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Pedagogical Praxis: The Professions as Models for Learning in the Age of the Smart Machine

David W. Shaffer[1]

Dewey's collected writings remain a classic and unsurpassed elaboration of the relationships among cognition, learning, technology, and citizenship in the context of the practical problems of teaching and learning (Dewey, 1915, 1938, 1958; Menand, 2001). However, Dewey's work, written in an industrial era, cannot be applied directly to educational practice in an age increasingly marked by social and economic transformations of new technology. Many leading philosophers and historians of ideas have wrestled with Dewey's continuing relevance in the past 15–20 years in what has come to be known as a pragmatist revival (Menand, 2001). The theory of *pedagogical praxis* returns to the program that lies at the core of Dewey's work in order to ask in both a theoretical and practical way: What would it mean if we took this program seriously today? What new relationships among learning, technology, and citizenship emerge if we ground educational practice in the post-industrial technologies of communication and information? What would such a program look like, and what would its implications be?

It is easy to forget after almost 100 years that Dewey's "lab schools" at Chicago and Columbia were precisely this: laboratories for experiment in education and democracy. A critical research problem today is thus to develop such laboratories in an information age, when the school is no longer the only (or necessarily even the primary) focus of education, and when the boundaries of cognitive, social, and moral development are more complex and porous than even 30 years ago. To develop such a laboratory, pedagogical praxis turns to the broad learning contexts of young people, centered on environments designed for formal education but not restricted to schools as currently structured. Rather, the focus is on learning and the conditions and processes that facilitate learning in technology-rich contexts writ large.

To explore the potential of technology-based learning, pedagogical praxis focuses on after-school activities, investigating learning at the intersection of school, family, media, peer group, and community. The approach is psychological (it is centered on the learning subject) while systematically incorporating critical aspects of context into the research process. Pedagogical praxis extends research on communities of practice (Lave, 1991; Lave & Wenger, 1991; Wenger, 1998), using the concept of *thick authenticity* (Shaffer & Resnick, 1999) to investigate the effects of multiple layers of context on learning. The goal is to analytically separate the effects of layers of context and to reintegrate them in a more complex model of the

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learning process—one that incorporates emerging social, economic, and technological forces and their implications for cognition and citizenship.

The central framework for this reintegration draws from Donald Schon's work on *reflective practice* (Schon, 1985, 1987), which suggests that professionals learn to think in action, and that they learn to do so through their professional experiences. Reflective practice involves taking action and then reflecting on the results with peers and mentors. Pedagogical praxis extends the model of reflective practice and applies it to the problems of complex learning by adolescents. In so doing, the theory suggests that this form of thinking is essential to all complex learning: cognitive, practical, and civic.[2]

More broadly, such an investigation calls for a reexamination of (a) the skills, habits, and understandings young people need to become productive and constructive members of society and (b) the manner in which this collection of "things worth knowing" are organized and constituted in the educational process. The traditional disciplines (e.g., mathematics, history, science, and language arts) evolved to parse the intellectual landscape of the Middle Ages (Donald, 1991) and shaped the school curriculum in the 19th century. Indeed, part of Dewey's (1915) critique of schooling was that this traditional organization of knowledge was misaligned with the social and cultural realities of the industrial era. Accordingly, pedagogical praxis investigates the nature of learning and its relationship to the central cultural, social, and economic practices of the post-industrial era. The theory of pedagogical praxis suggests that professional practices reflect distinctive epistemologies—ways of knowing and ways of deciding what is worth knowing. These epistemologies of practice intersect with and overlap traditional academic disciplines such as mathematics, science, and history. Thus, the practices through which professionals learn provide an alternative route to developing important habits of mind and understanding key intellectual domains—and so an alternative model for creating compelling learning environments in a technological society.

Pedagogical praxis sets out a rich and ambitious agenda of research and reform. The goals of this paper are (a) to describe the basic theoretical claims of pedagogical praxis, (b) to explain the experimental methods that explore these claims, and (c) to present examples of technology-based learning environments that exemplify this process in action. As such, this paper serves as a prolegomenon—an overview of a larger argument. The examples and evidence are intended not to validate the theory of pedagogical praxis, but rather to clarify the kinds of claims it implies and the methods through which these claims are being investigated—to describe the shape and scope of this line of inquiry and to suggest how and why it may be a fruitful area for continuing research.

