

# Standardization from Below: Science and Technology Standards and Educational Software

**Kenneth R. Fleischmann**

College of Information Studies, University of Maryland, College Park, MD, USA // [kfleisch@umd.edu](mailto:kfleisch@umd.edu)

## ABSTRACT

Education in the United States is becoming increasingly standardized, with the standards being initiated at the national level and then trickling down to the state level and finally the local level. Yet, this top-down approach to educational standards carries with it significant limitations, such as loss of local autonomy and restrictions on the creativity of educational software designers. This paper reports findings from a study of the design and use of frog dissection simulations used in middle school and high school biology classes. The paper builds on the existing literatures on science and technology standards in education, using interviews, participant observation, and content analysis guided by grounded theory. The results highlight the ways that top-down educational standards constrain science teachers and software designers. The discussion presents an alternative to the top-down regime of educational standards, namely, a bottom-up approach of standardization from below. Finally, the conclusion argues that local control of educational experiences in the form of standardization from below can improve upon the traditional regime of top-down standards.

## Keywords

Information technology, Computers, Science standards, Technology standards, Frog dissection simulations

## Introduction: Top-Down Educational Standards

Standardization in education, including the growth of both science and technology standards, is a major ongoing trend in education in the United States. Although educational standards have historically been created and enforced at the state level, the recent trend has been toward the creation and enforcement of national educational standards. The explicit goal of this standardization is to enable all students within the United States to use the same computers with the same educational software. Yet, the danger is that these standards represent a one-size-fits-all approach to education that may overlook the specific needs of local communities. Going too far in the direction of standardizing education may endanger more socially, culturally, and geographically appropriate education. This paper asks two key questions. First, how do current top-down science and technology standards influence the design, marketing, and use of educational software? Second, how might bottom-up science and technology standards, in contrast, differently influence on the design, marketing, and use of educational software?

Prior to the 20th Century, town meetings, gossip, and small newspapers gave citizens a local context and a shared experience. In the 20th Century, new technologies such as the telephone, the radio, and the television expanded the shared experience of humanity. Now in the 21st Century, the Internet has the potential to shape this shared experience at a global level. At each of these stages, the standardization of shared experience has depended largely on available technologies. One important form of shared experience is the educational experience, such as the secondary school experience. Educational policies and technologies are now being used to standardize this experience from one locality to another, so that the transmission of knowledges from one generation to another can become increasingly uniform. The goal of this paper is to determine the advantages and disadvantages of this top-down approach to educational standards as well as to consider the possibility of an alternative approach, a bottom-up approach to educational standards.

## Background: Top-Down Science Standards

Traditionally, educational content standards focused on the “Three R’s” of reading, (w)riting, and (a)rithmetic. High school exit examinations focused on these three areas. These examinations not only are required for graduation, but also may be used to determine funding for different schools, and may even be used to fire teachers or principals or even close high schools. As a consequence, English and mathematics were considered the most important areas of learning, and privileged above other domains such as the sciences, social sciences, and arts. Further, these standards

were typically set at the state level, with relatively little involvement by the federal government, including the United States Department of Education. Yet, recently these situations appear to be changing.

One important example of the growing importance of science standards is the National Science Education Standards, published in 1996 by the National Research Council. This document was publicized as the first nationwide list of science standards ever produced, and the primary goal was to increase the level of science understanding among all students. These national standards then trickled down to the state level, adding pressure on states to develop their own science standards in line with the National Science Education Standards. Indeed, as a direct result, “by the 2007–08 school year, all states are expected to measure students’ science knowledge at least once, at each level, in elementary, middle, and high school, under the federal ‘No Child Left Behind’ Act of 2001” (Hoff, 2002, p. 10). The “No Child Left Behind” Act further sped up the trickling down process for state science standards by two years, requiring that “by 2005–06, states must develop science standards” (National Education Association, 2003, p. 31). Thus, the National Science Education Standards and the No Child Left Behind Act were both responsible for promoting implementation of top-down science standards.

How do state science standards work in practice? Since schools and school districts rely on states for budgets for textbooks, software, and other educational materials, the states generally have the power to enforce their standards, especially when they are connected to statewide exit exams. For example, one California school district devoted two years to developing science standards for grades K–12. Yet, just as the school district finished this process, the state of California published its own science standards, which was spurred by the National Science Education Standards. Since there were significant differences between the organization of the state and district science standards for grades 6–8, the state demanded that the district immediately revise their standard to match the state standards, threatening to withdraw textbook purchasing support if the district did not immediately comply (Evans, 2002). Thus, the standards in this process began at the national level, then trickled down to the state level where they were enforced through the power of the purse strings, and finally trickled all the way down to the school district level where they overruled the local standards that had recently been developed. This story provides a clear example of top-down creation and enforcement of science standards.

