Challenges and Opportunities for the Open Education Movement: A Connexions Case Study

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A grassroots movement is on the verge of sweeping through the academic world. The *open education (OE) movement* is based on a set of intuitions shared by a remarkably wide range of academics: that knowledge should be free and open to use and re-use; that collaboration should be easier, not harder; that people should receive credit and kudos for contributing to education and research; and that concepts and ideas are linked in unusual and surprising ways and not the simple linear forms that today's textbooks present. OE promises to fundamentally change the way authors, instructors, and students interact worldwide.

The OE movement takes the inspiration of the open source software movement (GNU Linux, for example, Raymond, 2001), mixes in the powerful communication abilities of the Internet and the World Wide Web, and applies the result to teaching and learning materials like course notes, curricula, and textbooks. Open educational resources (OERs) include text, images, audio, video, interactive simulations, problems and answers, and games that are free to use and also re-use in new ways by anyone around the world.

This chapter discusses some of the key opportunities and challenges of the OE movement using Connexions (www.cnx.org) as a case study. It also points towards an as-yet unrealized vision for OE that not only enables new ways to develop and share educational materials but also new ways to improve student learning by riding the wave of Web development from Web 1.0 to Web 2.0 and 3.0.

OPEN EDUCATION OPPORTUNITIES

Participants in the OE movement are working toward a broad set of timely goals aimed at improving teaching and learning, including:

- bringing *people* back into the educational equation, particularly those who have been "shut out" of the traditional publishing world, like talented K-12 teachers, community college instructors, scientists and engineers out in industry, and the world majority who do not read and write English.

- reducing the *high cost of teaching materials*. The average community college student in America spends almost as much on textbooks as on tuition. Many schools in the United States get by with less than one textbook per child in many classes; the problem is far worse in the developing world.

- reducing the *time lag* between producing learning materials and getting them into students' hands. Many books are already out-of-date by the time they are printed. This is particularly problematic in fast-moving areas of science, technology, and medicine.

- enabling re-use, re-contextualization, and customization such as *translation* and *localization* of course materials into myriad different languages and cultures. This is critical if we are to reach the entire world's population, where clearly "one size does not fit all" for education.

Several OE projects are already attracting millions of users per month (as of October 2007). Some, like the MIT OpenCourseWare project (www.mit.edu/ocw) and its OCW consortium (www.ocwconsortium.org), are top-down organized institutional repositories that showcase their institutions' curricula. Others, like Connexions (www.cnx.org), are grassroots organized and encourage contributions from all comers.

OPEN EDUCATION CHALLENGES

While the OE movement is gaining speed rapidly, its current trajectory is taking it towards several roadblocks that will have to be carefully navigated for it to prosper.

The challenge of re-use. Unfortunately, widely used OER formats like PDF yield materials that are open in theory but closed in practice to editing and reuse, rendering them often merely "reference" materials that are to be seen and not used. This stifles both innovation on the materials and also community participation.

Fragmentation. To date, many large OE projects have been institution-based repositories. However, intellectual ties are often much stronger between colleagues in the same discipline but at different institutions. Institutional repositories fragment a domain's knowledge base into distinct repositories and hinder inter-institutional collaborations.

Infrastructure cost. Those who have put in the effort to develop new OERs or innovate on existing ones often have little opportunity to make the results accessible to a broader public. In the developing world, for example, it is a real challenge for many governments and institutions, let alone individual authors and instructors, to deploy and maintain indefinitely the hardware, software, and connectivity for their own OER repositories.

Intellectual property. There is a debate in the OE world regarding whether open materials should or should not be commercially usable. Licensing that renders open materials only non-commercially useable promises to protect contributors from potentially unfair commercial exploitation. However, a noncommercial license not only limits the spread of knowledge by complicating the production of paper books, e-books, and CD/DVD ROMs, but also cuts off potential future revenues that might sustain non-profit OE enterprises into the future. Interestingly an anti-commercial stance is contrary to that of the more established open source software world (Linux, Apache, Firefox, and so on), which greatly benefits from commercial involvement. Where would Linux and Apache be without the value-adding contributions of for-profit companies like Red Hat and IBM, for instance?