New Technologies, New Opportunities, New Challenges

New technologies make it possible for young people to participate more directly in the world of adult activities, whether using software tools to develop new mathematical proofs (Lichtfield, Goldenheim, & Dietrich, 1997), participating in the collection and analysis of real

[2] Lewis Friedland's expertise on the work of John Dewey and the pragmatist tradition—and his great editorial skill—were invaluable in developing this section of the paper.

scientific data (Evans, Abrams, & Rock, 2001), or publishing work on the Internet. Thus, new technologies make it easier for students to learn about the world by participating in meaningful activity. This idea is not new; rather, it explains one way that new technologies support Dewey's (1915) vision of bringing the "life of the child" into an environment for learning (p. 30).

Dewey argued that knowing and doing are tightly coupled, and thus learning needs to take place in the context of activity (Dewey, 1915; Menand, 2001). Moreover, as Dewey suggested in *Art as Experience* (1958), learning involves meeting and overcoming obstacles in the process of trying to accomplish a meaningful goal. "Resistance and check," he wrote, "bring about the conversion of direct forward action into re-flection" (p. 60). Schon argues that professionals enact this link between knowing and doing through a process of reflection-in-action: literally, "a capacity to combine reflection and action, on the spot, . . . to examine understandings and appreciations while the train is running" (Schon, 1985, p. 27). Schon's work suggests that professionals learn to think in action, and that they learn to do so through their professional experiences. Reflective practice involves taking action and then reflecting on the results with peers and mentors.

As Vygotsky and other theorists have suggested, this reflective process is progressively internalized: the norms, habits, expectations, abilities, and understandings of a community of practice become part of the identity of the individual (Lave, 1991; Lave & Wenger, 1991; Vygotsky, 1934, 1978; Wenger, 1998; Wertsch, 1998). Lave and Wegner describe a community of practice as a group of individuals who share a repertoire of knowledge about and ways of addressing similar (often shared) problems and purposes. In the process of participating in the learning practices of such communities, individuals develop ways of thinking and reframe their identities and interests in relation to the community. For example, journalists share common ways of thinking and working, and individuals who work in the field of journalism incorporate these ways of thinking and working into their sense of self, coming to think of themselves, at least in part, as journalists.

Different communities of practice (for example, different professions) have different epistemologies: different ways of knowing, of deciding what is worth knowing, and of adding to the collective body of knowledge and understanding. Of course, in the context of professional activities, these ways of knowing are constituted in practice, and the processes of professional training are designed to link praxis and epistemology through pedagogical activity. The challenges from the perspective of educational design are thus three-fold. First, one must uncover the structure of learning practices as they are currently constituted: the relationships among activity, pedagogy, and epistemology that different learning practices embody. Second, one has to map the relationships between the epistemologies of practice and the kinds of understanding (cognitive, social, moral, and practical) that we want young people to develop in the course of their education. And third, we have to develop techniques for adapting extant learning practices to create environments that are true both to the ways of knowing of those practices and to the central skills, habits, and understandings that young people need to incorporate given their developmental trajectory. That is, we need to know how learning practices work, how they relate to what young people need to learn, and how to use technology to bring those practices within young people's grasp.

Environments that develop constructive skills, habits, and associations function as *coherent systems* (Brown & Campione, 1996; Papert, 1980; Shaffer, 2002). Any successful implementation of a context for learning depends on a clear articulation not only of "surface procedures," but also of the underlying "principles of learning" (Brown & Campione, 1996, p. 291). One approach to creating such coherence, explored many designers of thoughtfully innovative learning environments, is to articulate a set of principles that will guide the design of activities and assessments (Bransford, 1994; Brown & Campione, 1996; Enyedy, Vahey, & Gifford, 1997; Goldenberg, 1996; Goldman-Segall, 1997; Hmelo, Holton, & Kolodner, 2000; Jackson, Stratford, Krajcik, & Soloway, 1996; Jacobson & Lehrer, 2000; Kafai, 1996; Kolodner, Crismond, Gray, Holbrook, & Puntambekar, 1998; Resnick, 1994; Scardamalia & Bereiter, 1996). A challenge in this approach is that the number of principles and practical constraints multiplies quickly; designing an environment that simultaneously addresses a complex system of requirements can be daunting.

Pedagogical praxis takes a different approach. Because professional learning practices have evolved into coherent systems over time, pedagogical praxis suggests that professions such as accounting, architecture, mediation, engineering, journalism, law, and medicine can provide particularly powerful models for developing technology-based learning environments where young people learn important skills, habits, and associations (Shaffer, 1998, 2002). The model of pedagogical praxis is to uncover the principles embedded in existing learning practices (a problem of cognitive anthropology and descriptive ethnography), develop technologies to help students participate in these practices (a problem of engineering and technology development), and then create experimental learning environments designed to develop life skills through participation in a community of practice (a problem of program design and action research).

