Special Issue on Opening Educational Resources

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virtual universities for the 100 million people who otherwise will be denied access over the next ten years.

Will OER evolve to serve these potential customers of higher education? A lower-end disruptive technology may enter the market and provide a product which has lower performance than that which is already in the marketplace but which exceeds the requirements of ignored segments, thereby gaining traction. This disruption targets the least profitable customer first, who is satisfied with access to the lower-end product and cannot/will not pay for enhancements, such as residence universities.

Not all disruptive innovations, however, are of lower performance. At times, the disruptive innovation will outperform the current technology but is not adopted by existing players in the market. This typically occurs in industries with a high level of investment in older technology—where there exists a high cost and greater inertia for the older infrastructure to be replaced. The education industry is certainly an older technology, tied to tradition with embedded cultures.

As an analogy—originally roads were built for horses not cars. Nevertheless, the potential for greater convenience and speed resulted in roads redesigned for cars after overcoming technical and political barriers. Like the car, OER offers added value. Even if innovation is recognized, existing businesses are often reluctant to use it to their advantage, since it would involve competing with their existing, more profitable approach.

Is OER a disruptive educational technology innovation, or is it compatible with traditional norms of education? With respect to certain targets, like open textbooks, disruption is likely to be true. For example, the additional features of cost reduction, increased timeliness, and ability to include immersive games and embedded assessments, make an open-only textbook highly valued in the education market.

However, does making high-quality educational content freely available compete with traditional school structures and higher education? This is possible as OER can alleviate a gap not currently being filled by traditional constraints, be disruptive with respect to the nature of teaching, the ready ability to be actively engaged in production of knowledge, the awarding of degrees, and perhaps with respect to the nature of semester systems.

**Conclusion**

Students learn best when they have opportunities to apply their knowledge—to create, problem-solve, and collaboratively participate. These are all competencies needed for the 21st century and for leading economies. Open Educational Resources are potential enablers of such a shift, but only if they are disruptive enough to restructure educational policies and organizational frameworks to empower teachers and learners to make good use of such resources.

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**Connexions: An Open Educational Resource for the 21st Century**

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The technology for information organization, communication, storage, and use today is the book. It has evolved over 3000 years (in its modern form over 500 years) to the mature object we currently enjoy. The book is now the primary technology used in education. But with the development of the computer and the Web, a new electronic information technology is challenging the book and laboratory, and it promises to allow significantly improved learning. The author and colleagues have developed and are using an Open Educational Resource called Connexions where the content is organized in small modules, open to use and reuse in creative ways consistent with modern pedagogy and open to new systems yet to be discovered or invented. This article presents the Connexions Project at Rice University as an example of that new technology and outlines the experience.

**Introduction**

The technology for information organization, communication, storage, and use today is the book. It is a mature technology, having evolved over hundreds (even thousands) of years to the current state that is relatively stable and unchanging. The book and laboratory are the main technologies used by teachers in education today. Authors, teachers, students, publishers, book sellers, and a surrounding infrastructure have built a powerful system that has served us well even though the high cost of books, journals, libraries, etc., and the long time to publication are causing concern.

Current developments in computer hardware and software, in computer networks, in cognitive science, and in information theory indicate there are better systems for the generation, organization, storage, and use of information. Indeed, the subject of this article is

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a system that we feel is a step towards a much better system based on electronics in addition to paper. It is the system of the Connexions Project started at Rice University in 1999 (http://cnx.org/).

There have been three major shifts that have occurred in the history of information technology. The first was the development of writing, which resulted in the shift from an oral to a written system [1]. This depended on several other developments, such as an alphabet and an educated community who were literate. The second shift was from a written to a printed document, which was a result of the invention and development of the printing press [2]. This also depended on several technologies, including paper, ink, and movable type presses.

The third shift is occurring just now and that is from a print to an electronic or digital system. It is more difficult to see this shift because we are all in it and part of it [3]. However, the supporting technologies of computers, networks, radio, video, software, storage, and miniaturization coupled with results from information theory, cognitive science, artificial intelligence, computer languages, computer systems, and open source software allow systems such as Connexions to be developed.

