Constructive Activity for Teaching Elementary-School Math and Communications

Well, they did it again.

Mrs. Denney’s third graders, that is. Just when we thought we had technology education neatly divided up into separate areas such as communications, construction, manufacturing, and transportation, twenty-four third graders at Derby Ridge Elementary School in Columbia, Missouri, once again defied our attempts to teach just one “area of technology.”

It all started when the children were encoding and decoding numbers, converting them from base-10 to base-2 and back as part of our communications technology unit. We led a class discussion about encoding and decoding words as well, eventually talking about hieroglyphics, computers, and CD-ROM technology. By the time they were using an electronic camera to encode images into ones and zeros (base-2 numbers again), we had a problem: all this talk about “technology” was fine, but it wasn’t speeding up the children’s ability to perform mathematical base conversions.

Wait a minute, you say: why should kids have to learn how to convert friendly decimal numbers into binary (ones and zeros)? As it turned out, doing a few base conversions can do wonders for a third-grader’s understanding of place value—an important, yet often elusive, mathematical concept.

A Constructive Solution

Still, not all of the kids were getting it. For a third-grader, adding 9 and 15 might involve a little finger-counting. But try using your fingers to add the binary numbers 1001 and 1111—or worse, converting the decimal number 37 to binary. It’s not easy.

Being technology educators, we had a quick solution. If counting on your fingers was a good way to learn simple addition, there had to be a similar trick we could use here. The students had an answer too—they had been in Mrs. Denney’s class long enough to know all about math manipulatives. (In case you haven’t been in Mrs. Denney’s class, we’ll mention that math manipulatives are small objects children handle and arrange to help them learn math concepts better.) As a solution, we issued checkers in two colors—black represented the binary numeral “1;” red stood for “0.” And it worked—the children quickly saw that red plus red equals red, black plus red equals black, and so on. But as soon as one student opened his desk and sent the checkers flying, the class realized that this wasn’t a permanent solution.

We knew, as Johnson (1992) reminded us, that Kirkwood had developed meaningful, constructive
activities for teaching math concepts (see Kirkwood, 1992). It could be done.

With a little prompting the third-graders realized they needed some kind of a base with moveable markers representing ones and zeros. Due to time constraints, the children only had limited input into the design, and they accepted the solution we came up with. Clearly, the students could have been led through the design process if time permitted.

What we designed was a combination “Binary Counter and Jump-a-Tee Game.” This math manipulative could double as a game. The design was simple and straightforward: a strip of wood 1-1/2 inches wide by 7 inches long with nine holes drilled in it. Really, only eight holes were needed for the binary counter. But in order to play the jump-a-tee game, an additional hole was needed. Finally, the product required two different colors of golf tees, used to represent ones and zeroes. It didn’t seem too difficult for the students to mass-produce enough for everyone in the class, plus the other third-graders in the building, and of course the principal and Mrs. Denney.

But then we stopped dead in our tracks. We were foiled again!

“Binary Counter and Jump-a-Tee Game” has a nice ring to it, but if the children were going to be producing it from raw materials, we’d be doing manufacturing, not communications! Once again we had to resign ourselves to the fact that the popular “cluster” areas of technology weren’t isolated entities after all.

So resign ourselves we did, and began to discuss with the children how to make the binary counter a reality.

The Technology Unit
In an earlier discussion we asked the children what various electronic communication devices had in common. One student had volunteered that “they are all made by people.” We used this as the launching point for a discussion about how people satisfy their basic wants and needs through manufacturing. By the third grade, students may already have a concept of...
"factory" production, as opposed to on-site construction, but little notion about how things are actually made. They had not stopped to realize that many of them were wearing the same style and brand of shoes, or that they were all sitting in identical chairs. They were amazed by how pervasive the products of manufacturing are.

The most frequently cited skills educators expect children to get out of elementary school are reading, writing, and arithmetic. But how about following directions? Most parents and teachers would agree that this is also an important skill. In this case, the students and teachers had to make up the directions before we followed them. The children had ample time to inspect, touch, measure, and use a prototypical binary counter before we discussed how to mass-produce it.