In so doing, pedagogical praxis seeks to create environments that are thickly authentic. Authenticity is an alignment between activities and some combination of (a) goals that matter to the community outside of the classroom, (b) goals that are personally meaningful to the student, (c) ways of thinking within an established domain, and (d) the means of assessment (Shaffer & Resnick, 1999). Thickly authentic learning environments create all of these alignments simultaneously—for example, in the case of pedagogical praxis when personally meaningful projects are produced and assessed according to the epistemological and procedural norms of an external community of practice.

In this vision, new technology reinvigorates Dewey's (1915) idea of learning important life skills through active engagement in meaningful activity. Young people learn by working as "practicing" professionals (Schon, 1985, 1987; Shaffer, 1998, 2000, 2002).

The General Methodology of Pedagogical Praxis

Pedagogical praxis proposes that professional learning practices provide useful models for technology-rich learning environments for middle and high school students. This idea has been explored through design research projects. Through a series of studies, these projects systematically develop and test experimental curricula that build a bridge between practices appropriate for adult professionals and the needs and abilities of younger students (see Figure 1 next page):

1. *Baseline study*: Conduct a pilot study in which students engage in a prototype of the learning practices through which professionals are trained in a given field, exploring how students relate to the professional ways of thinking and working.

2. *Ethnography of practice*: Conduct careful ethnographic study of the learning practices through which professionals are trained in a given field.

3. *Technology development*: Based on the ethnography of practice and baseline study, develop or adapt technologies that bring the domain of practice within reach of middle and high school students.

4. *Outcome and process measures*: Based on the ethnography of practice and baseline study, identify, develop, or adapt outcome measures that assess progress in the target domain or domains of thinking, as well as observational procedures that document how learning takes place in the context of professional practice.

5. *Learning environment*: Create a learning environment using technologies built or adapted in technology development to help students learn using the pedagogies uncovered in the ethnography of practice.

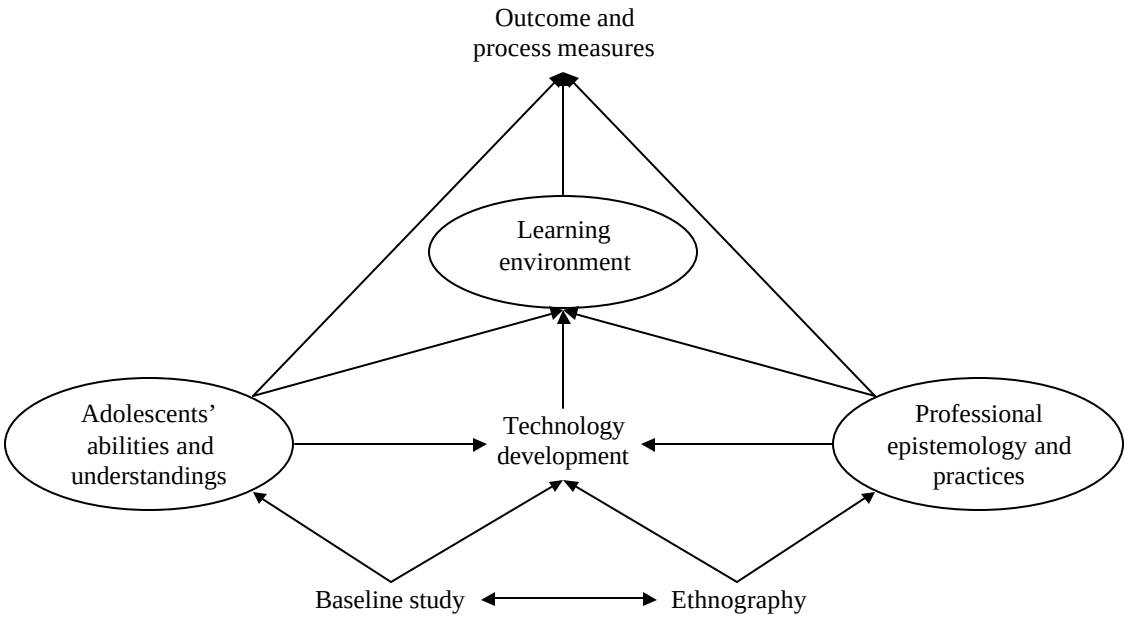

Figure 1. Pedagogical praxis uses technology to build a bridge between learning practices appropriate for adult professionals and the needs and abilities of younger students.