Quality control. Due to sheer volume of the OE universe, OERs exist in various stages of development and, hence, at various quality levels. How do we ensure that high-quality materials are easily accessible to users? This requires both a means to evaluate and credential OERs and a means to direct users to those deemed of high quality. Traditional publishers, as well as institution-based OE projects like MIT OpenCourseWare, employ a careful review process before their content is made publicly available. Such a pre-publication review is necessary in situations where the publication medium is scarce — the paper making up books, for example.

However, pre-review does not scale to keep up with the fast pace of community-based OER development, where materials may change daily or even hourly. Moreover, the traditional binary decision to accept/reject a work is inappropriate when an OER can improve in an evolutionary fashion. Accept/reject decisions also create an exclusive rather than inclusive community culture. And finally, pre-review does not support evaluation of modules and courses based on actual student learning outcomes.

Sustainability. A common and critical challenge facing all OE projects is planning for and ensuring their sustainability (long-term viability and stability). The complication is that the traditional revenue models employed as a matter of course in other educational settings (earning revenue from knowledge creation and dissemination such as enrolment fees, tuition, book sales, subscriptions, and so on) do not directly apply to OE projects, since their materials, and oftentimes their software platforms, are freely available on the Web.

CONNEXIONS AS AN OPEN EDUCATION CASE STUDY

Connexions provides a useful case study in navigating the potential OE roadblocks.

Background. Connexions (cnx.org) was launched at Rice University in 1999 to challenge current modes of teaching and learning as well as how knowledge is developed and shared (Baraniuk and Cervenka, 2002). Befitting its name, Connexions has two primary goals: 1) to convey the *interconnected nature of knowledge* across disciplines, courses, and curricula; and 2) to move away from a solitary authoring, publishing, and learning process to one based on *connecting people into global learning communities* that *share knowledge*. By design and as a point of differentiation when compared with many other OE projects, Connexions is an inter-institutional and even non-institutional endeavor.

Rather than the traditional content development model of one author to one textbook or course, Connexions invites and links worldwide communities of authors to collaboratively create, expand, revise, and maintain its OERs. In colloquial terms, borrowing from an Apple Computer slogan and a book by Lawrence Lessig (2001), Connexions welcomes authors, teachers, and learners everywhere to “Create, Rip, Mix, and Burn” OERs. In particular, in Connexions, users are free to:

- **Create:** to author new educational materials and contribute them to a globally accessible OER repository (the Connexions *Content Commons* at cnx.org/content);
- **Rip:** to customize, personalize, and localize the materials;
- **Mix:** to mix the materials together into new collections and courses;

- **Burn:** to create finished products like Web courses, CD/DVD ROMs, and even printed books.

Reuse. Connexions employs a two-pronged approach to encourage OER reuse. First, rather than organizing materials at the "course" or "textbook" level, Connexions takes a modular, Lego™ approach (similar to the concept of a learning object (Wikipedia, 2007b)). Smallish, Lego block *modules* communicate a concept, a procedure, a set of questions, and so on. Connecting several modules together into a *collection* creates a Web course, a textbook, or a curriculum that can be easily updated by adding, subtracting, or modifying modules. Breaking course materials into discrete modules drastically reduces the time commitment required of authors and instructors, who can now write a high-quality module or weave a customized course in an evening or weekend. A vastly expanded and diverse community of authors has resulted. Furthermore, once contributed to the commons, a module can be reused in myriad different settings and rapidly adapted to new settings. For example, translation projects are currently active into Spanish, Portuguese, Japanese, Chinese, Vietnamese, and Thai; many of these OERs are Connexions' most popular.

Second, all Connexions materials are encoded in a common, open, and semantic XML format (XML, 2007). Since XML encodes what the content *means* rather than how it should be *presented* (displayed), modules are multipurpose and flexible. They can be displayed as an individual Web page, woven seamlessly into many different courses, converted to PDF for printing, or even processed through a speech synthesizer to accurately read material to the blind or illiterate. Mathematics encoded in content MathML can be copied and pasted into tools like Mathematica to experiment with formulas; similar XML markup languages exist for chemistry formulae, musical notation, and many other domains. The ultimate presentation of a module depends on a *style sheet* that can be customized by the end-user.

