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The Role, Value, and Limits of S&T Data and Information in the Public Domain for Education

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I want to focus on education, which I define broadly to include learning in K-12 schools and universities, informal learning, as well as learning in the workplace. I want to make an argument that attention to the role of the public domain in education is not only important for education, but also can give us a better understanding of what the public domain means and how to think about it in a larger society. I am going to group my comments into four areas. The first is to lay out a context for thinking about education and its relation to information today. The second is to describe Biology Workbench, a tool that has been used increasingly in K-12 and college education. Third is a classroom example to show some of the things that students are doing with this tool. Finally, I will address some of the implications.

RESPONDING TO A CHANGING WORLD

We hear a lot of talk about societal change and change in the workplace. One of the constants of education has been how we cope with change. We see today new technologies for communication and transportation, business, industry, manufacturing, medicine, and so on; globalization; immigration; evolving languages and incorporating words from around the world; a shift to knowledge work; and changing social values in organizations. Many people call this a paradigm shift. They say it calls for a new kind of 21st century education, which responds to a new kind of world that we are living in. We might call this the turn of the century problem in education. But it is important in thinking about these changes to realize there have been changes in the past. Many people argue that the change from the 19th to the 20th century led to greater changes on all of these dimensions, at least in the United States. For example, the technology changes during the late 19th and early 20th centuries included the telegraph and telephone, the phonograph, radio, motion pictures, mass printing, and other inventions with profound consequences for science and education.

All of these changes in the larger society led to many kinds of changes in education. First of all, there was a huge expansion of schooling as the waves of immigrants in the late 19th century were incorporated into the school system. The progressive education movement developed. New subjects were created. In 1880, one study complained that there were over 30 high school subjects taught and that was too many. In one recent count, there were 4,000 different subjects offered in high school today.

The beginning of research universities and what people call the American Library Movement, all of these things happened early in the last century in response to changes similar to those we see today. During this time, one

of the key notions that developed was inquiry-based learning. It is the idea that in a world that is rapidly changing, where there are vast amounts of information—conflicting and redundant information—it is often hard to find what is crucial. In this context, we need to have learning tools that are open ended, inquiry based, group and teamwork oriented, and relevant to new careers. This is something the National Science Foundation has been pushing, as have the Boyer Commission on Undergraduate Education and a wide variety of other groups. It contrasts with the textbook-oriented learning that many of us experienced.

One model for this starts with the idea that it is not just important for students to be able to solve problems. They need to learn how to ask good questions; to find problems as well as solve them. Second, they need to learn how to investigate complex domains of knowledge, not just to read the chapter and answer questions at the end, but to integrate multiple sources of information. Third, they need to learn to be active creators of meaning, to construct knowledge, not just to follow directions. Fourth, they need to learn how to work with others, to discuss and to understand different perspectives. Finally, they need to reflect on what they have learned and articulate those meanings for themselves and others.

BIOLOGY WORKBENCH: OPEN-WORLD LEARNING

We could spend a long time talking about inquiry-based education, but one way to convey that and to bring it back to the public-domain data and information is to take one concrete example in the area of bioinformatics. Dr. Potenzone talked about the vast amounts of information that are available now for doing molecular biology, for investigating gene sequences, diseases, and so on.[1] Bioinformatics is developing as a distinct science and, in fact, many people are arguing that biology itself is being transformed into an information-driven science. Biology Workbench is one of the tools that has been built to address this. It is a web-based interface to a set of tools and databases, which researchers can use to access information stored throughout the world. Investigations that might previously have taken two years in the lab can now be done in a day sitting at the computer. There are tools for sequence alignment of proteins and genes, visualization tools, a digital library of articles, and so on. New knowledge has come out of using the Workbench. People in pharmaceutical companies, universities, and other places have made discoveries that would certainly have taken much longer without a tool like this.

In addition to looking at sequences and sequence alignment, a user can use the Workbench to visualize the structure of molecules, for example, that of hemoglobin in both its normal and the sickled form that causes sickle cell anemia. This visualization shows a mutated region of the molecule, in which it is easy to understand how one sickled molecule can hook into other molecules and create the sickling phenomenon.

Researchers also use this tool to investigate relationships among species. So, for example, users can compare horses, chickens, cows, vultures, dogfish, tuna, and moles to examine their degree of relatedness. By looking at the similarity, researchers can build phylogenetic trees or cladistic diagrams. These show that the tuna and the dogfish are more closely related to each other than to the other organisms, such as the horse, cow, and mole. The mammals are all more closely related, and the horse and cow are more closely related than either is to the mole, and so on.

Using Biology Workbench, a user can become an active investigator of the kinds of studies reported regularly in *The New York Times* science section. For example, when some new discovery about relatedness of organisms comes out, a reader could verify or challenge those results using a home computer connected to the Web.

