

## The Connexions Project: Promoting Open Sharing of Knowledge for Education ([cnx.rice.edu](http://cnx.rice.edu))

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### Abstract

The *Connexions* project at Rice University has created an open repository of educational materials and tools to promote sharing and exploration of knowledge as a dynamic continuum of interrelated concepts. Available free of charge to anyone under open-content and open-source licenses, Connexions offers high-quality, custom-tailored electronic course material, is adaptable to a wide range of learning styles, and encourages students to explore the links among concepts, courses, and disciplines. Connexions fosters worldwide, cross-institution communities of authors, instructors, and students, who collaborate on the creation of knowledge building blocks from which courses are constructed. The ideas and philosophy embodied by Connexions have the potential to change the very nature of teaching and learning, producing a dynamic, interconnected educational environment that is pedagogically sound, both time and cost efficient, and engaging.

### Faculty and Student Perceptions of Education

*“Why don’t they see the bigger picture?”* vs. *“Why am I studying this!”* The frustration experienced by instructors and students alike throughout the teaching and learning process has been a key motivation for developing Connexions. After teaching one of his undergraduate Engineering courses in Digital Signal Processing (DSP), Dr. Richard Baraniuk had the feeling that his students just weren’t “getting it.” Their knowledge reflected in the exams showed they had absorbed what he had taught, but he doubted they understood how the pieces were related. So he took a handful of his most successful students from the course and asked them to tell him what they had learned. They were quick to recite the topics they had learned in the order he had taught them (“first we learned *a*, then we learned *b*,” etc.) It was a linear progression through the course rather than a deeper understanding of how the topics they studied were interrelated. Rich realized that it was important to somehow present the information in a way that would show how the concepts in his course were connected to each other, as well as to concepts they studied in prerequisite courses and courses that would follow. In this way, students could easily refresh their memories with information they learned earlier and look to other courses to see how what they were learning now would be relevant to more advanced topics.

A significant contributor to the linear learning process students experience is the course textbook. Textbooks provide students with more in-depth explanations of concepts than an instructor can during a lecture, given the time constraints of courses. As a reference source, textbooks provide a persistent store of explanations that students can review to

help in working on problem sets and mastering knowledge for their fields of study. If, however, it is assumed that learners have mastered prerequisite topics, the textbook can be a source of frustration when a student is grappling with trying to apply concepts that are nowhere to be found in the text at hand. It may be that a prerequisite course did not cover the topic, or the student just didn't quite "get it" at the time it was studied. Students need a way to refresh their knowledge base, as well as look ahead to better understand how the concepts they're learning now will be important in future courses. Since each student's knowledge and interest will vary, multiple paths through the concepts would provide a more meaningful learning environment, helping to better motivate students throughout their studies. Instructors also need insight into what the students have learned from their own colleagues and what those colleagues are expecting the students to know when they arrive for related courses. When courses are taught in isolation, with textbooks selected to meet the needs of a single instructor, both the teaching and learning processes suffer.

While on-line textbooks can include hyperlinks that allow users to explore topics in greater depth, they fail to provide environments that encourage learning the interrelationships of concepts, especially in how the concepts relate within varying learning contexts (e.g. a common topic studied in engineering, physics and math). The following are some of the limits to electronic versions of traditional textbooks:

- Electronically published textbooks can only link to themselves or to external Web resources that can be freely accessed, unless users have licenses that allow them to view other textbooks or journal articles as well.
- Links to other resources will not always place the user at the point where the relevant information is located.
- Even though published on-line, electronic textbooks retain their linear presentation of topics, with a structure that assumes students will move steadily through from one subject to the next, without exploring the relationships throughout.
- Copyright protections can prevent timely updates to the textbooks, making the on-line versions of textbooks as out of date as the print versions. The inability to update hyperlinks can compound this problem when linked resources change, disappear, or are discovered to lack credibility.
- When students begin to explore hyperlinks, it is not uncommon for them to get lost in the vast sea of information on the internet. Getting back to where they started – or even remembering why they launched into the traversal in the first place – can be a challenge and quite disruptive to learning.
- The ability of an instructor to modify parts of the textbook to better fit the context or learning needs of their students is impossible due to copyright restrictions.
- The textbook does not provide a collaborative environment for authors to share their knowledge to create a book that is not only comprehensive for the subject, but reflects the strongest collective expertise on each of the concepts within the subject.
- There is no map associated with the book that shows the prerequisite knowledge base and the future directions that can be followed once the knowledge in the

