# Reinventing the Wheel—Again

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There is a great deal of talk in science education about the problem of constantly reinventing the wheel, that is, individual teachers or curriculum development projects often seem to be doing the same thing over and over again, coming up with new ideas that aren't very new at all, that are just slight variations on ideas that have been around for a long time. This seems to be a waste of time, just as the project of reinventing the wheel would be. If a solution to a problem has already been found by one teacher or one project, why not just make use of it, instead of starting from scratch yet again.

## Thinking about Evolution & Teaching

Better communication among teachers and more effective dissemination of curriculum designs is often seen as the solution to the reinvention of the wheel problem. But I had an experience last summer that made me think that reinventing the wheel may not be such a bad idea after all, and that it may even be an essential part of curriculum design and of an individual's development as a teacher. I was at a workshop on teaching evolution in college biology classes sponsored by the BioQUEST Curriculum Consortium at Beloit College. During the course of a week, some 40 biology educators broke into groups and worked on projects dealing with different approaches to teaching evolution, particularly to undergraduates. One group tackled the problem of what essential concepts should be included in a course on evolutionary biology. Because they wanted to use active-learning approaches, they reasoned that content would need to be, if not sacrificed, at least streamlined, and so they set out to come up with a bare-boned list. But the list turned out to be quite long, with 17 major concepts that needed to be covered, most with a number of subheadings of auxiliary concepts that *couldn't* be left out; proving once again that reducing course content is never easy.

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After the group created this preliminary list, I joined a couple of other people to give our thoughts on it and to develop a concept map of ideas on evolution. Now this is really reinventing the wheel in its most extreme form: reworking a list that has just been developed, to say nothing of the fact that the National Academy of Sciences has recently published a book, *Teaching about Evolution and the Nature of Science* (Working Group on Teaching Evolution 1998), and there is *Evolution, Science, and Society: Evolutionary Biology and the National Research Agenda* sponsored by the National Science Foundation and the A.P. Sloan Foundation http://www.rci.rutgers.edu/~ecolevol/fulldoc.html), to name just two of the initiatives in evolution education. It seems like hubris for a group of us to be sitting around a lab trying to produce yet another framework, but despite its apparent futility, this was nonetheless a wonderful exercise. First of all, each of us had very definite ideas about what to teach and how to teach it, and none of us seemed shy about voicing our opinions. We each had thought hard about concepts in evolution and how best to present them to students. Of course, by the end of our discussion we hadn't come to a complete consensus, but I think we all considered the experience exhilarating and useful. We had shared a great many ideas in a way that we rarely have the opportunity to do.

## The Wheel Metaphor

There turned out to be something very satisfying about reinventing the wheel which got me thinking about this metaphor and its limitations. Yes, it does make a point. Reinventing the wheel can be a waste of time. If someone else has found a better way to teach about sexual selection or population genetics, then it makes sense to use that approach rather than wasting time developing a lesson that may not be nearly as effective. That's why it's important for teachers to publish their ideas in journals like *ABT*, and also increasingly, on the Web. But that doesn't mean that reinventing the wheel is always a waste of time and therefore should always be avoided. At Beloit, we found our exercise in reinvention to be very effective. We all learned a lot—about how concepts in evolutionary biology relate to each other, as well as different ways to approach these concepts.

The reinvention of the wheel metaphor, like all metaphors, has shortcomings. A metaphor is a comparison between two unlike subjects—in this case curriculum design and creating a piece of technology. One of the dangers with any metaphor is that the similarity between the subjects will be mistaken for identity. Yes, creating an evolution course and creating a wheel are alike in that they both involve planning, as well as consideration of the necessary materials and how to put them together. But a wheel is different from a course; it is a piece of metal or wood that does something, rather than a conceptual framework. And while there is some value in the process of creating a wheel, it is the product that is really important—thinking about a wheel is not nearly as important as the wheel itself and what can be done with it. But I would contend that the process of creating a curriculum can be almost as important as the curriculum itself—especially when the creator or creators themselves will also be using the curriculum.