A tool like this creates great possibilities for education. It also poses challenges. Many educators feel uncomfortable with tools like this, or what my group has called open-world learning, in which there are open, dynamically changing data, computational tools, and community interactions.

Imagine an instructor who prepares a lesson, checks it out the night before, and goes in the next day to teach about it. By the time the class begins, the data have changed. When students look at the computer, they find a different answer, a different set of information, because these databases are being constantly changed. This scenario reflects the first characteristic of open-world learning, that the set of data is open and changing. The

[1]See Chapter 6 of these *Proceedings*, "Opportunities for Commercial Exploitation of Networked Science and Technology Public Domain Information Resources," by Rudolph Potenzone.

Biology Workbench also implies an open computational environment: Many of the tools are open source and new tools are being created all the time. Third, it is an open community, which encourages direct communication between industry and university and between researchers and schools.

Classroom Examples

As an example of this approach, a recent article in *Nature* argues that Neanderthals and humans could not have interbred because of genetic differences. Students investigated this claim and found that Neanderthals and humans were actually more similar than other organisms, which are known to interbreed, such as horses and llamas. Another example focused on fungi being more closely related to animals than to plants. In another case, students looked at cetaceans, whales, porpoises, and so on and how they are related to hippos.

Students often take on these investigations as part of their class experiences. As one teacher said, this enables them to do projects in which they have to learn things that are not covered in the textbook. In addition, they get access to technologies that professional scientists are using. This means that students are not only using the tools to learn things, but also learning about the tools and the practices of science. They are also learning how to collaborate and how to articulate their knowledge.

This kind of investigation is not possible without access to the Workbench. Students could get books, but the number of books needed would be too expensive in most schools. Not only that, the information is rapidly changing. Through the Biology Workbench, students were able to find articles online that talked about research that they were investigating. In effect, they entered the scientific community, became participating, practicing scientists, and potentially could make their own contributions to the larger scientific literature. Instead of simply being recipients of knowledge created elsewhere, the students become creators of knowledge and participants in the knowledge-making community.

CHALLENGES AND OPPORTUNITIES

I want to make a few comments here about challenges and opportunities and then some closing comments about the public domain, education, and democracy. Inquiry-based learning is not a universal approach among educators. Moreover, many educators do not view public-domain data and information as an unvarnished good. Where most of us here today say we need more access to information, different models of education more or less accommodate and welcome use of public domain or information.

The fact that information is becoming more abundant, more complex, and rapidly changing is exciting to some people and scary to others. There is a challenge in any case. Even if you think, as I do, that it is absolutely crucial to education today, it is a challenge to think about how to make this kind of information not only available but truly accessible to students, particularly students in marginalized groups and with less than the latest equipment. The reason it is important is it creates so many kinds of opportunities. One is access to resources for inquiries. Students can now investigate questions that they could only pose before. Now they can engage seriously in carrying through an investigation to seek answers, which then generate new questions for further inquiries.

The very fact that this information is in multiple forms is exactly a reason students should be given the opportunity to engage with it. They need to learn how to cope with this abundance of information, media, and genres of representation. By using tools like Biology Workbench, which is but one example in one domain, students can become part of a larger community of inquiry: they learn not only the concepts or the skills of biology, but also learn what it means to be a biologist. This kind of activity elides many of the distinctions between practice and research, students and teachers, learners and researchers, and learning and research.

James Boyle spoke about the generational difference in how people think about public domain information.[2] He also spoke about how environmental studies in the 1960s changed the way we thought about the environment.

[2]See Chapter 2 of these *Proceedings*, "The Role, Value, and Limits of S&T Data and Information in the Public Domain in Society," by James Boyle and Jennifer Jenkins.

Those are educational issues and they exemplify why education should be at the heart of the debate about public domain knowledge. How do each of us acquire the beliefs and values that tell us what is just, what is feasible, what is desirable, independent of any particular law or policy of the moment?

It is common to talk about schooling and society as two separate realms. We think of school as the place where ideas from society go, once they are well formulated, well worked out. We think of society as the place where students go once they are fully prepared. But we treat school and society as two different worlds, which just touch on graduation day.

John Dewey, who did much of his writing during that revolution in education of a century ago, challenged people to rethink dichotomies, such as that of school and society. As he did with similar analyses of public and private, individual and social, or child and curriculum, Dewey pointed out that treating those terms as oppositional leads to an impoverished understanding of both. He went on to argue that education was fundamentally about democracy and that a democratic society cannot exist without an educational system, which encourages and fosters the development of individuals who are capable of self-government. At the same time students cannot learn about democracy and about a democratic society if they do not have the chance to participate in it, both in the classroom and in the larger society.

Because data and information are inherent to meaningful communication, the public domain is absolutely crucial, not only for the development of knowledge in general and not only for learning, but ultimately for the development of a just and equitable society.