TWO

The Elements of the Teaching for Understanding Framework

Generative Topics and New Technologies

3

Choosing the topics students will study and deciding how to organize curriculum plans are some of the most difficult decisions a teacher makes. And they are among the most important. Especially when teachers invest the extra effort to integrate new technologies, they want to be sure that the topic merits extra planning and is worthy of students' sustained attention.

What kinds of topics are worth teaching for understanding? Teachers and researchers who worked on the Teaching for Understanding project developed a way to answer this question. They reviewed many curriculum units, across a range of subject matters, that teachers found to be especially effective in developing their students' understanding. Some examples were (1) "the sense of place" in a literature class, (2) classification schemes in a biology class, (3) the Industrial Revolution in a history class, and (4) proportional reasoning in a mathematics class.[1]

Analyzing these cases in relation to theories of effective teaching and learning revealed some common features across the units. In each case, the topic was significant because it related to several important ideas in the subject matter, was easily connected to students' experience and interests,[2] and could be approached in multiple ways through a range of curriculum materials and entry points.[3] Also, the teacher was passionately interested in the topic. Finally, the topic had a bottomless quality because the more students delved, the more they generated new questions to investigate. The Teaching for Understanding project coined the term *generative topics* for curriculum topics that met these criteria as a way of emphasizing that they generate and reward sustained inquiry.

Features of Generative Topics

- Connect to multiple important ideas within and across subject matters
- Are authentic, accessible, and interesting to students
- Are fascinating and compelling for the teacher
- Are approachable through a variety of entry points
- Generate and reward continuing inquiry

New technologies are often particularly appropriate and valuable for enhancing the generative qualities of curriculum topics. The Internet can link the classroom to the students' experiences in the real world by connecting schoolwork to authentic problems, actual data, and outside experts and collaborators. Multimedia technologies, with dynamic images, video, and audio, enrich the usual classroom materials and enable students to learn through a broader range of entry points. Expanding the variety of curriculum materials and means for accessing information enables students to pursue their own interests, ideas, and pathways through an investigation rather than simply follow prescribed steps in a set chapter or workbook. Students are more likely to become engaged in studying a topic if they are able to approach the material in ways that particularly pique their interests and suit their preferred ways of learning.

TIP

Q: How do you decide which topics and which technologies to choose?

A: Focus on topics that are "targets of difficulty."

In some respects, the endless wealth of possibilities opened up by new technologies can pose more of a problem than a solution to the teacher faced with the challenge of selecting curriculum topics. How do teachers decide which topics and which technologies to choose? One response is to focus on the problem spots that tend to recur every year. What topics are perennially difficult for students to learn that are also central to the subject matter and potentially made easier by the use of new technologies? The Educational Technology Center at the Harvard Graduate School of Education recommended such "targets of difficulty"[4] in the curriculum as worthwhile topics on which to focus the use of new technologies. Examples include heat and temperature or weight and density in science, ratios in mathematics, and stereotypes in history and social studies classes. These topics are difficult to understand, centrally important to the subject matter (that is, if students fail to understand these topics well, they will not be able to succeed in further studies of the subject), and likely to be made more understandable through the use of new technologies.

Generative topics that are also targets of difficulty are worth investing the extra effort needed to design and implement curriculum that thoughtfully integrates complex educational technologies. By focusing the application of new technologies on such topics, teachers may alleviate some serious and significant

Targets of Difficulty

- Perennially difficult problem spots in teaching and learning
- Central and critical to the subject you teach
- Likely to be understood better through the use of new educational technologies

teaching and learning challenges in their current program rather than simply dress up lessons that are already working reasonably well or that are only moderately important.

