CHAPTER

9

Differentiating through Computer Environments

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Disclosure and disclaimer: DreamBox Learning is an adaptive online learning company that I have worked with for the past three years as a content consultant. The inclusion of this chapter does not indicate NCTM endorsement of the product. As volume editor, I decided to include a chapter on DreamBox Learning solely because I am intimately aware of how it uses the landscapes of learning (described in chapter 2) as a framework in the lessons, in coding users' strategies, and then in adapting the activities offered. I felt that a description of DreamBox could serve as a prototype for how educators might use online environments for intervention.

—*Catherine Twomey Fosnot*

Compared to many other human endeavors, education has made very modest progress in the past hundred years. We've added thirty years to human life spans, increased farming productivity fiftyfold, and reached the moon. Yet a teacher from 1910 would quickly feel at home in a classroom in 2010.

—Ben Slivka
Cofounder, DreamBox Learning

Can we harness computer technology and the World Wide Web for intervention? If so, what types of products would be helpful: drill on procedures, basic fact practice, environments designed to make routine math practice fun, exploration with feedback? Many current computer products on the market offer these things, and more, but are these enough to ensure powerful learning?

Prior chapters characterized good teaching by dynamic assessments, celebrating what children do know, and then challenging in ways to support development. The learning and teaching were interactive. A few interactive software products do exist, but the sequence of the programming usually follows a predesigned linear progression of activities and the feedback loops are static and predictable: student does *a* and the computer always responds with *b*. The coding focuses on answers (in contrast to strategies), and when answers are correct the computer provides the next activity in the sequence.

But a linear progression of concepts and skills does not characterize powerful learning; powerful learning is complex and personal, consisting of diverse possible pathways on a landscape of big ideas, strategies, and ways of modeling. Powerful teaching (as previous chapters show) comes from teachers understanding mathematics development and the multitude of pathways, identifying what learners do know and how they learn, and then providing appropriate personal challenges. Can we harness computer technology to do this?

In 2006, a team of entrepreneurs, engineers, researchers, and math teachers set out to achieve just that—to design an innovative, powerful, Internet learning environment that could dynamically assess and adapt to a student's needs. They called it DreamBox Learning. Understanding that computer technology offers much more than just coding correct and incorrect answers with feedback, the designers focused on using the technology to collect data about students' choices, preferences, and responses and to tailor the experiences to meet the individual needs of each student. Computers can "remember" everything students "tell" them. Which answers were incorrect the first time and correct the second time? How did the student use a virtual manipulative to answer that question? What strategy did she use? Did the student use a tool or solve particular problems mentally? Did she self-correct? How fast did the student respond to a question? What types of problems did the student choose to work on, and where did she leave off at the last visit?

Today's technology lets us track and gather such information about an individual user (anonymously), compare it with data from other users, make generalizations about user patterns, and offer that individual the most appropriate subsequent choice. Thoughtfully designed technology products can discern the needs of a diverse range of students (including fine motor skills, content knowledge, and social–emotional development) and adapt appropriately. Since the computer remembers the student and the student can go online anywhere, students and teachers can directly link work done at home to work completed in school—the technology affords a seamless school–home connection. Finally, technology can now advance all this potential by allowing peer-to-peer dialog through social networks and gaming. The DreamBox team harnessed much of this potential.

DreamBox Learners

Reece

Reece is a kindergarten student using an Internet-connected computer in her school. The school has adopted DreamBox as an "assistant teacher" in each class to provide differentiation. All children spend part of their time on the computer each day, in addition to daily math workshop. Reece logs in to DreamBox Learning K–2 Math for the first time. Initially, a short and exciting animation introduces Reece to the environment's characters. The graphics grab her attention, and immediately she wants more. Because she is a young student, DreamBox begins by assessing Reece's mouse abilities and determines that she has the skills needed to use the program. In the first ten minutes of play, Reece chooses a character to represent herself (an avatar), a theme, and an adventure story. These choices will serve as the context for the math investigations, games, and lessons that she will pursue in the online environment. Each decision also gives her increased ownership of the computer experience and therefore strengthens her engagement and investment in the program.