Of course, the steps of pedagogical praxis are constituted together as the design research process unfolds. The studies inform and support one another in the development process. However, for rhetorical convenience and conceptual clarity, they are separated above and in the discussion that follows.

Studies Discussed

The remainder of this paper uses data from three studies—Escher's World, the Pandora Project, and the ByLine Project—to illustrate the effectiveness of pedagogical praxis as a method for developing compelling learning environments. Two of these studies (Escher's World and the Pandora Project) are reported in more detail elsewhere (Cossentino & Shaffer, 1999; Shaffer, 1997, 1998, 2002; Shaffer & Scopinich, 2003), and the third study (the ByLine Project) is in the pilot stage. The context of these studies is described briefly below; specific information on methods of the studies can, of course, be found in the more detailed descriptions.

Escher's World

I developed the method of pedagogical praxis through a series of studies that led to the creation of Escher's World (Shaffer, 1997, 1998, 2002). Inspired by M.C. Escher, whose compelling visual images convey deep mathematical ideas, Escher's World is an environment where middle school students learn basic concepts in transformational geometry through graphic design activities in a computer-aided design studio. The Geometer's Sketchpad (Jackiw, 1995) was chosen as a tool that would allow middle school students to use mathematical ideas to support design explorations. In the software, mathematical ideas appear as relationships that determine the behavior of images on the computer screen; students can simultaneously explore the mathematical principles and the design properties of their creations. Outcome measures and observational procedures were developed to capture students' thinking during the learning process: a record of students' design work was compiled from copies of work done online, as well as from clinical interviews conducted as part of the design process. The project implemented a 4-week summer program in which 12 middle school students from a range of socioeconomic and ethnic backgrounds conducted a series of design projects leading up to an exhibit in a local gallery of students' "Postcards from Escher's World" (Shaffer, 1998, 2002).

The Pandora Project

In the Pandora Project, high school students learned human immunobiology and biomedical ethics through computer-supported negotiation modeled on exercises developed by the Harvard Program on Negotiation for training professional mediators (Susskind & Corburn, 2000). Students acted as lead negotiators for parties in a dispute concerning a fictitious company seeking governmental approval to begin experiments with the controversial biomedical procedure of xenotransplantation (the introduction of organs from other species into human patients as treatment for late-stage organ disease). The computational tool was a collaborative Web site that helped students conduct and share research and preparation materials for the negotiation. Conducting the negotiation required understanding information about genetics, epidemiology, and cell biology in order to assess issues raised by xenotransplantation, including cost/benefit analysis, differential risk/reward tradeoffs between developed and developing nations, individual and societal rights, and animal welfare. Outcome measures were developed to explore the extent to which students' thinking about these issues changed both in the specific context of xenotransplantation and more generally in the way they addressed social dilemmas. Twenty-four 17- and 18-year-olds participated in two experimental implementations of this 2-week, school-based curriculum.

ByLine Project

ByLine is a learning environment where students work as online community journalists to learn about emerging technologies such as the Internet, wireless communications, and (in the context of recent events) weapons of mass destruction, and study the impact of such technologies on their community. Preliminary work has been done on a baseline study of students' ability to work as online community reporters, on the ethnography of journalistic pedagogy, and on the development of a collaborative, Web-based tool to support online community journalism for high school students in neighborhood community centers.

Results

This section of the paper presents results from the three projects described above, showing how collectively these projects explore the effectiveness of professional practices as models for the development of technology-rich learning environments for middle and high school students as well as the learning processes that unfold for young people in the context of professional learning practices.

Escher's World: Learning Geometry Through Design

An ethnographic study of design practices analyzed the learning processes of an architectural design studio and described how the overall structure of the learning environment (including schedule, spatial organization, and presence of material and personnel resources) was used to support specific pedagogical features such as intensive, structured, one-on-one feedback sessions and public presentations of work, including design reviews and juries. This study showed how these practices support the underlying epistemology of design—the development and expression of unique and creative solutions to problems for which there are no "right" answers. Because design ideas reflect an individual interpretation of an architectural problem, students in the design studio were presented with challenges that had an infinite number of potential resolutions. Their task was to develop a unique solution, to understand that solution, and to convey in words, diagrams, and models how the solution they chose met the demands of the original problem. The idea they developed was of their own choosing—as long as they could develop a coherent design based on that idea and defend their rationale. As one design professor explained to a student: "You're in control. Make it whatever size you want. Then I'll ask: Why is it that size? And you'll say: Because it's doing this job. And you'll develop your argument."