Case Study: Analyzing Patterns Through Quilt Math

Many teachers and students experience math as the least generative topic in school. Too often, math is taught as a set of right answers that adults know, some smart kids can figure out, and many students can't learn at all. Rarely do students experience mathematics as a useful language they can apply to make sense of the world. As Judah Schwartz, one of the founders of the Educational Technology Center observed, "For the most part, the mathematics we teach in the primary and secondary schools is the mathematics already made by other people. Were we to teach language in that fashion, we would ask the students to learn a play by O'Neill, an essay by Emerson, a short story by Hemingway, but we would never ask them to write prose of their own."[5]

For Kristi Rennebohm Franz, a prime target of difficulty was helping her first- and second-grade students learn how to *use mathematics as a language for analyzing and predicting patterns in the world.* She devised the Quilt Math project (http://www.psd267.wednet.edu/~kfranz/Math/quiltmath2000/quiltmath2000.htm) to make this target of difficulty into a generative topic, and she gradually developed ways of using new technologies to intensify her students' investigations of the mathematics in this project.

Effective Generative Topics

Subject Matter	**Generative Topic**
Literature	Sense of Place
Biology	Classification Schemes
History	The Industrial Revolution
Social Sciences	Stereotypes
Mathematics	Proportional Reasoning

TIP

For Kristi, a prime target of difficulty was helping her first- and second-grade students learn how to *use mathematics as a language for analyzing and predicting patterns in the world.* Making predictions is key to building generative thinking by giving students an opportunity to create math ideas based on their own analysis of math data and patterns.

On the first day of school, Kristi began Quilt Math by taping a square of fabric (approximately 6 by 6 inches) to the classroom whiteboard and asking her students, "What do you see?" Kristi intentionally selected fabrics for math quilts that related to other curriculum themes the students were studying. For example, at the beginning of the year when students were studying insects, she chose fabrics with ladybug designs. A student might start by saying, "The patch has ladybugs on it," or "The ladybugs are red."

Building on what students said, Kristi asked students to think about how they could add a "math idea" to their comments. Then students might say, "We have one patch with ladybugs on it," and "It is a square patch with nine ladybugs." Thus began a process in which Kristi added one patch per day, five patches per row until five rows generated a 5 by 5-inch patchwork quilt over the first twenty-five days of school. The patches and their patterns became the focus for children as they observed, predicted, described, represented, analyzed, and modified patterns in quantity, shape, and color.

Although students' comments on the first day were few and short, with each added patch the quilt patterns became more complex, and the mathematical thinking expressed by the students grew exponentially in depth and breadth. The class used word processors, digital cameras, math software, and Web site publication tools to enhance the generativity of their mathematical studies. With these tools, they captured and represented students' mathematical ideas in ways that enabled students to analyze patterns in the physical quilt, generate mathematical variations with a virtual quilt, and communicate their ideas on-line in forms that deepened students' understanding. Technology helped students connect important math ideas to their own experience, approach mathematics through a range of entry points and materials, make mathematics authentic and interesting to students and compelling for the teacher, and deepen their understanding through continuing inquiry.

Generative Topic Features in Quilt Math

The class uses of new technologies enhance the generativity of their mathematical studies because they

- *Connect* mathematical ideas to students' own experience
- *Approach* mathematics through *multiple entry points:* visual, symbolic, verbal
- *Deepen* understanding through continuing inquiry about patterns in the physical quilt and the virtual quilt
- *Communicate* ideas on-line in forms that make mathematics authentic and interesting for students and the teacher

Writing Math Comments and Predictions

Students were eager to see what the new patch looked like each morning and to start writing their individual math comments, either on the computers in the classroom or in their paper notebooks. They recorded their observations in preparation for the Quilt Math discussion with the whole class.

During the students' individual writing time, a few students helped Kristi take a digital image of the quilt, download the image to the computer, edit the image, and insert it into a digital math photo journal, where the whole class later recorded its math comments. Students rotated through their turn as helpers with the digital image technology, so everyone in the class learned valuable math lessons while using the software tools for image editing—for example, proportional size cropping, scale dimensions of width and height, measurement in pixels, inches, and percentages, and relative numerical gradients of brightness and contrast. Students learned how to work with the tools for digital imaging by using them for the meaningful purpose of building their Quilt Math journal.