The first time Reece uses DreamBox, the academic program begins. DreamBox assesses Reece's performance dynamically and continuously, without her awareness because the assessment is embedded. She cannot distinguish between a game that only assesses and a game that both assesses and teaches. During this first half-hour session, Reece plays a variety of games, none lasting longer than a few minutes, and the computer codes her moves and decides what to offer her next. Behind the scenes, the computer is examining where Reece is on the landscape of learning (see chapter 2). Can she count with meaning? Does she understand one-to-one correspondence? What strategies for addition are in her repertoire? What virtual manipulatives would be good choices for her to work with (for example, ten frames, numbergrams, math racks, or number lines)? At the end of her first experience, Reece asks when she gets to play next.

That night, Reece plays DreamBox again on her home computer. This time using the data it accumulated from her first visit, the program offers her several lessons within her zone of proximal development (Vygotsky 1962), incorporating a variety of digital tools. She chooses to play a lesson using a math rack, and the program asks her to make numbers that range from eleven to twenty. See figure 9.1.

The math rack has two rows of ten beads each, in groups of five. The tool supports children to use the five and ten structures, in place of count-

Fig. 9.1. The math rack and number chart

ing by ones. This approach is an important strategy on the landscape that will eventually prove powerful as Reece works on getting the basic addition facts automatic. For example, if she can easily see 17 as 10 + 7 and 7 as 5 + 2, she can use this image for 9 + 8. She can image one bead on the bottom row as moving to the top, turning the 9 into 10. In other words, the tool supports her using a "making of ten" strategy: 9 + 8 = 10 + 7.

In this lesson, the program shows Reece a math rack "quick image" (a flashcard of a math rack for just two to three seconds) and asks her to build the same number on a digital version of this manipulative and to identify the value on a number chart. Initially, Reece is surprised to see the math rack image flash because earlier lessons in school had used only a static display. The computer had logged that such exercises were too easy for her and now has moved her to quick images. Her smile indicates that this new challenge is exciting and welcome. At first Reece struggles with this new version, unable to remember how many beads the computer flashed. She clicks "Help" and the directions are repeated on how to play, as well as how to click on the quick image to see it again. Apparently, this information is just what she needs. Reece clicks and sees the image again and completes the problem. On later problems she continues to click on the quick image to see it again. The computer registers that she is relying on this new method, apparently counting by ones while the image is visible, and so after three peeks on one problem the game will not let her see the image again. She sighs, completes the problem, and gets it right. She is elated. The next problem, 19, throws her. Twice she insists that the answer is 20. The computer registers that this exercise is now too hard and makes the image static. She still has not seen her mistake. She tries 20 one more time, and the program shows the answer as 19, using a chunk of ten beads on the top wire and nine on the bottom wire. See figure 9.2.

Fig. 9.2. The math rack indicates a value of 19.

She gently bangs the heel of her hand to her forehead, smiling, and says, "Ooooh!" Another "aha" moment has occurred. Reece sees her mistake and continues to play.

Throughout Reece's play, DreamBox gives her specific feedback based on the parts she has done right and wrong. If she builds on the math rack correctly and chooses the wrong number on the number line, the program gives her specific feedback that helps her identify and correct her mistake. The length of each game depends on her performance with the task. If she is getting everything right or wrong, the games tend to be shorter in order to quickly move her to more appropriate material. If she is getting some right and some wrong, the games are longer to provide more experiences at that level.

After two weeks of playing DreamBox four times per week, for about thirty minutes each time, Reece has completed one adventure story and started adventures with three other themes. She has earned five Adventure Friends and some tokens, which she can use in a section of the environment called the Carnival. This section has many open-ended math explorations, in contrast to the more guided lessons she has been doing. For example, she can play with two frogs as they jump on number lines, explore some geometry puzzles, or investigate directions through mazes. Occasionally, she will wander into a third section of the environment called My House. Here she can change her personal character, play with the Adventure Friends she has collected, or show off the certificates and trophies she has earned.

Regarding academic progress, DreamBox has offered Reece several lessons in her zone of proximal development and delivered this information and more to her teacher and parents. Reece has played several counting lessons focusing on numbers one through twenty, and DreamBox has offered her both additional counting lessons using more challenging numbers and lessons with other tools to strengthen her ability to use fives and tens. During the two weeks, her parents received several e-mails telling them what she is working on. The program also sent them ideas of short math activities designed specifically to celebrate Reece's accomplishments and to support and challenge her further. They could do these activities while in the car, preparing meals, or walking places together.

Reece's teacher also knows where Reece is working in the developmental landscape. The teacher can enter the environment through the teacher "dashboard," and once there she can see what activities Reece has completed successfully and which activities are unfinished. The teacher sees that the five and ten structures are still a challenge for Reece, noting that Reece is still relying on counting by ones. When she works with Reece in school, the teacher is alert to this challenge and encourages Reece to notice how one can make numbers with other numbers—for example, how all the teen numbers have ten in them, and how five is part of the numbers six to ten.