The Escher's World learning environment was developed based on this ethnography of practice. In Escher's World, middle school students learned geometry through graphic design activities in a computer-aided design studio. Pre-, post-, and final interviews showed that students in Escher's World were able to learn geometry through design activities. Students' scores on paper-and-pencil tests of transformational geometry rose significantly between pre- and post-interviews (mean pre = 9.5, mean post = 12.25; $p < .01$). These gains were stable in final interviews 3 months later (mean final = 12.0). Student scores in the final interviews differed significantly from those in the pre-interviews ($p < .05$) but not from those in the post-interviews ($p > .49$). Overall, students reported feeling more positive about mathematics as a result of the Escher's World activities. As one student put it: "I see that math is such a more broader, bigger

area of a whole bunch of different things." A common sentiment was simply: "I wish school [math] was like this."

To reveal the processes through which change took place in the learning environment—that is, to see whether mathematical understanding developed, and if so, how—records of students' design work were compiled from clinical interviews conducted during one-on-one feedback sessions. These records of student activity were assembled into design histories, which were coded and analyzed using qualitative techniques. Observed patterns were confirmed using fixed-effects logistic regression models.

Students reported some kind of mathematical insight in 22% of design episodes (176/806), and all students reported having conceptual mathematical insights at some point in the program. More significant, analysis of student work showed how the professional practices of the design studio played a key role in this learning. In Escher's World, students internalized the epistemic stance of design and applied it to the domain of mathematics, coming to think of mathematics as an expressive domain. Projects produced in the context of an architectural community of practice motivated students to "say something" about mathematics; starting a design exploration with a mathematical concept as an expressive goal made it more likely that a student would come to develop mathematical understanding in the course of his or her design work ($p < .001$). In the process of trying to "say something" about mathematics, students typically encountered problems creating the desired mathematical effect using the computational tool. Because projects were open-ended and personally meaningful, students were motivated to work through these problems. The practices of the design studio provided a framework for posing, and resolving, these problems through interactions with peers and experts, and ultimately, these interactions helped students uncover and understand the underlying mathematical concepts in their design work. Students were 54 times more likely to have an insight about mathematical concepts during conversations with a program leader ($p < .001$) and 30 times more likely to have such an insight as a result of interaction with a peer ($p < .001$) than with no interaction at all. Finally, the iterative nature of projects in the studio led to generative feedback from peers and experts, helping students further refine mathematical understanding. (More detail about this process is available in Shaffer, 1998; 2002.)

In other words, students were able to use the practices of the design studio to transfer the epistemic framework of developing and defending expressive solutions to open-ended problems from graphic design to mathematics. In so doing, students came to understand the mathematical concepts more deeply, and to appreciate mathematics in new ways.

The Pandora Project: Learning Immunobiology Through Mediation

In the Pandora Project, students took roles as lead negotiators for the various sides in a dispute concerning a fictitious company seeking governmental approval to begin experiments with the controversial biomedical procedure of xenotransplantation. Xenotransplantation is the introduction of organs from other species (in the case of this fictitious negotiation, pigs) into human patients as treatment for late-stage organ disease. Students researched issues raised by xenotransplantation and the positions taken by various stakeholders in the negotiation; they then conducted a structured negotiation modeled on exercises developed by the Harvard Law School Program on Negotiation (Susskind & Corburn, 2000). An important core of the epistemology of

negotiation is that stakeholders in a dispute have legitimate conflicting interests, and the goal of negotiation is to reconcile those interests in an equitable manner, given the constraints of the situation. The focus is thus on the parties involved in a problem, understanding their needs and analyzing how proposed solutions affect their legitimate interests.

Results from pre- and post-interviews showed that in the process of the simulated negotiation, students developed a better understanding of both the process of xenotransplantation and its social, economic, and personal consequences. Interviews and concept maps showed increased understanding of the complexities of the issues in xenotransplantation. Concept maps drawn by students showed significant change between pre- and post-interviews. Maps had both more nodes and more links in post-interviews. (Mean nodes pre = 9.6; mean nodes post = 10.6; $p < .05$. Mean links pre = 12.8; mean links post = 18.5; $p < .01$. See also Figure 2.)