After writing their individual Quilt Math comments, students gathered as a whole class in front of the quilt to share comments. As students described their observations verbally, Kristi recorded their oral comments on the whiteboard, and two students started typing these comments on the computer.[6] The class re-read and discussed the comments to be sure the math reasoning was clear and to support everyone in comprehending the math ideas being expressed by peers. As the quilt grew, the class developed ways of representing key features of the quilt, such as assigning a letter to represent each major color or fabric design in a patch. Then students could characterize the sequence of patches in a row with a formula. For example, a row of patches in the pattern

Yellow, Red, Red, Yellow, Red   became represented as A, B, B, A, B.

Subsequent Quilt Math designs became more complicated with each patch pieced from multiple fabrics. Students started using capital letters for the design or color of the large patch plus numbers for fabrics within the patch. For example, in a star quilt connected to the class astronomy science unit (http://www.psd267.wednet.edu/~kfranz/Math/quiltmath2000/starquilt.html), each square patch in a row was pieced from triangle shapes, with iterations of four different fabrics. Students represented this more complicated pattern as

A(1 + 2), B(3 + 4), C(2 + 3), D(4 + 1)

Such symbolic representations helped the students see how to recognize and communicate about patterns within patches and across rows. In this process, primary students began to learn important lessons about patterns and symbolic representations that paved the way for learning pre-algebra conventions in later grades.

Generative Topic: Feeding the Family: Balanced Diet–Balanced Budget[1]

Students often have difficulty understanding how to apply the math and science they learn in school to the complex contexts they encounter in the real world. To address this target of difficulty, the generative topic of this multidisciplinary unit for sixth-graders focuses on how to plan and shop for a week's worth of nutritious family meals while staying within a budget. Students "shop" for food using the PeaPod on-line grocery database, where they consider nutrition labels, special sales, generic versus brand-name products, coupon discounts, and unit pricing. The site's multimedia interface and twenty-four-hour access allow students to "shop" conveniently and flexibly without costly errors or impractical field trips.

After a series of lessons about nutrition and a guided exploration about unit pricing and family food budgets using interactive Web sites, the students work in pairs to plan a week's worth of meals for a hypothetical family with specific nutritional and financial needs. As students plan shopping lists, they learn to balance nutrition requirements and healthy eating choices with financial constraints.

The PeaPod on-line-shopping Web site offers efficient access to a detailed database of thousands of products organized just as in a typical supermarket, with product images, nutrition labels, and unit pricing information for each item. Students analyze their virtual purchases (substituting products, modifying quantities, and tracking the total cost of their selections) using a spreadsheet to record, organize, compare, and analyze information from the database. Working together, students engage in mathematical reasoning, data analysis, and negotiation, as well as rich discussions about good nutrition on a budget. PeaPod's database of products with sorting features and real-time data, combined with the spreadsheet as an analytic tool, allows students to think about generative connections among key ideas in math, economics, and nutrition within a real situation that is relevant to their own experience.

Resources

PeaPod Online Grocery Shopping Service
http://www.peapod.com

U.S. Department of Agriculture Food and Nutrition Information Center
http://www.nal.usda.gov/fnic/etext/fnic.html

Understanding Nutrition Labels
http://kidshealth.org/kid/stay_healthy/food/labels.html

Using Unit Pricing
http://www.fmi.org/consumer/unit/howtouse.htm

Nutrition Navigator
http://navigator.tufts.edu/

Eat Well for Less
http://oregonstate.edu/dept/ehe/ewfl/

[1]This example is based on the work of Linnie Regan.