We brought in a standard size of an inexpensive wood (nominal 2" strips of cottonwood) for the project, and the whole class participated in a discussion of how the wood could be made into binary counters. That seems easy enough, one of the children offered: just cut the wood and drill a few holes in it, right? But, we countered, how do we make sure they're all the same length? This discussion resulted in the following production line.

**The Assembly Line**

The production line consisted of seven stations. Two children worked at each station, and others were assigned to quality-control or materials transport duties. Each third-grader was able to perform most jobs on the line at least once.

Workers at the first station were responsible for cutting in half the eight-foot boards, which were deemed by the children to be too long to carry around the classroom. Next, the wood was measured and marked for cutting. At the third station, pieces were sawn to length. The measured marks made at the previous station were technically unnecessary because the cutting jig at the third station had a stop set at seven inches (since length was critical for the drilling jig). But the marks served as an approximation of the length, and also allowed the children to estimate how many pieces had yet to be cut. Besides, how often are kids this interested in measuring and doing math?

At the next station, children used two battery-powered drills to bore nine holes in each piece. Needless to say, this was quite a bottleneck! We constructed a drilling jig, but this station still held up the production line. The upside of this was that everyone in the class got to drill.

Once the pieces were drilled, they were moved to a sanding station, then to the finishing station, where vegetable oil was applied by latex-glove-wearing finishers. The nearly complete binary counters were then dried. At the end of the line was the seventh station, where packaging and final quality control took place. But quality control was not simply an afterthought. Several children were assigned to quality-control duty at various points in the production line.

The packaging station demanded more attention to detail than did those which employed fixtures. At this station, the correct number of each color of golf tees had to be placed in a plastic bag with the binary counter and directions for its use. Finally, the bag had to be sealed and labeled. The labels, designed by the third-graders on a Macintosh computer, read "Denney's Dragons Dynamite Device." The dragon is Derby Ridge Elementary's mascot.

Before the day of the production run, we showed the whole class the operation of each station. Some stations gave us the opportunity to expand the "manufacturing" portion of the unit to include a discussion of the material we were using. It was

![Mrs. Denney's students drilling holes in the binary counters.](image)
only natural to talk about the grain of the wood at the sanding station, for example, and grain and porosity at the vegetable-oil station.

At times there were more children than assembly-line jobs. This worked out well because there was a lot of other work to be done. Since the counters were to be packaged, students were responsible for developing a product logo, label, and packaging, as well as for writing directions for both the binary counter and the jump-a-tee game.

Although we didn’t intend to cultivate specific occupational skills in the students, we found, for example, one excellent measurer and an expert saw operator. Because we expected to do activities like this again with children like those in Mrs. Denney’s class, we asked these two third-graders to write descriptions of their jobs.

Kamara was in charge of measuring the pieces so the class could approximate how many 7-inch pieces could be cut from the stock brought into the classroom. To do this, one must “measure 7,” Kamara wrote; “write it dark. Keep on doing it till you run out of board.” Makes sense.

Lauren was our sawing expert. Once you get the marked boards from Kamara, she wrote, you should “cut the wood in half. Then carfly cut each 7 inch piece.” We forgot to ask if a carfly was like a housefly.

Back to Binary

The original topic of this unit had been communications, and one connection we still wanted to establish with the children was that computers and other devices which employ a “chip” are related to the concepts of language and numbers insofar as they all are (or they use) forms of coded information. This idea was met with nods from the children, but it took a fair amount of prompting for the students to realize that, for example, the three-letter combination “c-a-t” really wasn’t a pet—words, they soon realized, are just symbols that we use by convention to represent ideas. This concept was clarified by writing gato (Spanish for cat) on the board next to cat.

Now, most of the students were able to quickly grasp the notion that “10” was just a way of talking about a certain number of objects. Students needed this concept, as we were about to conceptually dive into the realm of binary numbers, a subject normally not introduced until the junior-high level and, as we were to discover soon, frequently difficult for college students to master.