**Disruptive Technologies**

When a truly disruptive technology is introduced, its impact generally occurs in two phases. First, the new technology does the same job as the old technology, only better. Second, the problem is redefined and radical (sometimes unexpected) changes occur.

Along with these two phases, there is another distinction, stated by G. Moore in Crossing the Chasm, that is helpful. The “early adopters” are those adventurous souls that apply the new technology even though it is hard and the short-term payoff is small. Then the “mainstream” users start using it as it becomes less difficult and more acceptable to the larger community. Finally come the “conservatives” and lastly the “laggards.” No one wants to be labeled a laggard, but the other three groups have good reasons for their actions.

The previous shifts occurred to solve problems that were limiting progress in information use. Human memory and oral transmission of information was not accurate enough, required too much expertise, and did not scale with the need to handle larger volumes of information with more creators and users. Writing solved those problems for many years. The growth of literacy coupled with the errors of hand copying manuscripts, the limited volume possible, and the cost were the problems that required the printing press to solve. Now, we again are faced with similar problems. A single high school or college text book often costs well over $100 and takes years to be written or updated. These books do not allow the searching or interactive processes that digital materials do. A single book must serve very different learning and teaching styles. So, we are in the first phase of the third shift that is attempting to solve those problems.

**Connexions**

In 1994, five other experienced digital signal processing (DSP) authors and I published a book of exercises or homework problems to be used with the computer software system, Matlab. It contained a large number of relatively short DSP exercises together with a brief, self-contained bit of theory. From this collection, an instructor could assign a set of problems that suited the course and philosophy he or she was using. Or, the self-studying student could choose the problems that he or she was intrigued by or that would help in learning a particular point. The problem set could be used with almost any DSP text book or set of class notes or used alone. And, it was priced very low. From the use of this book by many authors in many settings, we have seen how the flexible, modular arrangement detached from the text book worked well. But we also saw that many instructors or students using the book were using only a small fraction of the exercises. But, of course, different folks each used a different small fraction, so creating a smaller book was not the solution.

Although the exercise book was to be used with the software system, Matlab, it was not integrated with the software in an effective way and interactive experiments were clumsy. The collaboration in writing was not easy, even with word processors and LaTeX, and writing the second edition was not easy. I felt this book was a step in the right direction but was not the answer.

In 1999, Professor Richard Baraniuk came to me with the idea of writing a junior level book in electrical engineering. He was frustrated by the fact that the mathematical ideas, the design methods, the applications, the legal implications, the business possibilities, and the ethical dimensions were all separated in different courses taught by different instructors in different departments, all disconnected. He proposed writing a new book that would connect all these ideas. I challenged him not to do that—not to write still another book with only a different spin—but to design a completely new teaching tool using modern computer and information technology. He came back weeks later with the basic ideas that have become what we now call Connexions. This is a new system that “connects” not only ideas but people [4, 5, 6, 7, 8, 9, 10, 11, 12, 13].

The timing could not have been better. The physical technology of the Internet, the desktop and laptop computers, the mass semiconductor, magnetic and optical storage systems, and the new wireless protocols were
beginning to be applied to a new educational resource, whatever that might be. The beginnings of Web 2.0, XML, second generation browsers, better graphics and simulations, interactive systems, and social software were also asking to be applied to education. All of this was accompanied by a new legal vision inspired by Richard Stallman and Eric Raymond, in the open source software movement, to give an educational version of Larry Lessig's Creative Commons. This environment not only supports but encourages a deeper level of collaboration than that of the multiply authored book or curriculum. This does not mean a single point of view is given. On the contrary, the student and instructor are not limited to a particular book or even the books in a particular library, but they do have the guidance and recommendation of the instructor.

There are three parts to the Connexions system:

1. The information itself organized in the form of small modules that can be linked and searched. These modules use the XML protocol and are located in an open “repository” accessible globally over the Internet, a network, or on a disk or CD ROM.

2. Tools that help create, maintain, share, and use these modules. These tools are built into a Web and browser accessible service specialized for this application.

3. A community that develops and uses these tools and modules. The authoring community is modeled around the ideas of the open software projects but operate in a somewhat different environment.

For educational applications, there are several participants:

1. The author creates the modules. This is done by writing a new module or by modifying an existing one which may have been written by the modifier or by a completely different author. There are software tools to write, edit, and collaborate. This is strongly aided by the open Creative Commons copyright.