At the end of each Quilt Math lesson, students made predictions about the patch that would be posted the next day. Students had to explain the basis for their prediction, using math concepts and the patterns that were already evident in the quilt. Different students made various predictions with reference to the multiple mathematical dimensions represented in the quilts—for example, color of patch or number of ladybugs. Making predictions was key to building generative thinking by giving students an opportunity to create math ideas based on their own analysis of math data and patterns. In addition, the students' eagerness to learn what predictions would be confirmed fueled their desire to return to Quilt Math the next day.

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Building the Quilt Math Photo Journal

By the end of each daily Quilt Math discussion, the two students who were the designated word processor recorders for the day had finished copying the summary of comments that Kristi created on the whiteboard. They stored this text file with the digital image documenting the appearance of the quilt, which helped students check the accuracy of the comments. The recorders raised questions of clarification with the class and the teacher to be sure that all the students' ideas were accurately and completely captured. The teacher then helped the recorders edit this document to correct spelling and syntax. This process gave Kristi an opportunity to assess how the writing and reading skills of the two recorders were developing. Each day, the new pages of comments and predictions were printed and added to the Quilt Math photo journal notebook as an archived record of daily lessons. The class could re-read these comments at the beginning of the next day's Quilt Math lesson, or the teacher might assign the pages for reading practice to individuals or pairs of students. The Quilt Math journal was also posted on-line in the classroom Web site so students could revisit their work to review math ideas, make comparisons of changes in the quilt over time, and share the Quilt Math project with their families by accessing the Web site on a computer at home or in the public library.

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The class also used the Web site to share the Quilt Math lessons on-line with school peers in other locations within the United States and around the world as part of their participation in an International Education and Resource Network (iEARN) curricular project, "Connecting Math to Our World." More about the iEARN project can be found at http://www.orillas.org/math/ and in subsequent chapters of this book. More about Kristi's Quilt Math class is on-line at http://www.orillas.org/math/20012002/justforfun.html.

Key Features of Generative Topics

Although this example describes work with very young children, it illustrates features of generative topics that are important when choosing curriculum topics for learners of any age. This topic addresses ideas that are *central to the domain* of mathematics: analyzing patterns using multiple symbol systems and making conjectures. The topic also addresses a "target of difficulty" in that children perennially have difficulty appreciating mathematics as a process of actively forming and testing conjectures, not just memorizing mathematics created by others. The Quilt Math project was *authentic, accessible, and interesting to students* because quilts were part of their own childhood experiences, math ideas were presented through colorful fabric designs and geometric patterns that held students' aesthetic and visual interest, the fabric related to topics that students were studying at the time (see examples of Quilt Math related to study of Africa at http://www.psd267.wednet.edu/~kfranz/Math/africaquilt/africaquilt.htm and http://www.psd267.wednet.edu/~kfranz/Math/kenyaquilt/kenyaquilt.htm), and the quilts became beautiful and comforting objects in the classroom.

Generative topics are also *fascinating to the teacher.* Kristi became interested in quilts and how they could be connected to math through several women in her town who were avid quilters. They shared her passion for using quilts as teaching tools in the classroom and were able to help her locate the range of fabrics she needed for this project. Kristi's passionate commitment to teaching with quilts increased as she discovered how much students learned about math, writing, new technologies, and other subjects. This project also illustrates a final important criterion for generative topics: they are *connected* to multiple important ideas within and across subject matters and approachable through *a variety of entry points.* The Quilt Math project leads students into appreciating multiple key concepts and modes of reasoning in mathematics, while learning about how to think with several different symbol systems and display their knowledge in a variety of formats. It allows students to engage mathematics through aesthetic images and words, as well as numbers and other symbolic formulas.

How New Technologies Enhance Generative Topics

Kristi believes that students learn by talking and writing about their ideas, recording and sharing these thoughts, and then reviewing their recorded observations to revise and develop new ideas. In the Quilt Math project, her students used new technologies to record both verbal and visual observations to support a process of mathematical inquiry through observation, analysis, conjecture, revision, and communication of ideas.