To continue supporting Reece to use five and ten, the computer now offers her several games with the ten frame and several with number line strips of ten that she can use to build a hundred chart. Reece chooses the games with the ten frame. This time the program gives her pieces on the right of the screen that she can use to make the numbers that are flashed. Her choices are single pieces, twos, threes, fives, or tens. See figure 9.3.

The screen flashes the numeral 7, and Reece clicks on one dot seven times to fill the frame. The computer notes that she counted by ones because she took seven moves to get it correct. In response, the computer asks whether she can do it again but in fewer moves. This time Reece uses the unit of five and the unit of two, and the computer congratulates her.

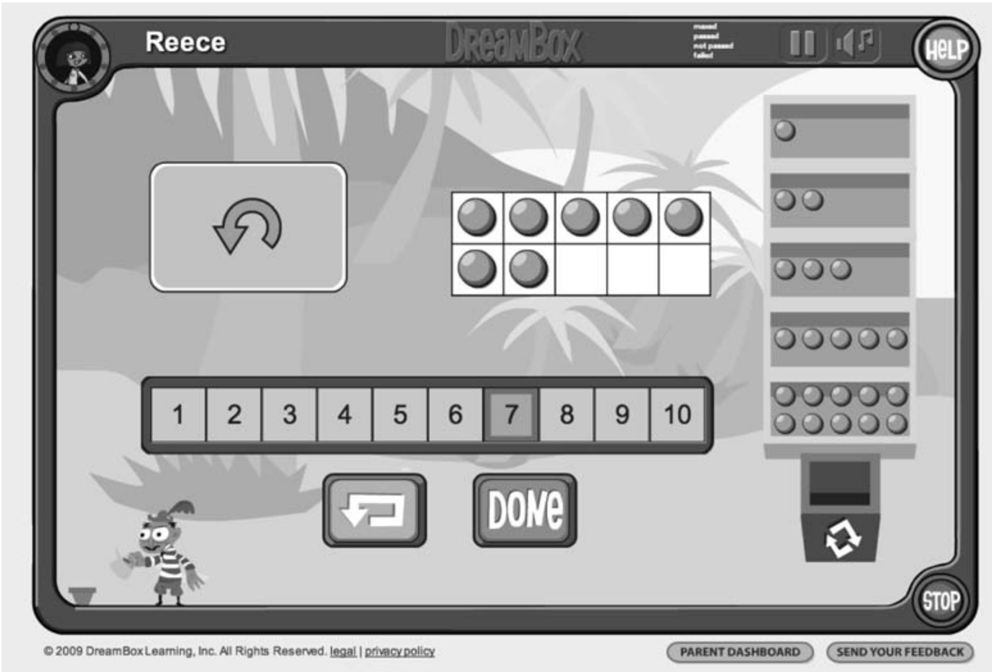

Fig. 9.3. A ten-frame game in DreamBox

As Reece builds more numbers, the computer codes her strategy each time. By noting how many moves she makes to build the number, the computer knows what pieces she used—whether she is using the five or not. For example, the only way to build 8 successfully in two moves is to use the five and the three. Eventually Reece shows that she can easily make numbers up to ten with minimal moves (using the five), and the computer adjusts the games accordingly, this time with larger numbers and a ten frame to 50. Now the program challenges her to make numbers like 38 with four tens minus two, or with three tens, a five, and a three. As she builds these numbers, Reece uses the reset button when she wants to start over and clicks the audio button to have the program repeat the number. Sometimes she uses the audio button in the middle of a problem and other times she uses it at the end. Over the next few weeks, Reece plays similar games, building numbers up to fifty, sixty, and finally 100.

Peter

Peter is a repeat second grader. By December, his teacher, Ms. Roberts, is quite concerned about his progress. Although he is a year older than most of his peers, he still knows few addition facts and usually just counts laboriously on his fingers. Ms. Roberts provides open-ended investigations with many different entry points and uses pair work so that he might learn from his peers as well. She also differentiates, often doing guided small-group work, but even in the small group Peter stands out as far behind. He often disengages and is beginning to make comments about not liking math. The class is a large one, thirty students, and Ms. Roberts often feels frustrated and wonders how she can possibly meet the diverse needs of all the children in her care. She needs to move on to addition and subtraction with two and three digits, yet she knows that doing so will be too great a challenge for some of her students—Peter in particular will need extra support. She had heard about DreamBox Learning from a friend and decides to try it.