## **Background: Top-Down Technology Standards**

Technology standards are also an important consideration in educational software design, marketing, and use. Technology in general is particularly dependent on the notion of standards. Without standards, it may be difficult or impossible for different technologies to interface. In the case of education, some amount of technological standardization is necessary to guarantee that the same educational software can be used in different classrooms and computer laboratories (Owen, 1999). Tremendous amounts of money have been invested in improving the level of technology in schools to meet technical standards. Further, the implementation of technology standards can help all students, and thus may help teachers to bridge the Digital Divide between technological haves and have-nots (Swain and Pearson, 2002).

Swain and Pearson’s (2002) analysis is particularly fascinating and compelling when they explore differences in students’ experiences with technology. They find that student ethnicity and socioeconomic status correlate to students’ experiences with technology. For example, they cite studies that demonstrate that “minority, poor, and urban students were more likely to use computers for lower-order thinking skills than their White, non-poor, and suburban counterparts” (p. 329). They use this finding to explain why increased access to technology does not always guarantee improved learning for students; learning depends not only on access to technology but also on the particular experiences with technology and the types of technology that are used. Similarly, Awalt and Jolly (1999) argue that technology standards would be useful for students, teachers, and administrators.

Certainly, technology standards play an important role in educational settings. Yet, it is important to consider that the use of educational technology in schools encompasses both technological infrastructure and educational software, which is influenced by content as well as by the computers that run the software and the networks that connect the computers. While technology standards in education focus primarily on infrastructure, there may be value to considering standardization for educational software as a technology that goes beyond content standards such as science standards that currently have a top-down impact on the development and use of educational materials such as textbooks and educational software such as educational computer simulations. This paper studies the issue of

educational standards in practice through studying how standards shape the design, marketing, and use of educational computer simulations.

## **Research Methods**

This study was part of a larger dissertation project (Fleischmann, 2004) and other findings of this study have been published elsewhere (Fleischmann, 2003, 2005, 2006a, 2006b). Data from a variety of sources, including semi-structured interviews, participant observation, and content analysis of software and promotional materials are used to examine the impact of science and technology standards on educational software design, marketing, and use. The larger case study that informs this paper included 51 interviews, including 14 designers of six frog dissection simulations (some of whom currently are or previously were biology teachers), 29 users of frog dissection simulations (including three biology teachers, a principal, and 25 biology students), and 8 animal advocates who play a role in marketing dissection simulations. Participant observation consisted of fifteen days of fieldwork over a six-month period, including six days spent at three dissection simulation design laboratories, four days spent at a science education conference, and five days spent in a high school biology classroom. Print materials included promotional materials produced by dissection simulation manufacturers and animal advocacy organizations and state educational standards and other materials published by educational policymaking bodies. It is important to note that the scope of this study is limited almost entirely to the United States (although the study did discover some anecdotal evidence of United States educational standards influencing educational standards and software design abroad (specifically, in Canada).

Data analysis for this study was based on the grounded theory approach to qualitative data analysis (Strauss & Corbin, 1998). Interviews were transcribed as soon as they were conducted, and each interview was coded according to a constantly changing set of categories that was initially based on the literature to date and then was continually modified as a result of new categories that emerged from interviews and old categories that lost their saliency as the data pointed to other categories. Specifically, the issue of standardization emerged as a result of the interviews, participant observation, and content analysis of software and promotional materials. Memos were written based on the coded interviews, and these memos then led to the development of theories that could best explain various aspects of the data. Specifically, the contrast between top-down and bottom-up standardization regimes was a result of this process.

## **Results: Teachers' Experiences with Standards and Educational Software Use**

The data collected for this study provide evidence that science and technology standards have a strong influence on the use of educational simulation software in biology classes, and this influence may be growing. As one teacher explains, "Everything that you're doing will be aligned to the standards, or will be addressing the standards." As one simulation designer and former teacher explains, "a teacher is looking for something that they can do their job with, and their job is to present those goals and objectives by the state or the nation." Similarly, another simulation designer and former high school teacher argues, "as long as a teacher's evaluation and salary is connected to the assessment tests, then what's going to get taught is exactly what's in the curriculum." Thus, standards come with a strong motivation to teachers, not only to 'do their job' but also to continue to get paid for doing it. Another science teacher in a state that has recently begun to implement science testing as a requisite for graduation is concerned that this emphasis on testing may create more emphasis on textbook learning specifically geared toward improving test scores without activities such as hands-on laboratories or educational simulation use that might provide more innovative and engaging opportunities for learning.