Connecting Central Mathematics Concepts to Students' Ideas

Students used word processors to harvest their various individual ideas and consolidate them into a consensus document that recorded ideas from the whole class. The text files provided valuable archives of the class discussions about math so that students could see how they developed their math thinking from simple to complex understandings. Students also used this technology to generate representations of their observations in various symbolic systems—an important form of mathematical expression that supports the recognition and prediction of patterns. Once the students captured their comments with a word processor, they could easily edit the document to correct spellings, improve the accuracy of the statements, and interweave additional ideas. In these ways, the word processor helped to make students' own ideas a key component of the mathematics curriculum.

Using Multiple Entry Points

By making a digital photograph of the quilt each day, the class maintained a visual record to correlate with their verbal accounts and mathematical representations in the Quilt Math photo journal. Students used the digital photo journal to review how the quilt looked on any given day and to support in-depth analysis of how the quilt patterns changed over time. Captured in digital form, the Quilt Math journal was easily printed multiple times for students to take home and discuss, and it was uploaded to the class Web site for even wider dissemination. The visual depiction of the quilt was not only a rich additional entry point to complement the verbal descriptions but also a more direct representation of the quilt. The visual representation was a stable record to check the evidence for students' assertions and the accuracy of their predictions about patterns.

Working with multiple representations is an important dimension of mathematical understanding and an overarching goal in Kristi's class. Many students are confused about the roots and role of symbol systems in mathematics. Taking a digital image of the quilt and entering it into a database gave them experience working with one kind of representation of a concrete object. As the students developed ways of representing features of the quilt with letters or numbers, they began to correlate visual, verbal, and symbolic representations of a physical phenomenon.

Kristi's students also used a software program called Shape-Up to create virtual quilts. Using this program, students could replicate the rows, columns, and shapes of the fabric quilt and then change the colors of the quilt shapes to generate new patterns. As they created different versions from the basic quilt layout, they saw multiple iterations of shapes and patterns. The technology enabled students to manipulate the quilt design to generate new math patterns in ways that were not feasible with the fabric patches. In this way, students made their own discoveries about the relationships of lines, spaces, and color in the creation of shapes and patterns.

Connecting Mathematics to the Real World

By posting their Quilt Math photo journal on the class Web site, with its record of their analyses and conjectures along with the visual images, Kristi and her students connected their classroom to the outside world. Students could check the class Web site from home at the end of the day and share their math work with parents. Parents reported that their students used the Web site as a prompt to talk with great detail about the math thinking that happened at school. The class Web site was also a major link between Kristi's class and other classrooms around the world that conducted their own Quilt Math projects. In these ways, the technology helped students appreciate how the mathematics they learned in school was useful for authentic purposes that extended beyond the walls of the school.

Planning to Teach Generative Topics with New Technologies

Figuring out how to organize curriculum around generative topics or targets of difficulty may not be a simple process. Teachers must analyze their subject matter, their learners, the resources that are available, and their own passions. There are a number of ways to begin this process.

Educators might begin by asking, "What do our students always struggle with that is really essential for their success?" That may reveal some targets of difficulty that could be alleviated by incorporating new technologies into lessons. Another strategy is to ask, "What are students fascinated by that might suggest a way into some of the material they need to learn?" Teachers might also formulate generative topics by reflecting on their own interests and expertise, knowing that their capacity and motivation to design inventive lessons will be enhanced by their own passionate engagement. The teachers' own hobbies or areas of deep knowledge may indicate a generative approach to an important curriculum topic.

A professor of architecture figured out a generative topic by building on one of his own passionate interests.[7] He wanted to use new technologies to motivate students who enrolled in his required course on architectural structures—a course that students found notoriously boring because it dealt with physics rather than the aesthetic aspects of architectural design. When asked about how his passions related to structures in architecture, the professor's eyes lit up and he twisted in his chair to pull a book about bridges off his shelf. "I love bridges!" he exclaimed, with eyes twinkling. His imagination was sparked by the prospect of organizing his course around the structure of bridges and developing animated models of bridges to illustrate key structural concepts, such as stress and load.