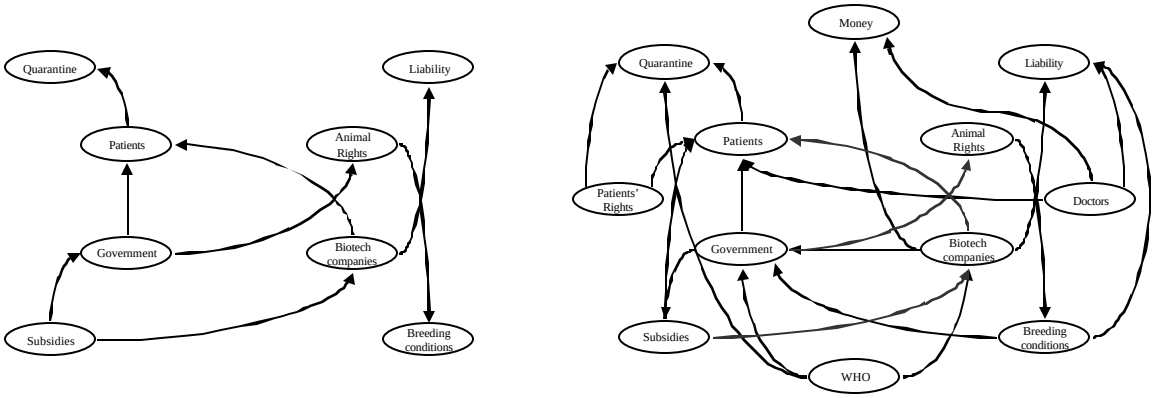

Figure 2. One student's concept maps from pre-interview (left) and post-interview (right) show a significant change in complexity of thinking about xenotransplantation.

The curriculum began with an excerpt from a news broadcast about a teenage girl who was suffering from liver disease and waiting for a donor organ. Participants were asked at the beginning and end of the curriculum unit whether she should consider accepting a xenotransplant if one was available. At the beginning of the 2-week unit, one student wrote:

> I think that [she] should accept the transplantation. As I see it she has two options: (1) Not get the transplantation, and turn yellower and then die. (2) Take a risk and get the transplantation.... There is a possibility that it would work out, and she would be fine, plus one pig liver. Whatever.

At the end of the unit, the same participant wrote:

> If anything, I am now convinced that I cannot make that judgment without a lot more information on the procedure and its accompanying issues. . . . But I can come up with the questions I think [she] would need to have answered: (1) Is there a quarantine? How long? How strict? Can I see my family? How long am I going to be restricted to a hospital bed for . . . ? What kind of a life would I have saved myself for? (2) What happens if the transplant works, but I get even sicker from a disease I get from the pig? Is [the company that developed the procedure] going to just abandon me because they don't want to dirty their hands? Is this something no one will know how to deal with? What kind of a life will that be . . . ? (3) How much do I want to be a part of this procedure, which is an experiment, when I know that the results are so unpredictable and I am so aware of the risks?

At the beginning of the negotiation unit, 82% of the students (9/11) similarly said the girl should take the transplant with relatively few reservations; the remaining 18% (2/11) recommended against the transplant. At the end of the unit, 45% of the students (5/11) recommended the transplant, but only if certain conditions were met; 36% (4/11) recommended against the transplant; 18% (2/11) were skeptical but felt that they did not have enough information to make an informed recommendation. Overall, 91% of the students (10/11) reported that they had changed their opinions about xenotransplantation over the course of the unit. The same proportion reported that they understood xenotransplantation better, and 55% (6/11) said that they now understood a range of perspectives on the questions raised by xenotransplantation.

Students also responded to four more general (far-transfer) questions in pre- and post-interviews. For example, they were asked to respond to the following scenario:

> FieldFarms, an international grain supply company, has developed a new form of wheat that is far less expensive that traditional forms of wheat. However, the grain is sterile, meaning that farmers cannot store seeds from one harvest to use the next year; they have to continually buy seeds from the company. The United Nations Food and Famine Commission is concerned that farmers in developing countries will be tempted by the lower price for the grain, but then become dependant on these grain supplies, and be required to pay whatever price FieldFarms demands for its grain. What conditions, if any, should be imposed on the use of this new form of wheat?

Before the negotiation about xenotransplantation, one student responded:

> [I]f Field Farms made it, they have the right to sell it however they want to. . . . [T]he farmers should be made aware that they might have to pay higher prices, but I think they have to take that risk . . . of knowing that they might in the future have to pay higher prices for it because they could always buy it from somewhere else if Field Farms raised their prices too much. So, I don't think that they should require Field Farms to have any certain price because I think supply and demand will take care of that in a way in these foreign markets.