## Ownership

''Ownership'' is a word that has positive connotations in many education circles. It is considered a good thing for students to have ownership of the course material, meaning that they have made it their own; they feel some deep connection to it because they have worked with it intimately enough to have taken possession of it. But I think it can also be argued that ownership is an important issue for teachers. It is much easier to teach material that we own, with which we feel a deep connection, and this kind of ownership and deep connection can come about when we have developed a lesson or a unit or a whole course ourselves, when we have, in other words, gone through the process of reinventing the wheel.

Curriculum development requires a great deal of deep thought, of puzzling through problems, of questioning everything from content to method of delivery. It is a difficult and wonderful process; old ground is being reworked but the experience of the work is itself very rewarding—and necessary. Sitting down in front of a blank sheet of paper and asking ourselves to identify the essential ideas in evolution is very different from reading those ideas in a book. Yes, we can learn about evolution from a book but we are less likely to own it that way. It is not yet an essential part of our minds and our beings. That only comes through the mental sweat of curriculum design.

Of course for most of us, opportunities for curriculum design are few and far between. That's one of the reasons that a BioQUEST workshop is such a precious thing to me: a week when I can spend day and night thinking about biology and teaching, while sharing ideas with extremely talented teachers. During the school year, I don't have the luxury of being able to reinvent the wheel—then I have to rely on what I've done in the past or on the wisdom of others, on ideas, activities and approaches I've picked up over the years. I don't have time to sit back and reflect, to ask myself: what do I want my students to learn and how can I best help them to learn it.

Questions like this came up in discussions I had with Stacey Kiser, who teaches at Lane Community College in Eugene, Oregon. We started our collaboration when we were sitting in the lounge, called ''Café Bio,'' in Beloit College's Biology Department. Stacey was reading about cladistics, one of the many areas of biology of which I have little sense of ownership. We began to chat, and we admitted to each other that we had neither a partner nor a project to work on. It was midweek, and we were still directionless—not a good thing.

The workshop had begun with three mini-workshops on using three different types of tools in teaching evolution in college biology courses. One workshop focused on open-ended investigations with fast plants (*Brassica rapa*), another dealt with the new software module, *BIRDD*—Beagle Investigations Return with Darwinian Data (The Darwin's Finch Data Resource)—in volume five of the *BioQUEST Library* CD-ROM, and a third with using Biology Workbench, a whole host of computerized research tools for analyzing DNA and protein sequence data. Stacey and I were both attracted to the Biology Workbench because with it, students can compare sequence data for a particular gene or protein from several species. They can even generate a phylogenetic tree based on sequence similarities. But Biology Workbench was originally developed as a tool for researchers, so using it in the classroom requires some careful selection of its vast potentialities. Some of this selection has been done by curriculum developers associated with the Biology Workbench project at the University of Illinois (http://glycine.ncsa.uiuc.edu), but Stacey and I felt that we had to do some shaping of our own. In other words, we had to reinvent the wheel of Biology Workbench to gain ownership of it.

## Curriculum Design

As with many cases of serendipity in my life, my chance encounter with Stacey in Café Bio turned out to be very fortunate for me. We have similar interests because we both teach nonmajors, and we both teach a diverse student population, all of whom are commuters. More fortunately, Stacey is someone who thinks deeply about her teaching, and she has forced me to do the same. She suggested that we do more than just design an activity around the analysis of a protein sequence, that before tackling this project, we should consider what we hoped to achieve in such a lesson, what we wanted students to learn about proteins, and equally important, what our students would need to know about proteins in order to get the most out of the activity.

Stacey was already involved in the Biology Workbench project, so she had more of a feel for its capabilities. Also, as a graduate student at the University of Oregon, she had been involved in teaching labs in the Workshop Biology Program, a very successful undergraduate biology curriculum development program headed by Dan Udovic. Dan has developed a model for thinking about how students make decisions about scientific issues that come up in their daily lives: environmental issues for example. He sees these decisions as involving three components: knowledge, values, and critical-thinking skills. He argues that teachers tend to focus only on the knowledge component, while all three are important in decision making; this means that it's very difficult for students to become effective decision makers with such a lopsided education in biology. Stacey pointed out that Udovic's model is also useful for thinking about teaching, especially for those who see teaching as involving more than just transmission of a body of knowledge; it could help teachers focus on the values and critical thinking involved in curriculum design. She suggested that we use the model in designing our protein sequence module, and that we begin our planning by asking ourselves questions such as: What is the objective we wish to achieve? and How can we make the activity open-ended and creative for students?