Mathletics: Understanding Statistics Through Sports[1]

Thinking critically about statistical data is a target of difficulty for most high school students. In this ninth-grade "Mathletics" unit, students engage in analysis and interpretation of statistics through close scrutiny of a topic that is accessible and interesting to them: sports data.

The unit's generative topic is using statistics as they are used in athletics. Students examine how data actually are used in college and professional sports (for example, tracking player and league performance, tournament selections, team finances, and draft picks). They learn how statistics are generated, how to correctly apply multiple uses and interpretations of statistics, how to identify misleading and manipulated data, and how to represent data accurately.

Students begin by researching recent news stories about sports, noting how statistics are used. The teacher then guides the class through a model inquiry about athletes' academic and athletic performance in Big Ten universities. Students make observations and pose questions about the data and note how the data are used in news articles and NCAA policies. As they learn to evaluate claims based on statistics, students develop questions about a sports issue that interests them.

Students then apply mathematics to analyze their topic. They learn to use linear equations, correlation and regression analysis, and a variety of visual representations (plots, tables, charts, and graphs) as they apply statistical methods to the analysis of sports issues. They use graphing calculators and spreadsheets to evaluate sports writers' inferences and predictions, as well as to explore different ways of presenting, analyzing, and displaying sports data. Students use word processors, digital images, and PowerPoint® to record, reflect on, and present their understandings of statistics in sports.

As students delve into the data, they realize that statistics can be accurate or inaccurate, informative, misconstrued, or unclear, depending on how data are processed and represented. They learn how to determine whether claims based on data seem reasonable and are supported by contextual information. Even students who are not typically engaged by math can learn to approach numerical information with a critical eye. By focusing on students' interest in athletics, this unit helps students see how math relates to their world and cultivates interest and skills for ongoing inquiry.

Resources

American Statistical Association K12 Page
http://www.amstat.org/education/index.html#K12

Chance
http://www.dartmouth.edu/~chance/

WWW Resources for Teaching Statistics (including interactive Java Applets)
http://it.stlawu.edu/~rlock/maa51/java.html

ESPN Behind the Numbers (a monthly column on sports statistics)
http://espn.go.com/moresports/sillsarchive.html

Top Sports Sites
http://www.sporthits.com/top_sports_sites/maintopsports.shtml

The Athletics Statistics Page
http://users.rcn.com/bricklan/athletic/athletic.html

Hyperstat Online (a statistics "textbook")
http://davidmlane.com/hyperstat/

Gallery of Data Visualization: Best and Worst Statistical Graphics
http://www.math.yorku.ca/SCS/Gallery/

iEARN Curricular Project: Connecting Math to Our Lives
http://www.iearn.org/projects/math.html

[1]This vignette is based on the work of Audrey Ting.

Tips for Identifying Generative Topics

Begin with these questions:

- What do students always struggle with that is really important to learn?
- What are students fascinated by that might indicate a way into some of the material they need to learn?
- How might I connect my own passions to the curriculum?

Kristi's quilt project grew from her passionate commitment to engaging her students in learning through talking and writing and making predictions. But how could she get them talking and writing about math? The quilt project seemed a good way to make numerical and geometric patterns out of simple materials that would be visually appealing. She was amazed to discover how deeply engaged the students became. Although she had originally planned to do the project only for the first month of school, she continued it all year because it was so successful. Once Kristi realized how much students could learn from talking about patterns in the quilts, she figured out how to build patches to illustrate a range of mathematical concepts: fractions and part-whole relationships, geometric shapes, and algebraic expressions.