Perhaps the most interesting and vivid experience illustrating this point from the participant observation occurred during participant observation in the biology classroom. One day, the teacher began class by showing the students the state academic content standards for science (via the Web) and then explained, point by point, how the software that they were using, *The Digital Frog 2*, met specific standards in the area of physiology. Apparently, showing students the state standards is a typical activity for this teacher, since it helps to illustrate why it is important to learn the material. This example illustrates that not only are teachers aware of the state standards that they must meet, but they may also explicitly inform their students of these standards and use them to defend their use of educational software, in this case as a replacement for a hands-on laboratory activity, frog dissection. This state is also in the

process of requiring graduating students to pass a science exam, making the issue of meeting educational standards particularly compelling and current.

The emphasis on science standards on schools in the United States has a significant impact in shaping the content of all curricular materials, ranging from textbooks to educational software. As a teacher asks, “if it’s not addressing the main topics of the curriculum, which are the standards, then what is the point?” While textbooks were the original model for this, the same forces are now shaping educational software adoption. A teacher explains:

Nobody these days will buy a book that’s not aligned [to state standards], and I see the same thing could definitely happen with software, although it doesn’t seem to be at that level yet because software is not as widely implemented as textbooks, but that will probably change too. So I think the companies would do well – it would serve their clientele better to align the curriculum with their software – but states have different standards.

Interestingly, as one informant pointed out, this leads to a major problem in terms of equity – large states traditionally run the textbook industry, and may now have the same impact on the educational software industry, because adoption by large states can determine whether or not a textbook is successful. Smaller states, then, tend to follow the lead of the large states, and are not able to have as much of a direct impact on textbook and educational software adoption. Thus, the reliance on state standards has the effect of privileging large states while disempowering smaller ones.

Given the constraints they are under, teachers seem to naturally gravitate toward materials that make explicitly clear how they correspond to state standards. For example, a teacher comments, “I think it would be awesome if the materials were provided with the standards links embedded, and some materials are.” The teacher continues, “I would think that software companies would do enormously well to produce software...that addresses the standards and make sure that it’s targeted to the standards.” The teacher then provides the following example:

For me as a teacher, if I was to purchase this particular software...the superintendent and the board, they will not approve it unless I can show that it’s aligned. I would choose software that already says to me, it’s aligned; these are the standards that are addressed and here’s where they are addressed in the package. Then I can present it and say, look, it’s aligned already, and here it is. If that’s work that I have to do, if I have to go through and find the links, then honestly I would rather find one that’s easier to present and easier to get approved.

This hypothetical example clearly illustrates why it is important, under the current educational standards regime, for educational software to meet state standards and explicitly demonstrate how their software meets various state standards, at least, as noted above, for the large states that play the most powerful role in influencing nationwide textbook and educational software adoption.

An interesting feature of the high school, which was located in a very rural area, was the emphasis on technology. The high school had fairly sophisticated computing resources, and placed significant emphasis on these resources. The biology teacher and principal frequently referred to their high school as a “Digital High School,” since it was supported by a state educational initiative of the same name that provided technology resources to high schools across the state. As part of this program, the school must continue to make good use of these technology resources, and both the teacher and the principal explicitly explained that using dissection simulation software was one way to meet this requirement. The teacher and principal also emphasized to me that the computer use at the high school would help prepare students for the job market, since despite its rural surroundings, the high school was still relatively proximate to a major high-tech center. Educational simulation software use helps schools to spotlight and make good use of their technology resources provided as a result of technology standards.

Use of simulations is also often connected to technology standards that control the types of computers available in computers as well as the student-to-computer ratio (Fleischmann, 2005). Specifically, the student-to-computer ratio is important for science software design. One of the key findings of this study published elsewhere (Fleischmann, 2005) was that although an assumption is typically made based on the conventional understanding of human-computer interaction that students should each get their own computer and work individually to complete computer-based tasks, this social environment differs from the traditional K-12 dissection experience and other science

laboratory activities, which are built upon interaction among students working in small groups. As a result of transforming the learning process in science from a richly interactive and social environment to a solitary activity, students have less opportunity for peer learning and social support. As a result, the overall educational experience may suffer, an outcome presumably not intended or expected by educational software designers and technology standard-setters.