I will admit that discussing Udovic's model and thinking about what questions we needed to ask got us off the track of working on the specifics of our module, but that's one of the beauties of a BioQUEST Workshop—digressions are encouraged, and I think this was a fruitful one. For our presentation at the end of the workshop, we gave our interpretation of Udovic's model and then asked the other participants what kinds of questions they thought were important to ask before designing an activity, a unit, or a course. This precipitated a lively discussion and a long list of questions ranging from: How appropriate is the design for the culture of the institution? to What investment in time and resources will it require? Many questions were of the reinventing the wheel variety; in other words, they have been asked many times before by generations of biology teachers, but the fact that they keep coming up indicates their importance and the value of answering them once again.

Each year, or even each semester, as we enter the classroom and face a new group of students, we face a unique situation, and so we are forced, if not to reinvent the wheel, at least to modify it for this specific circumstance. Having a set of questions that are especially useful to keep in mind might help in making these modifications swiftly, as well as in creating more extensive design projects.

## Looking at a Protein

Though posing questions about curriculum design was our formal contribution to the workshop presentations, we also did some work on our protein sequence module. First of all, we decided on a protein to investigate. I like to focus on hemoglobin when I teach about proteins, but it is a large, complex protein, and the fact that it has two different kinds of protein chains produced by different genes would make sequence analysis more difficult. Stacey uses the lipid storage protein involved in Gaucher's disease, but Joel Hagen of Radford University suggested a simpler protein: insulin, and this made sense for a number of reasons. Insulin is a small protein, so its sequence is relatively short, yet it does have a fair amount of complexity, with two different subunits (A and B) connected by disulfide bridges, and with each of the subunits including alpha-helical regions. Also, insulin is first formed as preproinsulin, with two regions that are later removed enzymatically: a signal region for processing by the Golgi apparatus, and a connecting region linking the A and B subunits. When we used the Biology Workbench to compare insulin sequences from several different species, we found that the A and B regions were very similar—in other words highly conserved—over long evolutionary distances. This makes sense, because changes in sequence could lead to loss of function. But there was much less similarity among species in the connecting region, and this too makes sense; this region isn't highly conserved because it has no real function, so a change in sequence is not likely to cause difficulties.

Biology Workbench allows students to align sequences (either nucleotide or amino acid), and it visually highlights sequence similarities, so it's easy for students to compare the extent of similarity from one protein to another. This is very similar to one use researchers make of the Workbench. If a new protein is discovered and sequenced, this sequence can then be compared with the thousands of other protein sequences stored in the databases to which Workbench gives access. This is how researchers discover which protein family a new-found protein belongs to and how closely related it may be to the same protein in other species.

The computer algorithms behind such matching programs are quite complex, and the *Trends Guide to Bioinformatics* (Brenner & Lewitter 1998) provides a very thorough and useful introduction to the advantages as well as the limitations of such programs. The use of computers is absolutely essential to analyzing the huge amount of DNA and protein sequence data available today and has spawned a new field called Bioinformatics. This field has quickly become so important in genetics and in medical research on the genetic basis of disease that it is crucial for today's biology students to have some appreciation for it.

## Molecular Imaging

It is also possible to visualize proteins studied in Biology Workbench with a molecular imaging program such as RasMol (http://www.umass.edu/microbio/rasmol/raswhat.htm) or Chime (http://www.umass.edu/microbio/chime). Stacey and I attempted this, with the aid of Ethel Stanley, the director of the BioQUEST Consortium and an expert on making computer tools accessible and understandable to even someone as technologically naïve as myself. We managed to download RasMol from the Web and used it to look at a three-dimensional image of human insulin that we could rotate and view in a variety of different modeling forms from space-filling to ball-and-stick. Once we got RasMol downloaded, it was easy to use, but I think that if you haven't had experience using such a program, be prepared to spend some time playing with it before you can use it in a class presentation or have your students use it.