At first the computer works with Peter on strategies that help him automatize the basic facts, such as using fives and tens, doubles and near doubles. Soon he can use friendlier expressions in place of the ones he finds hard. For example, the program encourages him to envision 8 + 7 as 7 + 7 + 1, and 9 + 6 as 10 + 5. Ms. Roberts notes that Peter loves to accumulate his tokens and play in the Carnival, exploring the frog-jumping events. Here he initially built his frogs' race course by placing flags at every tenth interval. Then, his frogs could race against the competition. In the race he chooses the starting point closest to the presented number (the fly finish line) and tells his frog the correct distance to hop in order to win. See figure 9.4.

Fig. 9.4. The frog racetrack

In early levels, the starting points were always on a multiple of ten and on the positive side of the number line. But as Peter progresses to later levels, he begins to work on the left side of the number line track with negative numbers—and successfully. Noting how well he is doing with these investigations, the computer routes him to addition and subtraction problems with the open number line. Here the program gives him strings of related problems to develop strategies for addition and subtraction. As he solves them, the game records a representation of his strategy on an open number line (resembling the frog track), and at times the computer asks Peter to use the representation to finish a strategy. Peter realizes that this activity is similar to what he was doing with his frogs. In fact, he is learning strategies that he can use in a later frog competition. "I love DreamBox!" he exclaims. See figure 9.5.

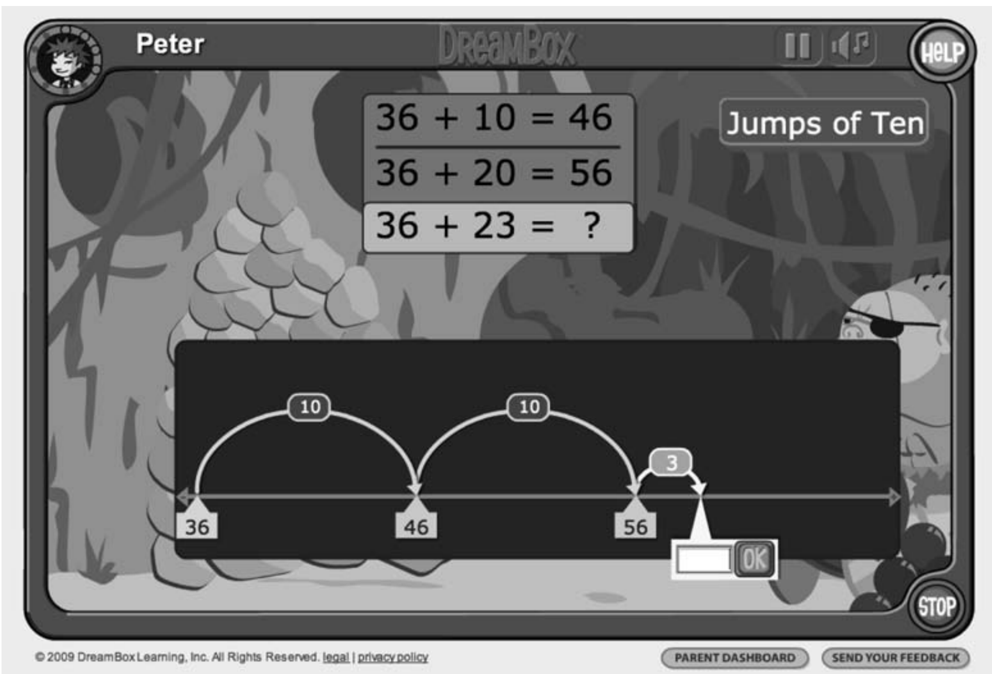

Fig. 9.5. Addition problems on the open number line

Ms. Roberts is amazed. Monitoring his progress in DreamBox from the teacher side, she can see that Peter is quickly developing a deeper sense of number than many of her other students. He can easily take jumps of tens and adjust; for example, to add 19 he adds 20 and removes 1. When subtracting he just uses a simpler expression. For example, to solve 71 – 36, he uses 70 – 35.