## **Results: Designers' Experiences with Standards and Educational Software Design and Marketing**

Science and technology standards also have a strong and growing influence on the design and marketing of educational simulation software. Indeed, this influence is so strong that a product may succeed or fail due largely to standards. A software designer explains, "Every software manufacturer that does anything with client software in particular has to look at goals and objectives [contained in science standards]. Maybe on a state level, maybe on a national level." One particularly compelling example is of a software product that failed because of national and state standards. In this case, the product focused on a topic that was not covered within most state standards, and as a result, it was doomed to failure. As one of the designers explains, "we found out after that product that if our simulations aren't part of the standards and part of the standard course of study, then there's not going to be much interest in it." Thus, when designing simulations, designers must be mindful to match the content of their simulation to existing educational standards.

Another educational software design company was also influenced by science standards in its development of educational simulations. After finishing their first simulation, a frog dissection simulation, the company began developing a series of digital field trips, which explored various ecosystems. Yet, the company made a major strategic readjustment, moving from digital field trips (including canceling a half-completed product) and instead chose to focus on curriculum-specific units to meet particular standards. In this case, the standards seem to have robbed the software designers to some extent of their creativity, and certainly of their intellectual freedom to develop content, since they must develop content specifically to meet standards.

Educational standards also have a significant impact on the marketing of educational simulation software. For example, the website of one of the studied educational software manufacturers includes a page where teachers and administrators can find out how the company's software meets specific science standards. The page includes the science standards of eight U.S. states (including four of the five largest states in the US) and two Canadian provinces. For nine of these states and provinces, the company has developed their own page, but in the case of California, the site links to an external page developed by the California Learning Resource Network which evaluates the company's simulations and how well they match up with the California's science standards. The California Learning Resource Network was established by the California Department of Education to evaluate educational software and its alignment to state academic content standards. It has reviewers that provide the information about particular software. Software must be submitted for review, and this particular software package is apparently the only frog dissection simulation that has been submitted for review by its designers. Thus, educational software manufacturers can conduct their own analyses of its software's compliance with state and province standards and also submit their software for review to websites such as the California Learning Resource Network.

Teacher conferences are a good opportunity for simulation designers to interact directly with teachers. Frog dissection simulation designers routinely attend national, state, and local science teacher conferences in an effort to market their simulation products and boost their sales. Animal advocates representing various organizations also attend these conferences. The primary message of the animal advocates is that dissection simulation software and other alternatives to dissection can meet science standards as well as or better than the practice of wetlab dissection. So, at teacher conferences, not only do dissection simulation designers argue that their products cover educational standards, but so do animal advocates. Further, animal advocates, both in their print materials and in the interviews, emphasize that state science standards do not contain any explicit requirement for students to participate in animal dissection, and that in contrast, many states have passed dissection choice laws requiring teachers to provide alternatives such as dissection simulations to students who object to the activity of animal dissection on moral or ethical grounds (Fleischmann, 2003). Interviews with students revealed a variety of perspectives on the issue of alternatives to dissection, ranging from emphasis on student choice to a preference for required dissection.

Design and marketing of simulations in classrooms are also tied to technology standards. For many designers, it was their interest in technology and the growth of technology use that interested them in simulation design, rather than the particular content of the simulations that they participated in designing. Further, without the increased availability of computers in schools brought about in part by technology standards, they would not have an adequate market for their products. In the marketing of educational simulations, an emphasis on the importance of learning about and with technology is often present in the literature of dissection simulation manufacturers as well as their allies in the animal advocacy movement (Fleischmann, 2003).

The most compelling quote relevant to the issue of standards in educational simulation design was provided by a simulation designer and former teacher, who argues “The selection of the curriculum ought to reflect the local community...with a state-wide curriculum, there are needs that are not addressed or overly addressed in different areas of the state.” This teacher argues that standards may be a step too far in the wrong direction – instead of standardizing everything, teachers should have the ability to tailor their curriculum to meet the needs of their local school district. Certainly, this issue has direct relevance on the design of educational software, since educational standards reduce not only teachers’ ability to meet the specific needs of their students but also designers’ ability to innovate and produce products that are relevant to particular target audiences.