While programs like RasMol open up a new world for students, they also make major demands on teachers' time—and patience. When I got back to my campus, I was all set to use Chime, but found that the version of Netscape needed to use this program wasn't available on the university server. This is a little glitch, but the kind of thing that can sabotage a project, particularly during the school year when spending an hour finding a way around such a problem is an unaffordable luxury. But that's why Stacey and I were working on our project during the summer. We were not expecting this unit to be unique or earth-shattering, but it is our very own wheel that we have painstakingly invented, using Biology Workbench, RasMol, and Chime, as well as more traditional in-class activities. It blends our usual treatment of protein synthesis with these technology-based resources. This unit is our answer to questions about content, critical thinking, and questions of value. I'm sure we'll continue to rework, if not reinvent, this unit from semester to semester. We will have to, because none of these Web-based resources will stay the same. In fact, a new version of Biology Workbench will be available soon.

In learning to use these resources I am not just reinventing the wheel, but myself as well. I am over 50 years old, and unlike my grandson, I did not learn to use a mouse before the age of three. I am of an age where it is tempting to consider just ignoring the new technology and trying to make it to retirement without getting too involved with Web pages and databases. But I just can't take this tack, because I would be missing out on too much. It is fun to compare protein sequences. Sure, I can find such comparisons in books, but with the Biology Workbench, I have access to a huge amount of data and can compare any sequences I care to. And I get a thrill out of using RasMol to bring up an image of a protein molecule and then clicking and having the water molecules that would usually surround the molecule appear. Wow. Performing this operation hardly makes me a technological wizard but it does involve a rather major reinvention of a rather conventional biology teacher.

## Web Sites & Databases

I can also use the Web to explore taxonomy and phylogenetics in a rather novel way with "The Tree of Life," which is being coordinated and edited by David R. Maddison of the University of Arizona (http://phylogeny.arizona.edu/tree). When I arrive at this Web site I have the option of clicking on some part of the taxonomic tree and learning more about a particular group of organisms. Depending on the portion of the tree I use, I may have the opportunity to learn a great deal: this site is connected to many others devoted to information on specific organisms, and the number of connections and the amount of information available is increasing rapidly. So the Tree of Life, like its namesake, is constantly evolving.

Web sites like the Tree of Life force me to upgrade myself technologically, as do some of the computer programs on the *BioQUEST Library* CD-ROM (http://www.bioquest.org). Right now, *BIRDD* is my favorite. Essentially, it is a database with information on the finches of the Galapagos that has been gleaned from many published studies. Students can use this information to answer questions they have posed about evolutionary biology. For example, is there a relationship between beak length and change in vegetation over time, or between rainfall and longevity? Like the Biology Workbench, *BIRDD* is a tool students can use in doing research, in finding out what it is to really do biology: to frame questions and then seek out data that will help in answering those questions.

Learning biology this way is very different from the way I learned biology, when open-ended labs were a rare oddity. It is a tired, but valid, truism that we tend to teach as we were taught, so using problem-based activities and using computers requires a real reinvention of my teaching style. This reinvention is necessary, however, both to better prepare students for future learning challenges and also to prevent myself from being infected by terminal stasis. But I suspect that the biology teachers of the future, even those taught with active learning techniques and exposed to problem-based learning, will have some reinventing to do as well, because the culture we live in is constantly evolving and presenting new challenges that will require new teaching techniques to meet them.

So it turns out that reinventing the wheel can have many positive connotations aside from its negative aspect of redoing what has already been done. In the context of teaching biology, reinvention is essential to keep both the teacher and the curriculum from becoming stale. Yes, it is time-consuming, and it is tempting to avoid the process by using what others have invented. This does help. It saves time and energy, and provides a head start on the reinvention process, but just taking over someone else's ideas or labs or activities isn't enough. We must make them our own. While species may go through long periods of stasis when there is little evolution, this can't be the case for teachers and teaching, especially now when technology is driving so much educational change. Today, it is seems particularly appropriate to use a metaphor involving a rather low-tech, but essential, piece of technology to describe what must go on to keep teaching and learning ever fresh and exciting.

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