Extremely pleased with the success of her decision, Ms. Roberts now has only one problem. All the other children envy Peter and want time on the computer. As she ponders this predicament, she begins to envision a powerful way to differentiate. If she has a group of kids working on computers while she works with others on open-ended investigations, she can provide multiple levels of activities. And she could do this grouping flexibly, knowing that the computer would adjust to each student accordingly—personalizing an appropriate learning environment. Each child would get some time on the computer and some time working with peers on investigations. This approach would free her to engage all her students in the more open-ended rich investigations she loves designing, and as they work with her on these they will also have ample opportunities for rich conversations—which she knows are also important for learning.

Billy

Billy is also a second grader who has been playing DreamBox Learning for a few months. He has progressed through addition and subtraction strategies and is now learning early multiplication ideas. Billy plays a skip-counting lesson using the open number line virtual manipulative—the same manipulative that Peter used for frog jumping, addition, and subtraction. He makes jumps of twos, and then fours and eights, and the computer asks him to predict common landing points. Over the next few weeks, Billy builds on his initial open number line experience. He successfully completes games that involve skip counting both forward and backward by multiples of ten, as well as skip counting with negative numbers. As he plays, he continues to choose a variety of other related games using different virtual manipulatives, such as the function machine to support early algebra. Without the computer, Billy would not have experienced such complicated content in grade 2. But he has worked his way through a series of activities where the lessons and problems were personalized, and according to his past performance he is ready for this. He has advanced at his own pace and interest—eventually working beyond his grade level.

The Power of Technology

We live in a society that relies on technology for many activities. Reflect for a moment on your day—maybe you placed a book order by using the Internet, used a search engine to find information, e-mailed parents about a field trip, or took attendance online. The advances in technology continue to progress at an astounding rate, yet the advances in *educational* technology are hardly keeping pace. DreamBox Learning was formed around the vision of bringing the latest technology and highly knowledgeable teachers together. This vision recognizes the potential for technology to provide a high-quality learning experience without the expense of a one-to-one student–teacher ratio. This scenario includes providing appropriate adaptation, monitoring student learning by using data, and personalizing each student's learning environment and experience.

The power to provide appropriate adaptation in the moment

Teachers adapt learning experiences for students all the time, but providing seamless adaptation that is differentiated for each child can be challenging, even more so when classes are large. Also, remembering everything a child did and said is impossible for human beings. After all, we are human; we are not machines. Through technology, we can supply online learning opportunities that adapt to meet the needs of students. These various adaptations include recommending lessons on the basis of a student's previous responses, varying the complexity of the questions offered, and furnishing dynamic audio and visual supports. Programs can determine the appropriate levels of adaptation through continuous assessment that analyzes student responses and individual placement.

On Reece's second day playing DreamBox, she chose to play a math rack lesson that involved building and identifying numbers from eleven to twenty. Though not obvious to Reece, the program had selected this lesson as one of the next "most appropriate," according to her interactions in the previous session, including placement lessons (used to quickly determine the most appropriate content) and instructional lessons (using a variety of adaptations to support new learning and practice). Since both types of lessons assess continuously, the program determined that Reece could successfully count and identify numbers from one to ten but that she was not yet using fives and tens and needed more experiences with numbers from eleven to twenty. Using these data, the program identified specific lessons appropriate for Reece. It made different decisions for Peter and Billy.

As well as varying the lesson recommendations, the program adapts to offer more or less complex problems depending on the student's responses. For example, Reece was initially given lessons with static math rack displays. Upon her success with these problems, the computer gave Reece more complex problems, such as using a display that flashed the number for a short time, requiring efficient number building (using groups), or both. When she struggled with a series of problems, DreamBox adapted and provided less-complex problems—the math rack display became static. If she had continued to struggle, the program may have decreased the number range or may have removed the requirement for efficient building. For Peter, given the success he was making in the Carnival with the frog-jumping event, the computer routed him to lessons using a number line model. Because Billy successfully skip counted by twos on the number line, the program (aware of the common multiples to investigate) suggested that he try it with fours and eights. When he was successful with this lesson, DreamBox offered the function machine, which allowed him to learn content at his own pace, beyond what would have occurred in his class.

DreamBox also adapts to each student by giving dynamic audio and visual support. One can see several of these supports by reviewing Reece's experience. When she had difficulty placing 79 on a number line, the nearby numbers appeared, lightly "ghosted" to provide a visual support. In the building lessons, when Reece had difficulty identifying the number she built, the program stated the name of the numeral as further support. The technology used these adaptations, and the student's resulting actions, to better understand which adaptations were effective as well as when to gradually remove the supports.