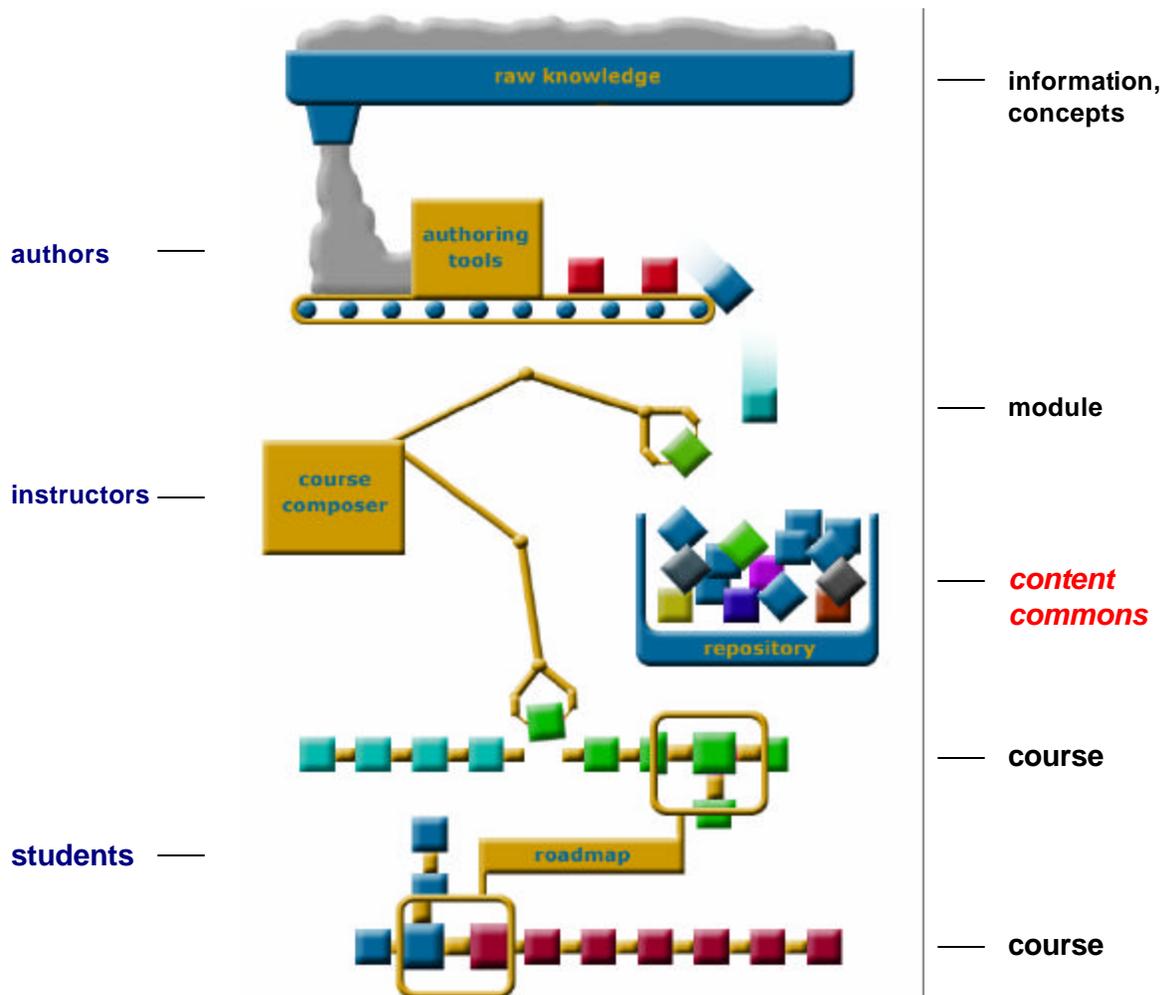
book has been mastered. This is usually true of the courses in an overall curriculum as well.

With this understanding of the limitations of textbooks, both print and electronic, Rich Baraniuk began to think of a new way of teaching that would overcome these barriers. Thus began the Connexions project.

## Connexions Overview

The Connexions project involves two basic, interrelated components: (1) a *Content Commons* of collaboratively developed material that is openly licensed, and (2) a suite of open source licensed software tools that foster communities of authors, instructors and students. *Figure 1*, below, shows the conceptual process of the Connexions environment.