Two weeks later, after the negotiation, the same student responded to a similar scenario:[3]

> Field Farms has a right to sell it at what price they want to, but because it's a monopoly on the thing, I think in the developed world . . . whatever the market demands, that's what they'll sell it for. . . . But I think in the developing world . . . much like AIDS drugs, I think . . . they should lower the prices a little bit. You know, make sure it's fair. Because obviously developing countries are a lot more dependant on agriculture than we are, and I think it's sort of holding them hostage if every year you can just jack up the price on the grain.

Answers such as these showed students' progression towards more nuanced views of complex problems. There was not, overall, a change in students' propensity to support or oppose innovations that raised ethical issues. However, before the simulated negotiation curriculum, more detailed responses came from students who were looking for more information ($R^2 = 0.46$, $p < 0.05$) and/or proposing a means to get more information about the problem ($R^2 = 0.85$, $p < 0.01$). After the negotiation experience, more extensive answers were still associated with a perceived need for additional information ($R^2 = 0.51$, $p < 0.05$), but such responses were also associated (as in the example above) with analogical reasoning ($R^2 = 0.82$, $p < 0.01$) and with

[3] Students were randomly assigned an A and B form of matched scenarios in pre- and post-interviews.

consideration of more viewpoints from groups of people affected by the proposed technology ($R^2 = 0.61$, $p < 0.01$). In other words, enacting professional learning practices helped these students think about ethical dilemmas using the epistemological framework of professional negotiation and dispute resolution. In this case, learning through simulated negotiation supported both a change in perspective taking and the development of conceptual understanding. (More information about this study is available in Shaffer and Scopinich, 2003.)

The Byline Project: Learning About Technology and Community Through Online Journalism

Two baseline studies have been conducted on journalism as the basis for adolescent learning, one at a Boston, Massachusetts, branch of the YMCA, the other at the Neighborhood House Community Center in Madison, Wisconsin. A total of 12 high school students, primarily from less-affluent urban neighborhoods, participated in a 10-hour Web-based journalism program. Students learned to use a prototype tool for collaborative Web site construction and then researched and produced Web sites about the impact of technologies on adolescents' lives and communities.

Preliminary results suggest that in this process, students develop more complex views of the relationship between technology and community. Students produce more complex concept maps about the impact of technology. They also come to see technology as more ubiquitous ("I don't think anyone can say 'I'm technology-free' nowadays. [Even] candy is made out of technology!"), more problematic ("[The Internet is] a very helpful source of information. At the same time, it is a terrible place to send your children."), and more critical as a life skill ("[If] you don't know how to use [the computer], you gonna be lost!"). It also appears that, as in the previous examples of Escher's World and the Pandora Project, professional pedagogy supported students in overcoming obstacles to develop understanding in pursuit of meaningful goals. In the Web-based journalism pilot study, understanding of the tool for Web site construction, the process of reporting and writing, and the impact of technology on young peoples' lives advanced as students tried to create a common vision for their Web site. "When you're going through other people's writing," one student observed, "you notice that everybody has a different style of writing. And when you bring it all together it gets very confusing and you don't know whose style is best. When you try to put it all together and you try to make a Web site out of it, it can be very, very difficult . . . [but] you have to incorporate it all just to make a Web page." More important, students were collaborating about substance as well as style: "You've got to all agree on things," said one student. "Everybody's got different views [and] you've got to come to an agreement."

The Byline Project is currently completing an ethnographic study of the training of journalists. This ethnography suggests that the concepts of a story and lead are major organizing frameworks for journalistic thinking. There is a standardized journalistic architecture by which the story (the events that unfolded and that are uncovered through reporting) is rendered into a story (a text that purports to represent those events in journalistic form). The existence of a journalistic architecture implies that the choice of lead (the perspective from which a story is told) is one of the most salient creative decisions in the reporting process. Interactions with instructors and editors, and the pedagogical opportunities they present, are structured (a) around the execution of journalistic architecture—focusing on rapid production of constrained stories;

and (b) around the choice of lead—focusing on extended investigations in which students progressively develop a set of stories on a single topic.

At the same time, work is continuing on the development of a Web-based tool that removes many of the technical barriers to producing Web content. In the pilot tests, adolescents with no prior Web experience created personal Web pages, then each researched, developed, and edited a page on a particular technology as part of a collaborative Web site.

In other words, although the process of pedagogical praxis is not complete for the ByLine Project, preliminary results suggest that the results of this continuing study will align with the processes and outcomes of Escher's World and the Pandora Project.