The power to monitor learning

Using data to monitor student learning and form the basis of teachers' instructional decisions has become both an expectation and a challenge in today's classrooms. Just managing the data can be cumbersome. Technology can not only collect large amounts of information about students but also analyze it, look for patterns, and make suggestions regarding instruction. Technology can also support the diverse learning needs of students and support the development of independence, such as self-correcting and self-monitoring.

Software engineers and experienced classroom teachers collaborated to design DreamBox's unique GuideRight technology. In addition to the program's drawing on the experiences of these classroom teachers, the large amounts of information can offer insights into the virtual manipulatives, adaptations, and lessons that are most successful with learners. This information and the flexibility of a Web-based product yield a teaching environment that the system can modify as soon as patterns in the data emerge, resulting in efficient and effective instructional changes.

Supporting students to become independent thinkers can be a challenge in a whole-class setting. A Web-based program can support students to learn at their own pace, to self-monitor, and to self-correct in a relatively safe environment. Billy spent hours on DreamBox working at his own pace, advancing beyond expectations. Peter spent his time with frog jumping and chose lessons that would help him develop strategies to win further frog competitions. Reece monitored her own learning and decided when to click the Help button or, in the quick-image lessons, when to click the image to see it again. Similarly, she demonstrated self-correction when she restarted math rack problems by clicking the Reset button. Both these features of DreamBox are empowering to students as they are involved in making decisions about their own learning needs—and the tools they need are at their fingertips.

The power to personalize the learning environment and experience

Think back to the first week of school—what kinds of "getting to know you" activities did your students participate in? How did you welcome them and encourage them to make the classroom their own? Personalizing a student's learning environment can increase engagement and support learning. Technology can support this endeavor both within each lesson and in the overall game experience.

During the children's first experiences with DreamBox, they chose a character, a theme, and a story. These choices drew them into the learning environment from the beginning. The adventure stories they chose encouraged them to play more games. The game stored the items they collected along the way (such as certificates, trophies, and adventure friends) in "My House"—a place they can visit anytime they want. The environment has become personal to them in the way they share the stories with their parents, proudly display their certificates to their friends (and for Reece, on her refrigerator), and talk about their adventure friends.

Virtual Manipulatives

Virtual manipulatives are exactly that: they are manipulatives that exist in a virtual environment, most often on the Web. Most available virtual manipulatives are simple applets, often written by a single developer. They are not designed by educators, associated with an in-depth educational program, or based on cognitive research. When virtual manipulatives are designed as an *integral* part of a thoughtfully constructed educational curriculum, learning is enhanced. Virtual manipulatives and technology can provide effective instruction, gather valuable information about students' learning, and give specific feedback that is appropriate to the student and in relation to his or her use of the tool.

The virtual math rack

Let us start with a virtual math rack. In DreamBox, this manipulative has anywhere from one to ten wires, each with five red and five white beads.

Here we will discuss the two-wire math rack with a total of twenty beads unless otherwise noted. The left and right sides of the math rack have tilt buttons, mimicking what happens when a student turns a math rack on its side. Left tilt means that all the beads are in play (the value represented is twenty), and right tilt means that all the beads are out of play (the value represented is zero). See figure 9.6.

Fig. 9.6. The math rack showing all beads out of play

When DreamBox built this virtual manipulative, the designers added visual and technological functionalities that are not possible with the hands-on version. The tool is attached to a number generator to produce random sets of problems, such as asking the user to build numbers from eleven to twenty with a slightly greater emphasis on numbers twelve to fourteen and sixteen to nineteen. The virtual version can also flash an image of the tool in order to challenge the user to mentally see the math rack without relying on a static image. The tool can show a number broken down into chunks of smaller numbers. For instance, it can show the number 8 as a chunk of 5 and 3 and the number 17 as a chunk of 10 and 7. The tool can also show a highly transparent set of beads on each wire, called ghosting, which a child can then match. Whereas visually representing numbers in smaller chunks pushes a user toward identifying or building numbers by using groups, the program uses ghosting to support students who need assistance in building the correct value. Finally, when the need arises, one can adjust the physical look of the tool. After testing with hundreds of students, the designers determined that the ten-wire math rack needed a small dash added to the frame, with extra space between the fifth and sixth wires. This visual change emphasizes that 100 is made up of two groups of 50. See figure 9.7.