A global community of authors, working collaboratively using specialized authoring tools, continually creates and refines small, self-contained modules of information that represent individual knowledge concepts. These knowledge building blocks are



*Figure 1: Connections as a Knowledge Factory*

maintained in a repository, or *Content Commons*, to be used, re-used, updated, and adapted. Instructors work collaboratively in workgroups, or alone, in the *Course Composer* environment to assemble the knowledge building blocks into a roadmap for customized courses that can be placed on the Web, presented in class, or printed as paper text. Students and other learners access Web courses or individual knowledge building blocks directly using special visualization and navigational tools designed to highlight the non-linear connections among concepts both within the same course, but more importantly, across courses and disciplines.

Within the authoring environment (shown in *Figure 2*), authors can create or modify knowledge modules representing individual concepts, identify links to other knowledge modules or Internet resources, annotate module content (e.g. “*This is based on the theory xyz, which has not yet been definitively proven.*”), share a working space for working drafts while the content is under development, search the repository for other relevant modules, and perform many other functions prior to committing the knowledge building block to the repository.

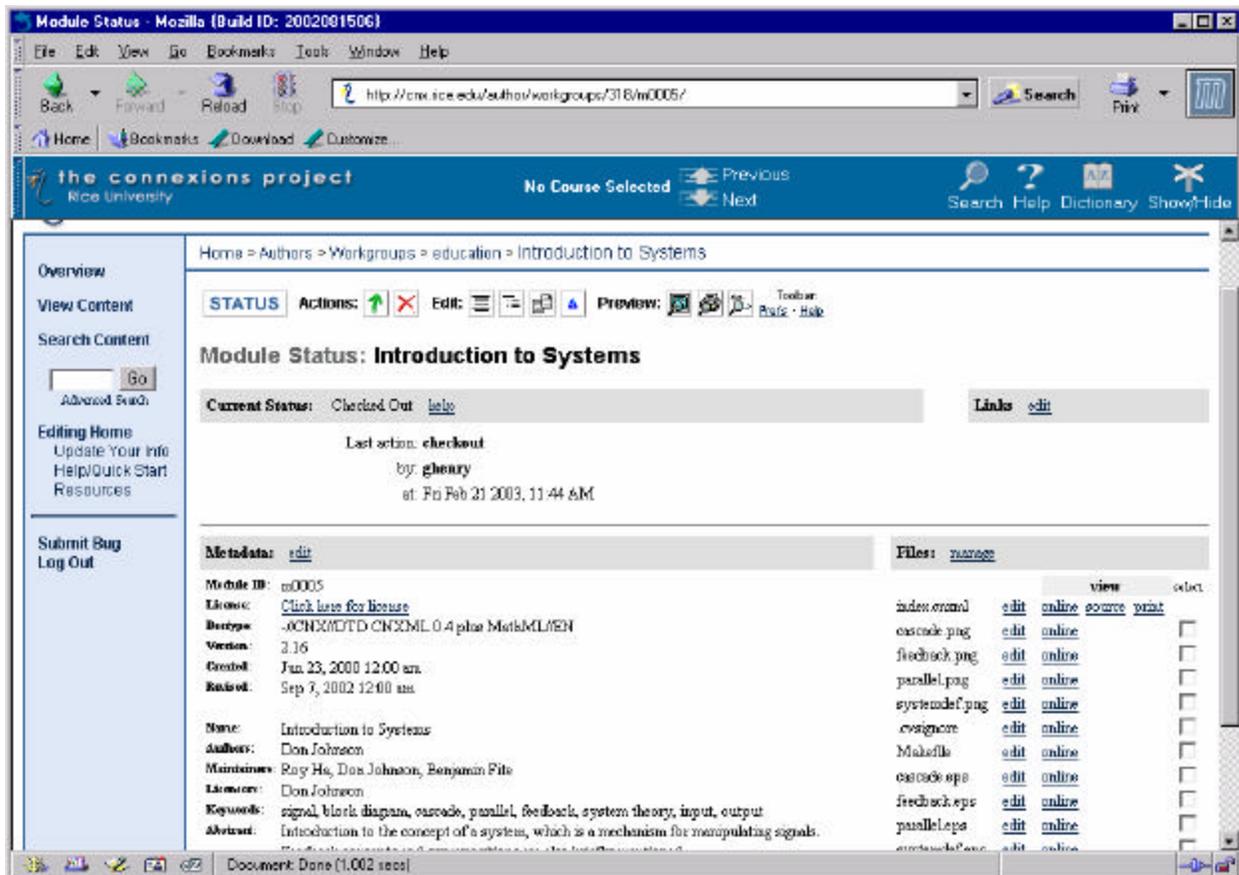


Figure 2: Connexions Author Interface

Content is marked-up, or *tagged*, using the extensible markup language (XML), which allows Connexions to expose the links among related knowledge modules, support a myriad of output formats (from Web pages to e-books to printed pages), enable