What about incorporating new technology—how does that process work? For most teachers, weaving new tools into their lessons is a gradual, somewhat happenstance sequence of events shaped by opportunity and interests. In Kristi's case, she realized that students would think harder about the mathematics in the quilt project if they had a way to record and review their ideas about the quilt. This led her to begin using a word processor to capture the students' ideas. Including a visual record of the quilt's appearance became important as a means of anchoring the conversation about the quilt with more direct, visual evidence. She wanted to encourage her students to talk about math at home, which led her to begin using a digital camera that could readily generate printed images that students could take home. Developing the class Web site, including the on-line Quilt Math photo journal, was one more step in the process of connecting Kristi's classroom mathematics to her students' lives outside school.

Teachers may start by considering the technological resources that they already have or might be able to acquire and asking, "How might these tools help my students learn important material more effectively than they do now?" Are there ways videotape or video cameras, audiotape recorders, computer software, related peripheral equipment such as scientific probeware, or the Internet could make curriculum more generative? Could new tools help make important topics more related to students' interests, more accessible through multiple entry points, more connected to the teacher's own passions? Are there ways of using new technology that would "open up" the curriculum, revealing connections to other key topics and engaging students in more active inquiry?

While pondering these questions, it is important to ask repeatedly, "Is this topic really central to curriculum priorities, and is it something that can't be taught and learned just as easily with less complicated technology?" After all, there is no need to cultivate a pocket garden with a huge tiller when a small spade will do; complicated technologies should be reserved for topics that are both important and difficult.

TIP

A tip for using new technologies is to look for ways of using them that "open up" the curriculum, reveal connections to multiple key topics, and engage students in more active inquiry.

Questions for Reflection

1. What are some topics in my curriculum that are really important yet difficult for students to understand?
2. How might I use a new technology to make one of these topics more generative by connecting it to students' interests and authentic purposes in the world, by building on my own passions and expertise, or by allowing my learners to approach this topic through multiple entry points such as visual art, music, narrative, or mathematical representations?

NOTES

1. For more examples of generative topics, see *Teaching for Understanding: Linking Research with Practice* (Wiske, M. S.) and *The Teaching for Understanding Guide* (Blythe, T. and Associates), both published by Jossey-Bass, San Francisco, 1998.
2. Taking account of students' interests is an important element of many syntheses of effective designs for learning. See the focus on "learner-centered" designs in *How People Learn: Brain, Mind, Experience, and School.* National Research Council. Washington, D.C.: National Academy Press, 1999.
3. Gardner, H. *The Unschooled Mind: How Children Think and How Schools Should Teach.* New York: Basic Books, 1991.
4. Educational Technology Center. *Making Sense of the Future: A Position Paper on the Role of Technology in Science, Mathematics, and Computing Education.* Cambridge, Mass.: Educational Technology Center, Harvard Graduate School of Education, 1988.
5. Schwartz, J. "Symposium: Visions for the Use of Computers in Classroom Instruction." *Harvard Educational Review,* 1989, *59*(1), 51.
6. Many people doubt that such young children could be capable of the activities Kristi's students were. Yet students in her first- and second-grade classroom carried out this kind of work year after year. Children in her classes were a mixture of the kinds of children typical in the school, including some with diagnosed special needs; approximately half were eligible for Title I support. Throughout this case, and in the cases included in subsequent chapters, more information is provided about how Kristi developed a culture of inquiry and collaboration among her students, developed their abilities to write,

used "sound spellings" initially with young children and gradually taught them conventional spellings, and built their technological skills through engaging them in meaningful tasks with a wide range of tools. Kristi also gradually developed her own technical expertise, the range of tools available in her school, and her network of supportive relationships with colleagues, parents, and other volunteers. Teachers who doubt whether they or their own students could accomplish the kinds of learning that Kristi's classes have done might take heart from realizing that these stories build on many years of experimentation and refinement.

7. Eddy Spicer, D., and Huang, J. "Of Gurus and Godfathers: Learning Design in the Networked Age." *Education, Communication and Information, 1*(3), 2001, 325–358.