### **Discussion: Top-Down Educational Standards Versus Local Knowledges**

What are the motivations for implementing standards? According to Feng (2002), standards historically have been used to achieve several different goals, including consistency and efficacy. These motivations may occur in the case of educational standards such as science and technology standards. Feng argues that consistency is used to make arguments that standards can serve the cause of social justice, by serving as an equalizer. Swain and Pearson (2003) make a similar argument about technology standards. However, Feng cautions that efficacy of standardization leads to hegemony, as a form of uniformity from above. The potentially hegemonic nature is illustrated in the example provided by Evans (2002) above, where the state board of education uses standards to dictate content to school districts and schools. This power relationship is also present in the data provided above, such that teachers must follow state standards and software developers must produce products that not only follow state standards but also explicitly demonstrate which standards they address.

Do standards serve social justice? Swain and Pearson (2002) make a convincing argument that they do, since they can help to ensure that all schools, teachers, and students have equal access to equipment, training, and software that builds higher-order thinking skills. Yet, there is a danger that, swooping in from above, standards may ignore the social, cultural, and geographic context in which the students are learning. Monahan (2005a, 2005b) cautions, in some cases, that “the question of where standards are set and by whom determines where power is shifting to, on the one hand, and where autonomy is lost, on the other” (2005a: 601). When seen in this way, standards from above can be seen as endangering local control of educational experiences. The final quote provided in the results section above most clearly makes this point.

According to Geertz (1983) and Hess (1995), all knowledges are socially, culturally, and geographically situated. Hess relies on the case of medicine, and discusses the various non-Western medical traditions that have evolved, like biomedicine, over long periods of time, and which, at least in many cases, are becoming increasingly popular in the contemporary United States. Eglash (1999) demonstrates that local knowledges can also apply to areas such as mathematics. He finds that many African cultures developed a deep understanding of fractal geometry long before it was “discovered” in the West. He then puts this research into practice by using it to encourage achievement in mathematics by African-American students. In his current research, he makes a similar intervention into the teaching of Native American students. Thus, local knowledges can be useful for stimulating interest in an educational subject, especially among specific social, cultural, and geographical groups. While standards clearly have many positive benefits as described above, they may also reduce the autonomy and specificity of local educational curricula when they are created and implemented through a largely top-down process.

### **Conclusion: A Bottom-Up Approach to Science and Technology Standards**

Science and technology standards play a significant role in the design, marketing, and use of educational software. Certainly, there are benefits to science and technology standards, as discussed above. Yet, the standardization

process is currently a largely top-down process, with design occurring primarily at the national and state level while implementation takes place at the local level with pressure applied from above, as explained by Hoff (2002) and Evans (2002). As demonstrated here, top-down state science standards have the effect of stifling innovation in software design, as in the case of two of the simulation design companies described above. Similarly, technology standards may not take into consideration the specific needs of local communities. After examining the impacts of the current top-down regime of science and technology standards on educational software design, marketing, and use in practice, it seems useful to consider an alternative approach to standard-setting, a bottom-up approach.

Is a top-down process the only or even the best way of designing and implementing science and technology standards? Standards-setting processes are often promoted as participatory, with input being sought from teachers and lower-level administrators. Yet, this is still a top-down approach, since standards are first set at the national or state level and then trickle down to districts and schools who are compelled, often through incentives such as standardized testing and the purchasing of texts, software, and other equipment, to adopt the dominant standards. Further, at the state level, it is the large states that have the most impact on textbooks and software, creating an inequality of fairness among the states. A bottom-up approach to educational standards would replace the centralized power of standard-setting bodies at the national level and within large states with a more diffuse power that is spread more evenly among schools and school districts, giving them more autonomy to control their own classroom content and giving software developers more room to innovate to meet the diverse needs of local schools.

Perhaps it would be useful to examine not only the effectiveness of this structure but also the potential of inverting it to allow for more local control of educational content and equipment. In such a scenario, schools and districts might begin the standard-setting process, which would then be built up to the state and then the national level as a process of consensus-building. Local standards-setters could get the input of larger educational bodies in an advisory role, rather than the reverse. A process of standardization from below might allow teachers, students, and administrators to reap the benefits of standardization discussed above while still retaining local autonomy and control over content, and leaving the door open for more innovation in educational software design, marketing, and use. By empowering teachers to serve not only as software designers (Fleischmann, 2006a) but also as standards-setters, it would allow them to control the content that they teach rather than merely implementing the wills of faceless standards boards, ensuring that they would be able to meet the real needs of the students in their classrooms.

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