powerful search mechanisms, and display and print clear and attractive mathematics (using MathML for mark-up of mathematics content). Connexions' specifically designed markup language for educational content is called *cnxML*. Since XML encodes what the content means rather than how it should be presented (displayed), modules are very flexible – the same *cnxML* knowledge module can be displayed as an individual Web page, woven seamlessly into many different courses, converted to PDF, PostScript, or LaTeX for printing, or even processed through a speech synthesizer to read material to the blind. The ultimate presentation of a knowledge module depends on a stylesheet that is chosen by the end-user and not fixed a priori by the author. Equations marked with content MathML can be easily modified to meet the needs of an instructor for varying contexts or students. In addition to textual content marked up via XML, knowledge building blocks can contain rich multimedia content like images, videos, and interactive applets and demonstrations.

Each knowledge module is licensed under a Creative Commons license  that allows the content to be re-used, modified, and used for commercial purposes, all provided the authors receive attribution throughout the use of the module, even when modified. This promotes the greatest sharing of the materials possible. The benefits of open licensing are discussed in more detail, below.

The *Connexions Course Composer* environment (*Figure 3*) allows instructors to search the repository for knowledge building blocks, group them into “chapters”, and assemble them into a roadmap for the course.

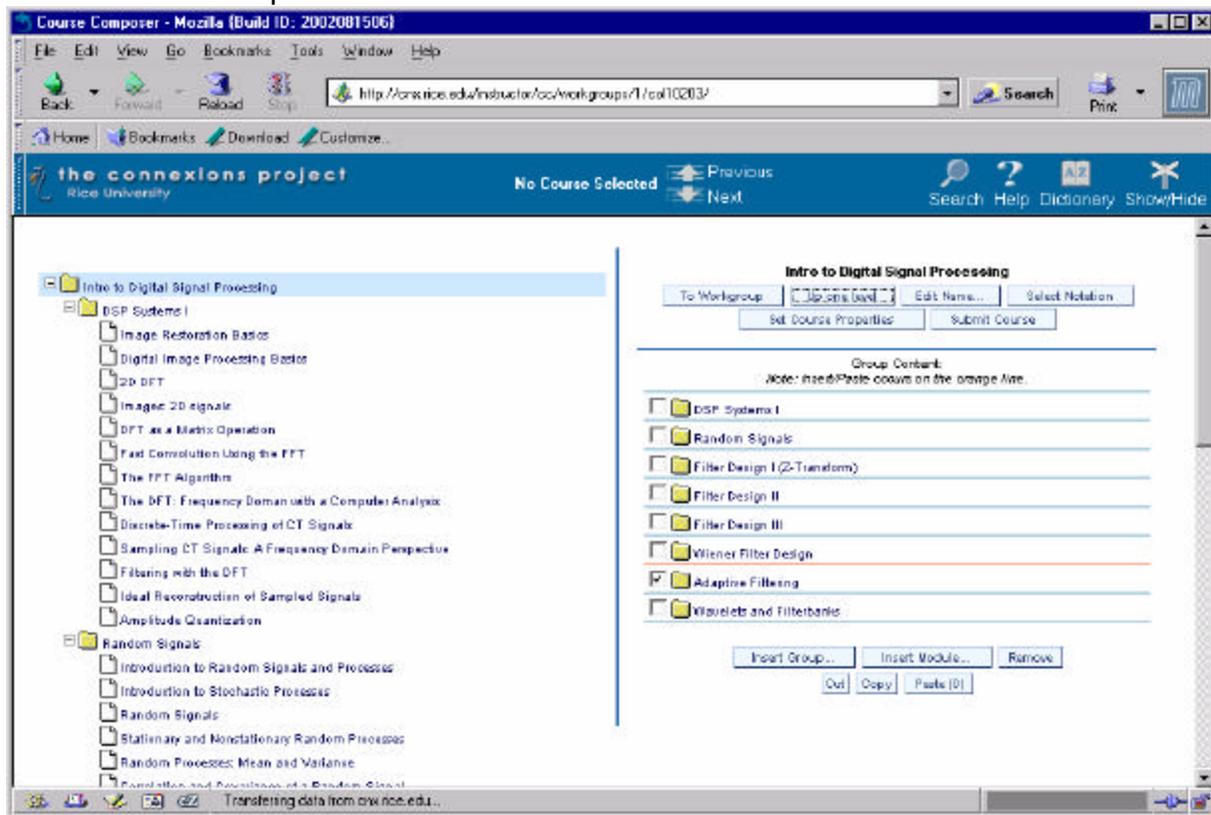


Figure 3: Connexions Course Composer Interface

They may customize their course by adding segues between knowledge modules, overlaying new links on previously unlinked modules, and adding annotations. If the material contains mathematical equations, the instructor may also select a notational style for the course. Once completed, the course path and customizations can be stored in the Connexions repository and accessed via a Web browser. Additionally, a linear PDF or PostScript version can be created for printing locally or spooling to an on-demand publisher such as Kinkos.

The *Connexions Roadmap* tool (Figure 4) is a Web browser plug-in that guides students through each course, helps them visualize the non-linear connections among the concepts in different modules, courses, and curricula, and encourages them to explore related topics and then return easily to their course path. They can add personal annotations to the materials to help them in studying, as well as interact with the content in varying ways. Embedded problems can be worked, then the student can click on the problem for the solution. Math equations can be cut and pasted into applications such as Mathematica that recognize content MathML.

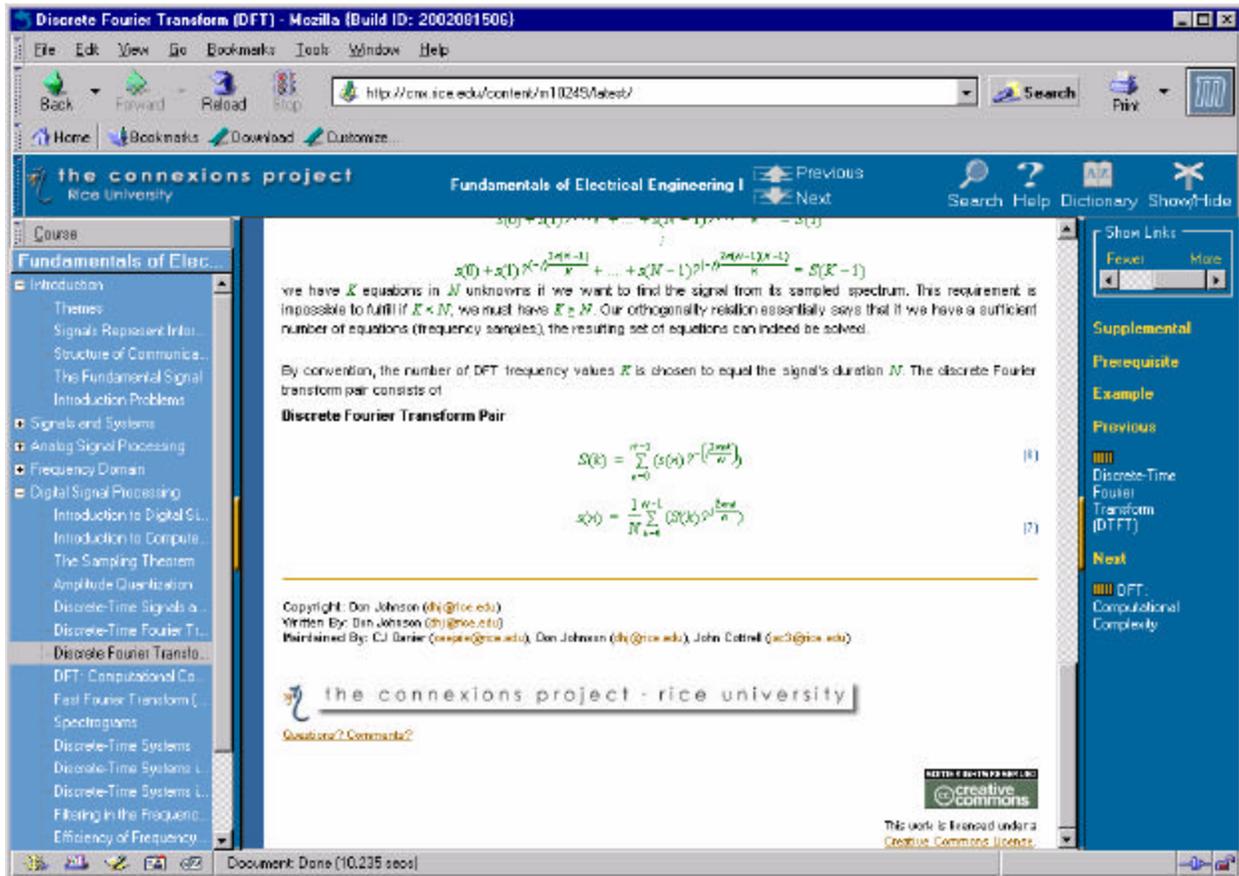


Figure 4: Connexions Roadmap and Course

The repository, the *Content Commons*, stores the knowledge modules and manages their access (see Figure 5). At present, the repository is a central, rather than distributed, storage system to simplify maintenance, access, and reliable functioning.