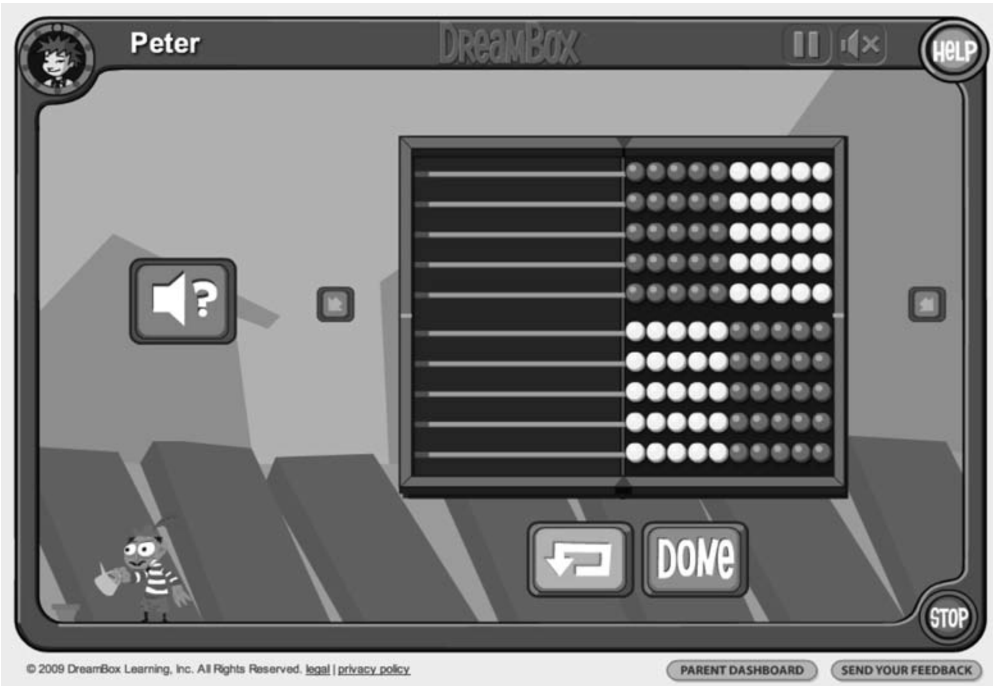

Fig. 9.7. Revised math rack showing design changes to clarify relationships

The virtual math rack responds to a user in relation to how the user manipulates the tool. The virtual manipulative's programming includes the minimum number of clicks needed to build each number. For instance, a student can build 4 in one click (moving a group of four beads), whereas 14 requires at least two clicks (one click moving ten beads on one wire and a second click moving a group of four beads on another wire). Many lessons track how many moves a player uses in order to determine a user's efficiency and sophistication with part–whole relations. By tracking how many moves a user makes, the computer learns something about that user's strategy and developmental understanding of numbers. Did the user click on one bead at a time, indicating that she is still counting by ones? Did she click on groups of ten and five? How often did she reset the problem or peek at a quick image? The more information DreamBox gathers about a user, the richer and more personalized it can make the learning environment.

A virtual open number line

The open number line is a well-researched, powerful representation that many teachers use in classrooms to represent students' computation strategies. In contrast to a closed number line (with counting numbers written below), an open number line is an empty line used to record children's strategies with various operations. The virtual open number line records only the numbers children use, and it records their addition and subtraction actions as jumps or leaps. Representations such as these help children move beyond inefficient strategies, such as counting by ones, to strategies such as jumps of tens, compensating, and using landmark numbers. Research shows that the open number line aligns with children's invented strategies and stimulates a more powerful mental representation of numbers and operations for developing mental arithmetic strategies. Students using the open number line are cognitively involved in their actions (Klein, Beishuizen, and Treffers 2002).

The DreamBox virtual manipulative version provides enhanced functionality to support the development of unifying numbers as both quantities and units of measurement by requiring learners to fill in the distance of the jump as well as the number that was landed on. The tool then adjusts the jump to approximate scale and provides immediate feedback. Again, this tool is attached to a number generator, which quickly provides a variety of unique problems. The program may ask students to find a number on the line, identify the distance of a jump, or input both line and jump numbers. The virtual open number line tells us much about how a child solves a problem. Is he efficiently using landmark numbers, using jumps of ten, or using jumps of multiples of ten? Is the user simply jumping the number of the addend by ones and incorrectly solving the problem on the first attempt? Is he even using the virtual open number line to solve problems? Is requiring use of the tool appropriate, or is it time to remove this requirement? Again, DreamBox thoughtfully designed a powerful virtual manipulative that teachers use as an integral part of the educational environment to support learners in developing sophisticated problem-solving strategies. This kind of technology can truly enhance the usability of a manipulative and create a powerful teaching environment.

