosions, failed experiments, "wrong" or unanticipated results, and null data. The laboratories look and feel like a real-world laboratory; there are no built-in instructions or guidance. The rooms and lab benches are constructed to look like real rooms with real equipment, and the goals and learning outcomes for students are expected to be supplied by the instructors as they would be in an actual laboratory setting. Indeed, the programs provide a virtual rendering of a residential laboratory setting with lab benches, drawers containing equipment, stockrooms with necessary supplies, and lab books for recording observations, data, and results. Research and anecdotal evidence show that students perform better on lab exams and in the laboratory when these virtual laboratories are combined with actual laboratory work (Woodfield et al., 2004; Woodfield et al., 2005; Swan, 2008).

Conclusions

Accessible Elements provides the first comprehensive look at what is needed to produce a DE science course. The book provides a snapshot of the theory of learning behind these courses, describes what is needed to provide laboratory experiences through home kits, residential labs, and remote labs, and concludes with discussions on the administrative logistics of delivering these courses. The book is useful for those currently involved or interested in producing an online science course and provides meaningful experiences, research, and information. A serious weakness of the book, however, is the exclusion of any meaningful discussion of virtual labs and how they could be used to enhance the laboratory component of any online science course.

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