The Connexions commons is less a digital library or collection of courses than a dynamic *knowledge ecosystem* that is in a constant state of creation, (re)use, and improvement (Atkins, Brown, Hammond, 2007). Since Connexions began long before the current XML boom, the cost for all of this flexibility has been the (fairly considerable) cost of developing a suite of open-source XML authoring, editing, and collection building tools. Examples include a Microsoft Word / Open Office to XML converter; a Web-based XML editing tool (Edit-in-Place); a Web-based CollectionComposer to weave modules into collections, courses, and textbooks; a print-on-demand pipeline that creates print-ready PDF files; and a version tracking system for all resources. Still in design and development are advanced and easier-to-use authoring and collection tools, advanced book formatting and printing, disciplinary community pages, import/export APIs for a variety of formats, translation and accessibility support, integration with learning and course management systems, and a distributed repository infrastructure.

Fragmentation and infrastructure cost. The Connexions Content Commons houses works produced by authors from around the world in a single globally accessible repository. This obviates authors from developing, maintaining, and publicizing their own OER websites; all they need is a simple Internet connection to upload their materials to make them globally available and reusable.

While a central repository of XML modules and collections goes a long way towards preventing content fragmentation, it also introduces several potential issues of its own. The first is the perception of Connexions as a kind of "Rice University OCW" when in fact most of its content has been contributed by authors from outside Rice University (fortunately, moving from the URL www.cnx.rice.edu to www.cnx.org has done a lot to change this perception). The second is the infrastructure that must be developed and maintained to deal with the large traffic loads (already several hundred thousand users per month and growing rapidly). The third is the pressure to ensure the sustainability of the infrastructure indefinitely to preserve the valuable OERs. A solution to these three issues is the planned development of a distributed repository infrastructure that will enable many different institutions to distribute the ownership, maintenance, and load of the Connexions Content Commons.

Intellectual property. Connexions employs the Creative Commons "attribution" license ("CC-by", www.creativecommons.org) on all content to ensure attribution and academic credit for authors. The commercial usability of the Connexions OERs invites for-profit and non-profit companies like publishers to become involved in the OE movement by adding value to the materials by enhancing them in some way (much as Red Hat and IBM enhance GNU Linux for their customers). For example, on-demand printer QOOP, Inc. (www.qoop.com) is producing print textbook versions of Connexions collections at very low cost (for example, a 300-page hardbound engineering textbook for only $25 rather than the more usual $125). Commercial competition resulting from the non-exclusivity of the Creative Commons license will work to keep print book prices as low as possible so that everyone has inexpensive access and no one is exploited.

Connexions is collaborating with for-profit National Instruments (www.ni.com) to build a free "LabVIEW player" specifically for use in Connexions that will enrich and enliven mathematics, science, and engineering content and promote active learning, exploration, and experimentation by users. This will allow an educator to provide an interactive visual simulation of a theoretical topic and enable a student to run and interact with the simulation virtually anytime and anywhere. NI is adopting a model similar to that used by Adobe for its Acrobat PDF viewer, where any end user (a student or instructor, for example) is able to make free use of the technology without purchasing the software necessary to run the simulations. The

user merely has to download and install a simple plug-in to activate the free technology on their computers.

The main challenge to Connexions' OER licensing strategy is in fact a challenge to the entire OE community: there are a multitude of different Creative Commons licenses (at least twelve at last count), which can confuse contributors and users. Unfortunately, when presented with such a large choice, contributors often default to the most restrictive, and hence least open, license. License incompatibility precludes some potentially innovative uses of OERs. The fact that mixes of materials from a project like Connexions with materials from a project like MIT OCW (which carry a "noncommercial" license) cannot be placed back into Connexions contributes significantly to the fragmentation of the OE movement and unfortunately thwarts the primary aims of the OE movement (like enabling re-use and reducing time-lags).

Quality control via lenses. Connexions recognized early on that a pre-publication review process would not scale to the eventual large size and activity level of the Content Commons. So, rather than make a single pre-review accept/reject decision regarding each module or collection, Connexions opens up the editorial process to third-party reviewers and editorial bodies for *post-publication review* (Baraniuk and Cervenka, 2002; Baraniuk, Burrus, Johnson, and Jones, 2004). While Connexions users have access to all modules and courses in the repository (whatever their quality), users also have the ability to preferentially locate and view modules and collections that have been endorsed by third parties using a range of different *lenses* (see Figure 1).