Connexions proxy cache servers have been implemented for improved access to frequently used modules. An architectural extension to permit multiple distributed repositories is also planned. Content modules are stored as text in a version control system (currently CVS) to maintain their complete revision history. Version control software is crucial to track changes to a module, to attribute who changed what, and to lock in a specific version for a given course so that it does not change under an instructor's nose. Metadata for each module is stored in a database for easy search and retrieval. The metadata includes module title, authors, keywords, and the linking structure (which modules link to which other modules). In addition, Connexions is implementing the standard metadata tags from the Dublin Core Initiative.

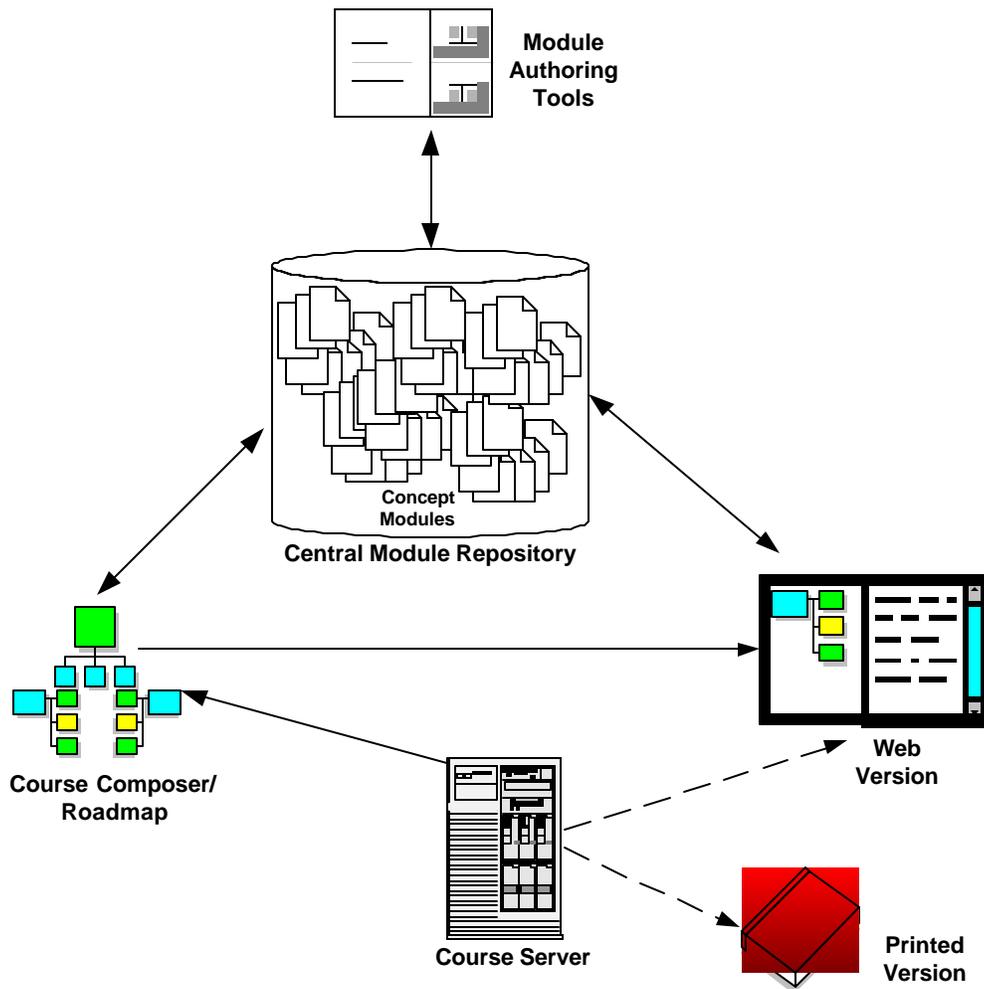


Figure 5: Connexions Components

## Why be Open?

*Connexions* features a synergistic mix of both software and content to meet the needs of the academic community. It adopts open licenses for both the content and software to promote sharing and maximum distribution of scholarly knowledge. In *Connexions*,

content is developed collaboratively by a community of authors under a [Creative Commons](#) open-content license. All materials are thus freely available to worldwide communities of authors who can collaboratively create, expand, revise, and maintain materials in the *Content Commons*. This system has a number of advantages: it is cost-effective, time efficient, lowers the barrier to entry into the author community and thus fosters diversity of opinion and subject matter, and increases the quality of the resulting materials.