Discussion

The goal of this paper has been to describe the basic theoretical claims of pedagogical praxis, to explain the experimental methods that explore these claims, and to present examples of technology-based learning environments that exemplify this process in action. As a prolegomenon, or overview, to a larger argument, the paper has sought not to validate these claims but rather to clarify the issues that the theory of pedagogical praxis raises.

That said, data from the three studies presented here do suggest that professional learning practices can successfully inform the development of compelling learning environments for middle and high school students. Taken together, these projects show that pedagogical praxis can be successfully used to design effective learning environments for students from a range of cultural and socioeconomic backgrounds; that an environment based on professional learning practices can support learning in a range of domains (including mathematics, biology, ethics, communication arts, and civics), leading to significant changes in attitudes and mores as well as the refinement of cognitive skills; and that a range of professional practices (including architecture, mediation, and journalism) can inform the development of learning environments for middle and high school students.

The purpose in developing such environments is twofold. From a practical point of view, it is helpful to have a usable model for developing after-school programs that engage students and help them master important skills, habits, and understandings from the traditional curriculum. It is even possible to imagine that teachers, curriculum developers, and other practitioners might borrow from this work in developing new and innovative curricula for traditional classrooms, which has in fact happened in several instances.

From a theoretical point of view, the goal of pedagogical praxis is to understand the relationship between activity and learning in the context of professional learning practices. As Brown, Campione, and others have argued, successful curricula are not collections of isolated pedagogical elements; rather, effective learning environments function as coherent systems (Brown & Campione, 1996; Papert, 1980; Shaffer, 1998). We know a great deal about some of the epistemological and pedagogical underpinnings of compelling learning environments. However, orchestrating these elements into a coherent whole remains a challenge.

The hypothesis that this work is only beginning to explore is that professional practices—and thus professional learning practices—embody distinct epistemological norms, and that by participating in professional learning practices, students can internalize and transfer these epistemological norms to new situations. That is, after working as an architect in Escher's World, as a negotiator in the Pandora Project, or as a journalist in the ByLine Project, students begin to think like architects, negotiators, and journalists in other contexts. Thoughtful enactment of a practice necessarily involves making decisions about ways of knowing, ways of deciding what is worth knowing, and ways of adding to the collective body of knowledge and understanding. In learning to participate in a practice, students internalize these ways of thinking, which they are able to apply in other venues.

In some senses, this is not a radical hypothesis. The concept of "transfer" is certainly not new, nor is the idea that learning involves participation in the practices of a community. Others have written about professional norms, and more generally about the role that external assessment can play in learning (Baron & Wolf, 1996; diSessa, 2000; Erickson & Lehrer, 1998; Lehrer & Chazan, 1998; Lehrer, Erickson, & Connell, 1994; Shaffer & Resnick, 1999; Sizer, 1984, 1992). However, the existence of epistemologically coherent pedagogical systems in the learning practices of the professions suggests that it may be possible to satisfy the theoretical requirements for creating innovative learning environments by adapting existing practice rather than designing from first principles. As Brown and Campione (1996) might argue, this adaptation cannot merely be ad hoc borrowing. Rather, the adaptation would have to understand and preserve the essential epistemological principles of the original.

In order to demonstrate the validity of these claims, researchers working with the theory of pedagogical praxis need to show that professional practices have distinct epistemic norms, that these norms can be internalized through participation in the learning practices of the professions, and that these norms can then be applied in other contexts. These issues are the subject of continuing study and forthcoming manuscripts.

The implications of this approach are potentially quite broad. If, indeed, professional practices present a set of coherent epistemic frameworks, then such practices may provide an alternative model for organizing our educational system. Perhaps the power of new technologies to bring professional practices closer to the purview of middle and high school students provides an opportunity to move beyond disciplines derived from medieval scholarship constituted within schools developed in the industrial revolution. It may be that rather than constructing a curriculum based on the ways of knowing of mathematics, science, history, and language arts, we might imagine a system in which students learn to work (and thus to think) as doctors, lawyers, architects, engineers, journalists, and other knowledge workers—not in order to train them for these professions in the traditional sense of vocational education, but rather because learning to work in such professions provides students with an opportunity to learn about the world in a variety of ways that are fundamentally grounded in meaningful activity and well aligned with the core skills, habits, and understandings of a postindustrial society.

The studies described above clearly do not provide conclusive evidence that such a vision is possible, or even desirable. But they do suggest that pedagogical praxis may be one way to return to Dewey's intellectual program, reinvigorated by Schon's theory of reflective practice, in another era of dramatic social and economic transformation brought about by new technology.

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