Each lens has a different focus; examples include lenses controlled by traditional editorial boards, professional societies, or informal groups of colleagues as well as automated lenses based on popularity, the amount of (re)use, the number of incoming links, or other metrics (see www.cnx.org/lenses). The National Council of Professors of Educational Leadership (NCPEA) has launched a Connexions lens based on a rigorous peer review process involving both faculty from educational leadership programs and practicing principals and superintendents. National Instruments has deployed a lens for engineering content using LabVIEW. Index-based and "referatory" educational resources such as MERLOT (www.merlot.org) could also naturally serve as Connexions lenses.

While lenses were hypothesized from the inception of Connexions, the emergence of Web 2.0 "social software" has greatly simplified their implementation. Indeed, the prototype lens incarnation was based on the social tagging tool del.icio.us.

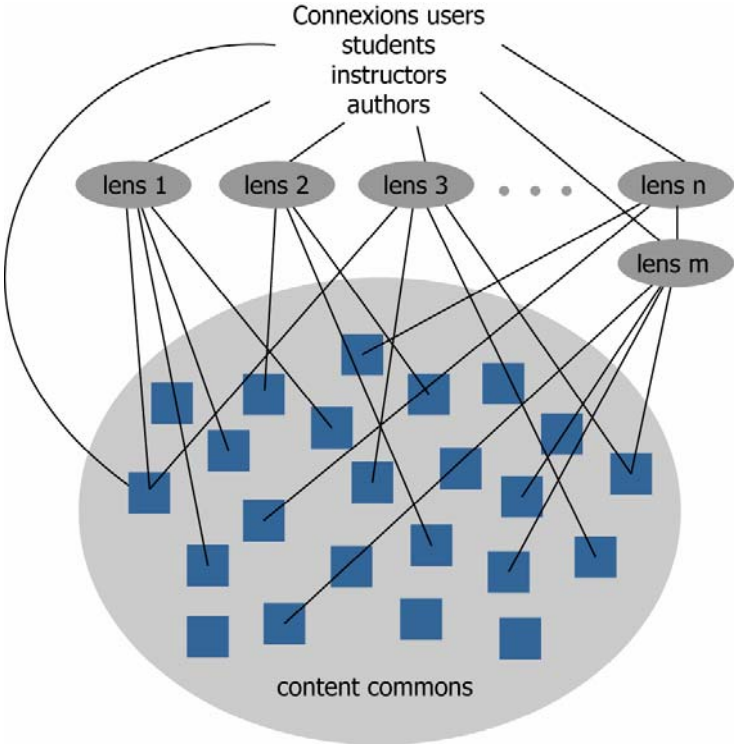

Figure 1: Connexions lenses for peer review and quality control.

Sustainability. The crucial long-term sustainability question for OE projects appears to be: "How do we acquire an adequate and ongoing stream of financial resources to keep our project running?" This leads immediately to considering various tactical programs to generate revenue; unfortunately, such programs often fail. The Connexions view is that a tactical approach is myopic, because it focuses too much attention on the "product" – the features of the project and the technology underlying it – and not enough attention on understanding the users and working deliberately to grow their value (Dholakia, Roll, and McKeever, 2005; Bagozzi and Dholakia, 2006; Dholakia 2006). The Connexions approach to sustainability is more "user-centric"; it focuses on increasing the aggregate value of the project for its constituents to the greatest extent possible. In its start-up and growth phases, Connexions aims first to gain and maintain a critical mass of active, engaged users and second to provide substantial and differentiated value to them; otherwise revenue models will be unlikely to succeed in the long run.

The important first step has been to gain a deep understanding of who Connexions' users are (and should be) and what constitutes value for them. Utpal Dholakia of the Rice University Jesse H. Jones Graduate School of Management has been studying the diverse Connexions users through formal marketing research, by attending to user feedback, and via informal observation and interactions. He has

found, for example, that the primary motive for a majority of academic textbook authors who contribute their original content to Connexions is not to earn royalties; rather, it is to have the greatest possible impact on scholars, practitioners, and students within their disciplines through the widespread dissemination and use of their educational and scholarly materials. As a result, while authors may agree to forgo revenues from their contributions, it is important that they receive full credit for them; not surprisingly, this is often a prerequisite for them to participate. This points to the criticality of the "attribution" clause in the Creative Commons license and the noncriticality of the "non-commercial" clause.