Earlier, while we were discussing electronics and coding, we introduced the notion that computers are not as smart as people because they can only count from “zero” to “one,” although they do it a whole lot faster than people can, and they can do it over and over to make bigger numbers without getting tired or making mistakes. For third graders this is a fairly radical idea because they can only count to 100 or so. We capitalized on this planned discovery by reintroducing binary numbers. Once they were allowed to use manipulatives, most students mastered the concept of decimal-to-binary conversion in about a half hour! Mrs. Denney’s student teacher exclaimed, “I never understood it before myself! This is great!”

At this point the students were working in groups and individually on a worksheet to convert decimal numbers to binary. We had only shown them the mechanics of conversion and addition—not formulas or guidelines. All of a sudden one boy jumped up and shouted, “I can convert 37 to binary!”
This was too good an opportunity to let pass by, so we had him go to the blackboard and explain to the class how he “discovered” it. As it turned out, he had derived the rules necessary to convert any number from base 10 to binary!

The most rewarding experience, however, occurred two days later when one of our Ph.D. students visited Derby Ridge to observe the activities in Mrs. Denney’s classroom. He knew very little about binary numbers. We captured on video one of the eight-year-old third-grade students at the blackboard teaching him basic binary addition.

**Outcomes of the Unit**

Several of the students worked together to compose a description of the word binary to distribute with the counter. Remember, these are third-graders who had very little adult help in composing this paragraph. They wrote:

A binary number system only uses the numbers 0 and 1 to make all the other possible numbers. Computers and video games and digital watches and many other things use the binary numbers to make them work. Also, binary numbers are used to make the bar codes on all the things we buy and the books we check-out and even our mail.

The children demonstrated an understanding of binary digits, as well as an ability to manipulate them. This was made clear by their performance on a base-10 to base-2 conversion worksheet.

Although Mrs. Denney hadn’t begun the school year with specific objectives related to having the children count in base-2 or to mass-produce a product, it was clear that this unit had been time well spent, and that it had increased student enthusiasm. And by design, it supported the third-grade curriculum that was already in place.

For example, some of the Columbia School District’s outcomes for third graders include “express ideas clearly,” “use multiple strategies to solve problems,” “use estimation strategies,” “measure to the nearest centimeter and inch,” and “participate in the democratic decision-making process.” These relate to curricular areas such as social studies, mathematics, and language arts, and they were our target competencies. Nonetheless, they were only a handful of the over 80 curricular goals for Columbia’s third-graders.

But in retrospect it was clear that other competencies were also addressed which were not academic—they were the dozen outcomes listed on the first page of every third-grader’s progress report. The complete list appears in Table 1.

So, more importantly than simply supporting Mrs. Denney’s established academic curriculum, the unit described here also reinforced the core work habits and personal-growth goals established for Columbia’s third-graders.

**Final Thoughts**

A variety of outcomes were realized in this elementary-school technology education unit. To begin with, the children made remarkable progress in their understanding of place values in mathematics and took a big step toward more clearly comprehending the logic underlying symbolic mathematics. They also had “practical math” experiences in estimating, measuring, and counting in which the success of the activity relied upon their math abilities. Furthermore, they learned about mass production firsthand. This is not only a “technology” concept; it will play a major role in the U.S. history they will learn as upper-elementary and middle-school students in Columbia.

In addition, this activity was able to reinforce the primary nonacademic goals for third graders—such as “follow directions” and “listen attentively”—without making these goals overt.

We can only guess what the long-term outcomes of a regular program of elementary school technology education would be at a school like Derby Ridge. Perhaps the children
would become accustomed to technology education if it became common in their school. On the other hand, maybe frequent technology activities would bring more meaning to a student's early schooling, strengthening those core outcomes and increasing interest, motivation, and attendance.

What we can say is that Mrs. Denney's class benefited from the activity. Just ask John. He e-mailed us a few days after the unit was over. "Thank you for letting us use your special tools," he wrote. "We appreciated it because we have never built in class before. Drilling, sanding, and oiling it is pretty fun. Thanks, John." Thank you, John!

REFERENCES


Michael D. Wright is Assistant Professor, University of Missouri—Columbia. Patrick N. Foster is a graduate assistant, University of Missouri—Columbia, Columbia, MO. This article was refereed.