### Cost-effective and Time Efficient

Open development is cost-effective and time efficient, because it leverages the efforts of a global community and allows each knowledge module to be re-used in varying contexts. Consider this quote from an electrical engineering faculty member: “For years I have wanted to write a textbook, because I love to write about FFTs. However, any complete text in my field also has to cover Z-transforms, on which I have no interest in writing.” Connexions will allow this faculty member, and thousands like him, to contribute his excellent materials in one area and then assemble his material with contributions from authors passionate about other areas. If an author simply wants to modify an existing knowledge module, she is free to do so.

One such global community of authors has been developed around digital signal processing (DSP), the mathematics of cell phones, medical scanners, radar, and more. Typically taught within electrical and computer engineering departments, DSP is a perfect subject area to demonstrate the efficacy of Connexions for several reasons: (1) the breadth of the field would require a comprehensive textbook of several thousand pages; (2) the field changes so rapidly that no standard paper text would be able to remain current; (3) the teaching of DSP has migrated from graduate, to undergraduate, and now to high school levels.

### Lowers the Barrier to Entry

Because authors can now contribute a high-quality knowledge module in an evening or weekend, many more college faculty, industry professionals, K-12 teachers, and even talented students will contribute materials. By opening up the authoring community, Connexions fosters diversity of opinion and subject matter, while (through the links and materials embedded in modules), supporting a multitude of learning styles. Current knowledge modules are available for viewing at [cnx.rice.edu](http://cnx.rice.edu).

### Quality

The open development ensures quality in a number of ways. First, authors are not distracted by having to create material in areas outside of their interest and expertise in order to develop a comprehensive textbook for their courses; they are free to focus on what they know the best. Second, because the system encourages collaborative development, groups of authors can work together, ensuring that the resulting knowledge building blocks benefit from the collective knowledge and experience. Third, because the materials are open to scrutiny by a global audience, authors feel compelled to create high quality materials. This also enables the materials to be constantly

refined, incorporating the latest research findings, for example, or allowing materials to incorporate effective teaching techniques.

A *post-publication peer review system* will further ensure a high quality *Content Commons*. This system is in contrast to pre-publication review used by traditional publishers. In a traditional pre-review system, a publisher relies on a panel of the author's peers to decide whether or not to publish a work. This system is too unwieldy to keep up with the fast pace of Connexions, where materials may change daily, constantly improving in an evolutionary fashion. Besides creating an exclusive rather than inclusive culture, pre-review does not support evaluation of materials based on actual student learning.

Instead, Connexions opens up the editorial process to an unlimited number of third-party reviewers and editorial bodies for post-review. While Connexions users will have access to all knowledge modules and courses in the Content Commons (whatever their quality), users will have the ability to preferentially locate and view knowledge modules and courses rated high-quality by choosing from a range of different lenses provided by these third parties.

### Open Tools

The Connexions tools will be licensed under an open source software license. Open source software provides many of the same benefits to software developers as open content licenses have for authors. The benefits of open source software are more familiar and have been discussed frequently (see E. S. Raymond, *The Cathedral and the Bazaar*, <http://www.openresources.com/documents/cathedral-bazaar/>).

To ensure that quality educational resources are available to anyone, anywhere, it is critical to ensure that the enabling technologies that allow those resources to be easily used do not become the barriers to improved education. By making the comprehensive suite of software tools developed for Connexions available under open source licenses, the open content materials can be easily used and incorporated in courses around the globe.

### Licensing Issues

There are two barriers that the current intellectual property world presents. The first is that there is no straightforward way for individuals to put educational material into the "public domain." Thus, *Connexions* proposes to allow authors to its *Content Commons* by effectively licensing the reuse of content.