The second step is to grow the value of Connexions for its users. Dholakia's research has generated four recommendations for how to provide significant value to Connexions' users (Dholakia, Roll, and McKeever, 2005; Bagozzi and Dholakia, 2006; Dholakia 2006):

1. Increase Connexions' **brand** equity by staying true to its values. This involves increasing awareness among Connexions' potential user base and creating a differentiated, consistent, and meaningful brand image where users associate the site with key elements or attributes that are important to them. The brand image must be aligned with the core values, principles, and purposes underlying the project, which include freely sharing knowledge, building communities, collaboration, and so on.

2. Provide ample, high-quality, useful **content**. Most users, particularly students, first find Connexions through a search engine like Google while looking for specific information on a particular topic. Research on virtual communities suggests that the initial motivations of most participants for joining a community are specific and purposive; that is, they join to solve a particular problem or to obtain a particular missing piece of information (Dholakia, Bagozzi, and Klein Pearo 2004). It is therefore important for Connexions to provide high-quality content across a wide spectrum of disciplines to attract new users and to encourage loyal users.

3. Foster an engaged and involved user **community**. One of the main objectives of Connexions is to foster collaboration among users. This follows from a vast literature in education research showing that collaboration and social interaction enhance students' learning experience as well as the quality and degree of learning (see, for example, Bowen, 1996; Tinto, 1998). Research on virtual communities shows that with repeated participation, users form relationships with others, and this increases their engagement with the site (Dholakia et al., 2004).

4. Improve the site **usability**. A key determinant of site adoption by authors and instructors is ease of use (Spool, et al., 1998; Wei et al., 2005). Authors

and instructors will only be interested in Connexions if they can upload their content and modify it effortlessly in the format and layout of their choice.

These four key recommendations are directly reflected in the Connexions tool, content, and community development plans.

Connexions is currently experimenting with a number of different sustainability models (Dholakia, 2006); space limitations prevent us from discussing all but two here. The first involves charging specific user segments for "value-added" services around Connexions' free and open Web content. In marketing terms, this is called "versioning" (Shapiro and Varian 1998). Examples of specific services that could be offered include: sales of paper copies of content organized around a particular topic, training and user support to institutional users for annual fees, housing and dissemination of copyrighted content within the Connexions site on a subscription basis, "ask-an-expert" services for a fee, and consulting services to provide custom education to corporate clients. To continue the example from above, the $25 final student price for the 300-page print-on-demand engineering textbook not only includes costs and profit for QOOP but also a small (10%) "mission support fee" for Connexions and a small (10%) contribution to a fund that enables disadvantaged students to obtain the printed book for free. This model naturally segments users at the individual level; they pay for a customized and value-added version of the content available freely within Connexions yet end up paying a fraction of what they would pay if they purchased an equivalent traditional textbook.

The second sustainability model revolves around academic publishing. Connexions is the engine driving the Rice University Press, which recently reopened as an all-digital press in early 2007 after a decade-long hiatus (www.ricepress.rice.edu). RUP operates just as a traditional academic press, up to a point. Book manuscripts are solicited, reviewed, edited, and submitted for final approval to an editorial board of prominent scholars. But rather than waiting for months for a printer to make an expensive paper book bound for a cavernous warehouse, RUP's digital files are instead modularized and input to Connexions for automatic formatting, indexing, and population with high-resolution multimedia and Web links. Users can view the monographs and books online for free (making RUP an "open access" publisher) or purchase a low-cost paper copy via print-on-demand. Unlike other presses, RUP's catalog will never go out of print and moreover will be continuously updated. The first RUP offering was the Mellon Foundation supported report *Art History and Its Publications in the Electronic Age* (Ballon and Westermann, 2006). Fitly, the conclusion of the report is that academic disciplines such as Art History are in jeopardy as more and more university presses shut their doors due to high operational costs. Connexions is currently building a consortium of presses that will adopt RUP's low-cost publishing model; in return, Connexions will charge a nominal sustaining consortium fee.