2. The instructor creates courses or plans for study by creating a “road map” through the modules in the repository. The instructor may write all of the modules for a particular course or some of them or none of them. The resulting course may be used by a class in a school, by an individual doing self-study or distance education, or a business for documentation. The course material may be used from a screen or be printed out as a paper book.

3. The learner or student uses Connexions to learn not only the factual information, but also the contextual “connections” to the piece of information. This allows the traditional instructor to lead teaching but also allows a learner to actively participate in a controlled discovery experience.

4. The community, which consists of all three participants, and especially the first two, allows all individuals to gain maximum benefit from this new technology. It also includes legal, commercial, and educational infrastructure.

Part of the motivation of Connexions is to create and organize information in a format that is more compatible with the way that people think, discover, create, and learn. This was the original motivation of hypertext [14]. The traditional book does a good job of aiding the memory of people and of preserving the hierarchical organization. It does less of a good job of presenting connections or links or of allowing easy searching, both of which the brain does routinely. The book tries to do these things with references, footnotes, and the index. Hypertext links and search engines operating on digital information are much better. Indeed, these are some of the reasons for the digital library. The choice of XML (extendible markup language) over HTML or some other format allows a semantic description of the meaning of the content as well as presentation which is central to Connexions and allows future developments in the Semantic Web with “metadata.” It also allows the use of embedded dynamic, interactive experiments through simulation applets, where a “virtual” laboratory can be created.

Connexions has the same problem that the Web itself has in quality evaluation and certification. Indeed, that is a major problem with traditional publications, where the amount of information and the extreme specialization makes reviewing more and more difficult. Connexions allows a post-publication reviewing system rather than (or in addition to) the traditional pre-publication review. This is done by having a “lens” where one may “look” at the repository through a lens (or filter) to see only a subset of the total. Various groups can create lenses to build the equivalent of a “reviewed” or endorsed repository. For example, one professional society has already built an endorsement system and others are in the process.

Connexions started in 1999 with electrical engineering [15]. It has now grown to cover a large part of electrical engineering and several courses in mathematics, some in physics, botany, history, and a wide range of other areas. Two of the most exciting applications have been a course in music appreciation at the university level and a course in music theory for teacher and children. Connexions boasts over 4000 modules, more than 220 courses or books, approximately 550,000 users (96% non Rice University), 2000 author accounts, and approximately 200,000 hits per day from 198 countries. We are now working with Teachers without Borders and UNESCO, bringing content to developing
countries, with QOOP, a printing company for low-cost text books, and National Instruments, bringing interactive applets for embedded demos and labs. We hope an added-value industry will grow up around Connexions content much as Red Hat grew up around Linux.

The system has been used in many traditional courses over the past several years as a primary text or supplementary document. It is now being used to supply the only text book for the introductory electrical engineering course at Rice, where a 300-page book written by Prof. Don Johnson can be purchased online through Connexions from QOOP for $20. Connexions is being used in a DSP course and a DSP lab at Rice and the University of Illinois. A rather surprising occurrence was the large success of a music theory course by Catherine Schmidt-Jones and a university music appreciation course called “Sound Reasoning” by Tony Brandt. The platform has been chosen by the Rice University Press to be its print engine and several university presses are considering Connexions to reduce costs, speed up printing, and keep books from ever going out of print. It can be used as an online text in a traditional course, it can be used to produce an inexpensive printed book, or it can be used in a distance education program. To see Connexions for yourself, visit http://cnx.org.

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Notes


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**Visitors Welcome**

Readers of *Educational Technology* Magazine are always welcome to visit the offices of the magazine, whenever you are in the Northern New Jersey–New York City Area, for informal discussions with the Editor, Lawrence Lipsitz, and staff of the publication.

Throughout its 47 years of publication, the magazine has welcomed both individual visitors and groups, including delegations from nations throughout the world eager to learn of progress in the field of educational technology in the United States.

Simply call the magazine’s offices a day or two in advance to arrange for a visitation. We enjoy discussing the field with our readers, and we believe that this leads to a greater appreciation among all participants of trends and ongoing developments.

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