All written material, whether expressly designated or not, is copyrighted under the 1976 Copyright Act (see "Cultivating the Public Domain," <http://creativecommons.org/learn/legal/cultivating>). This in itself is not a bad thing for authors, but it is bad for collaboration: it effectively chills the ability for willing participants to extend and to modify (to varying extents) existing content. In the commercial software world, these intellectual property restrictions have often made it cheaper and less risky to re-invent the wheel than to copy it. One profound solution to

this problem has been the creation of the Free Software and Open Source Licenses. These licenses create a commons—different from the public domain in that the material is both copyrighted and licensed under specific terms of distribution—that allows users to take existing works and use them as they see fit, and even to transform them into something new. In order to allow educators to accomplish a similar goal with respect to their materials, *Connexions* uses a licensing scheme similar to that used in the Free Software world.

Until recently, the existing open source licenses have been designed primarily for software and have not address issues specific to content, educational or otherwise. An open content license is necessary that allows content to be re-used and/or modified. Authors of *Connexions* content apply a Creative Commons license to each module they contribute to the Content Commons. This license addresses three main issues: *attribution, modification, and distribution.*

The issue of *attribution* concerns whether or not a module author's name must be associated with all subsequent uses and modifications of that module. For example, a textbook company that republishes content from the *Connexions* repository may be required to maintain authorship on that content. Note that the meaning of “author” here is limited to “copyright owner.” For collaborative objects and modified objects, the maintenance of authorship needs to be accomplished in less formal ways, by giving credit where credit is due. In this sense, the material in *Connexions* is not different than that in traditional textbooks and must be cited or referenced according to the norms of the academic world. Copyright protects work from undue financial gain, not from plagiarism. In the *Connexions* authoring environment, only copyright holders can be considered legal “authors” (that is, owners) in most jurisdictions. If there is a collaborative work of multiple authorship and the authors wish to own the material jointly, then those authors need to ensure that they are all copyright holders of the material.

Allowing content *modification* is one of the most powerful aspects of the *Connexions* system, but not all content is equally modifiable. Some content may pose an argument, the modification of which might invalidate it. Some content, on the other hand, might reference rapidly updated data, and need to be changed regularly. Authors should be encouraged to identify whether or not their content may be updated. Allowing for modification is what allows the content to be creatively re-used in the first place, and by issuing it under license terms that effectively grant these rights, *Connexions* opens the door to this kind of creativity. The license for *Connexions* has terms that require that *attribution* (that is, authorship not ownership) be maintained, both original authorship and subsequent modification.

The issue of *distribution* concerns the re-use of material for purposes other than educational re-use such as by textbook publishers, edited volumes, journals, or other online forums. For some people, the right to refuse commercial re-use of material may be an important motivator in contributing, for others, re-use in for-profit venues may not be troubling. By allowing authors to customize the licenses, *Connexions* can

accomplish both of these goals, without limiting potential contributors. For material that is introduced into the *Content Commons*, such attribution is the primary form of recompense. If there are authors who wish to profit from their teaching materials using the *Connexions* system, this will also be possible in the future. Textbook publishers, or individuals, can create “collective works” that can be published in other media, as long as the license terms of each module allow for “commercial use.” In this sense, authors can control who profits from their own work, but prevents them from restricting others if they themselves wish to profit from it.

The second barrier with current intellectual property approaches that threatens the *Connexions* open content licensing is that it must be incorporated into the technical structure of the content as metadata. The solution of this problem is greatly facilitated by the fact that *Connexions* is inherently a set of XML objects with associated metadata descriptions. By adding license terms to these objects, *Connexions* allows a great deal of flexibility in searching, identifying, and classifying content by license terms. The result is that material can be sorted according to its permitted uses, facilitating re-use based on the criteria of the people seeking to re-use it.

*Connexions* is actively collaborating with Creative Commons ([creativecommons.org](http://creativecommons.org)), a non-profit foundation dedicated to the enlargement of the public domain and the commons. Creative Commons has already developed licenses that solve the problems laid out above. Their legal expertise (with notable scholars and attorneys, including Lawrence Lessig and James Boyle) far surpasses any existing attempt to deal with content licensing, and their collaborators span the spectrum of content types. The Creative Commons licenses have provided needed solutions to the two main licensing barriers *Connexions* faced at the start of the project.

## Summary

The *Connexions* system currently hosts over 1,300 knowledge modules in the Content Commons and is used as the primary text for approximately twenty full courses at 4 universities. A number of courses are currently under development, increasing the breadth of subjects available in the system. The software that is currently in use is alpha level software. Release 1 of the software tools is planned for December 2003. Anyone desiring to use *Connexions* can request an authoring account or download the necessary software from the project’s Web site: [cnx.rice.edu](http://cnx.rice.edu).