Fortunately, while building the infrastructure and tools to support the Content Commons has required a significant investment in the short and medium term, Connexions' long term budget needs will be more modest as the effort transitions from building to maintaining software and communities.

A VIEW TOWARDS THE FUTURE

If the OE movement is gaining momentum, then can we predict which direction(s) it is headed? A simple but reasonable prediction can be based on the evolution of the World Wide Web, whose free distribution and global communication forms the substrate of OE. In this case, the prediction problem can be rephrased as follows: as the Web evolves new capabilities, how will they impact the models of development, (re)use, and sustainability for the OE movement in general and Connexions in particular? Following (O'Reilly, 2005; Markoff, 2006), over the last nearly two decades, two distinct sets of capabilities have emerged and dominated the Web (Web 1.0 and 2.0). A third (Web 3.0) is currently emerging and also holds great promise for OE.

Web 1.0 – Broadcast, the first incarnation of the Web, emphasized building and deploying the basic infrastructure for broadcasting simple HTML Web pages from mainstream websites under the slogan "Content is King". The results have included millions of personal websites, publishing projects like Encyclopedia Britannica Online, music distribution projects like mp3.com, and so on. Correspondingly, **OE 1.0** projects have emphasized the open resources – the OERs – that they broadcast freely to the world over the Web. The prototypical examples are MIT's OpenCourseWare, the members of its OCW Consortium, and EduCommons from Utah State University; these are top-down organized institutional repositories that expose static HTML and PDF versions of course Web pages, syllabi, and other curricular materials prepared by their faculty. Outside-of-institution contributions are not accepted, and quality control is carefully performed pre-publication by a dedicated staff.

Web 2.0 – Remix, which emerged around 2001, emphasizes participation and interaction under the slogan "Community is King" (O'Reilly, 2005). Using tools such as XML, wikis, tagging, and social networking, the results have included exponentially growing community websites like MySpace, the user-generated encyclopedia Wikipedia, hundreds of millions of user-generated YouTube videos, tens of millions of blogs, distributed file sharing projects like Napster and BitTorent, and so on. These sites cater not to the mainstream content at the "head" of the demand curve, but rather to the niche content in the "long tail" (Anderson, 2006). Correspondingly, **OE 2.0** projects have emphasized community building and participation on par with the open resources and admit user-generated content that is continually remixed into new OERs. Examples include Connexions, the British

Open University's OpenLearn LabSpace, ISKME's OER Commons, and Wikibooks and Wikiversity.

Web 3.0 – Semantic Web, which is currently emerging, will add intelligence via natural language processing, data-mining, machine learning, and other artificial intelligence technologies (Berners-Lee, Hendler, Lassila, 2001; Markoff, 2006; Jensen, 2007). The Web 3.0 will be attentive to and even predict user needs and behavior to provide richer and more meaningful and useful interactions. As such, it holds much promise for OE. **OE 3.0** projects will not just develop and deliver open content to students; they will also monitor student interactions with it, analyze those interactions, and then send *rich feedback* not only to the student about their learning, but also to the communities of curriculum builders, authors, and instructors to drive iterative improvement of the learning materials. To summarize in the language of control theory, while OE 1.0 dissemination projects run in a substantially "open loop" mode, by design OE 3.0 projects will "close the loop" and make educational material design, delivery, and redesign more interactive. An early example of OE 3.0 that currently focuses more on student feedback than continuous iterative content improvement is Carnegie Mellon University's Open Learning Initiative.

Connexions and Web 2.0/3.0. So what can Connexions in particular and OE projects in general do to more completely leverage the emerging capabilities of Web 2.0 and 3.0 in order to maximize student learning? Numerous opportunities exist (see Figure 2):

- Connexions should enrich its current feedback loops from students and instructors back to its author communities in order to accelerate the continuous content improvement process. Since ultimately this will involve deploying learning assessments (problems and quizzes), an assessment system should either be constructed, integrated, or linked into the current Connexions architecture.

- Since many teachable moments arise when no instructor is present, Connexions should encourage student users to tutor each other. Interestingly, the recent finding that on average eldest children in families tend to have slightly higher IQs than their younger siblings (Kristensen and Bjekedal, 2007) has been hypothesized to be due to the fact that they spend more time tutoring and thus consolidating and integrating their knowledge base (Zajonc and Markus, 1975). To encourage student self-tutoring, Connexions should develop a dedicated tutoring community area.

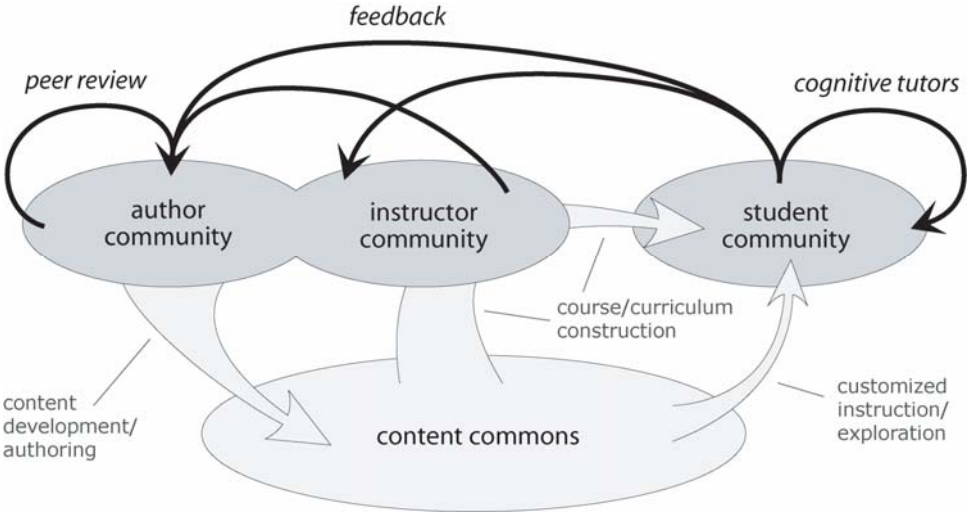

Figure 2: Connexions' architecture for OE 2.0 and 3.0 featuring enhanced feedback and Web 3.0 tools (from Rice 2003).

- In addition to student-to-student tutoring, Connexions should provide spaces for students to collaborate on interactive, multimedia problems and projects – what John Seely Brown calls "thinkering" for thinking + tinkering (Atkins, Brown, Hammond 2007).

- As an adjunct to instructor-to-student and student-to-student interactions, Connexions should experiment with artificial intelligence tools such as cognitive tutors. These software systems provide direct, immediate, and individualized feedback and instruction to students as they work on problems based on a cognitive model of their understanding and potential misconceptions of the material (Wikipedia, 2007a). While currently the design and implementation of realistic cognitive models is not scalable – they take PhD-level cognitive scientists, working with domain experts, years to create – OE 2.0 projects like Connexions can harness the efforts of a large, global community of contributors to incrementally and iteratively generate the feedback, instruction, and cognitive frameworks required by these systems.

- As the Connexions repository grows in breadth across disciplines and depth within disciplines, Web 2.0 and 3.0 technologies can automate the process of discovering interconnections between ideas from even far-flung disciplines. This will provide educators and students with valuable context information to go along with the OER content and could even result in surprising new discoveries.

- As the Connexions repository grows in size and as content updates accelerate, the communities controlling quality control lenses will need help from emerging Web 3.0 technologies for automated content filtering based on both computed metrics and user preferences. This framework for quality control has recently been dubbed “Authority 3.0” (Jensen, 2007).

CONCLUSIONS

The OE movement has real potential to enable a revolutionary advance in the world’s standard of education. Moreover, as it grows and spreads, the OE movement is likely to leave a large impact on the academic world itself. It promises to disintermediate the scholarly publishing industry, in the process rendering some current business models unviable and inventing new viable ones. It will also change the way that we conceive of and pursue authorship, teaching, peer review, and promotion and tenure. And by encouraging contributions from anyone, anywhere, Connexions in particular has the potential to aid in the democratization of the world of knowledge. While many challenges lie ahead on the road to these goals, with a concerted effort from the community of authors, instructors, students, and software developers, we can change the way the world develops, disseminates, and uses knowledge.

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