Research

During the development of DreamBox Learning K–2 Math, DreamBox gave thousands of users free access to the product. After all, if one is going to build a world-class product, getting as much feedback as possible is vital. Because DreamBox went through five different field tests, each time offering new and revised features, some parents would simply start their child from the beginning with each new release. Because of the program's specialized ability to assess and place students at their instructional level, this approach worked well.

Billy, Billy 2, and the results we all hope to achieve

One parent was flabbergasted to see how much his child learned over three months. During the first field test, Billy's father signed him up to play. Billy played for a month before life got busy, the holidays arrived, and he took a break from playing. After the holidays and another DreamBox release, Billy's dad created a new user account, Billy 2, for his son. Billy played for another month before his father decided to check Billy's progress on the Parent Dashboard. What did Dad find? In the original Billy account, his son rarely passed any placement lessons, meaning that Billy started the math curriculum from the beginning and played through many objectives. In the second account, Billy 2, the results were different: Billy 2 passed most of the early placements and started playing through the curriculum in the same spot as he left off on the original account. Undeniably, Billy learned math during his first month of play and retained this knowledge even after not playing for two months. Such outcomes show the kind of efficiency and retention that parents and teachers want and should expect from all educational software.

Two studies of interactive, Internet-based learning

Stories like Billy's are heartening, but are they generalizable? Margaret Jorgensen recently completed two formal studies on the effect of DreamBox. (Jorgensen, former senior vice president for product research and innovation at Harcourt Assessment, is a leading authority on assessment for K–12 education. She is also on the board of the Association of Test Publishers.) At the core of her research was the question of whether innovative, gamelike, interactive Internet instruction can affect a student's performance on tests given in the context of school-like accountability assessments required under No Child Left Behind. The first study (Jorgensen 2009a) used the embedded assessments in DreamBox. The average (mean) pretest for the group was 59.24 percent correct. The mean for the posttest was 88.70 percent correct. With a paired-sample (or dependent) t-test, the improvement in test scores (positive difference between pretest and posttest performance) for this group of students was significant at the $p < 0.05$ level. Students on average improved 29.46 percentage points from their first embedded assessment to their last embedded assessment before data collection for this study ended. Stated another way: students showed a 50 percent increase in average score on the assessments after an average of only 3.26 hours engaged in the instructional components of this learning tool. Jorgensen followed with a second study (Jorgensen 2009b). This time she examined the effectiveness of the DreamBox technology on mathematics learning over two weeks with twenty-seven second graders without using the embedded assessments. Students took a paper-and-pencil pretest on the first day of using DreamBox in an after-school program. They took a parallel posttest on the last day of the DreamBox after-school program. Jorgensen analyzed the results by using a paired-sample, or dependent, *t*-test, and the results were statistically significant, with an average improvement in test scores. This sample achieved a 19% increase in average score on the assessment after an average of only four hours of incremental instruction. These findings indicate that learning gained by using DreamBox Learning K–2 Math does transfer to school-like assessments even after relatively brief engagement.

Technology's Hope and Promise for Teachers and Learners

Technology runs our modern world. In most industries, it is as important as the lights and heating, whereas the education system lags behind. We track packages across the country better than we track a student's progress in school. We mail a package from one side of the country to the other and track its location every step along the way. Every package receives a unique identifying number. We know to the minute when the package is dropped off, is put on a plane, arrives at a distribution center, is loaded onto a truck, and arrives at the destination. Why not track a student in the same manner (but invisibly), thus letting parents know when a curriculum has been started, what lessons are in progress, what the child has recently accomplished (so it can be celebrated), and what challenges are on the learning horizon?

Online banking lets us see when checks clear and what credit card charges are pending. We can request more information about any transaction. Technology can harness this same level of thinking to keep parents and educators abreast of a child's progress. Current educational technology does its best to measure and track with paper-and-pencil assessments. But are these measures static or dynamic (see chapter 4)? As teachers, we do our best to complete report cards with accuracy, but how accurate are we? Technology lets teachers in different classrooms and different buildings assess students with consistent criteria. It can identify when assessments are off balance and suggest where errors are originating. Technology lets others dig deeper into the data to budget time and resources according to need. Most important, technology can directly link the data to adjustments in teaching *in the moment*.

Technology is more than just another resource at our disposal. It is more than the latest Smart Board or online attendance software. Online curricula are already replacing textbooks, and the data give us crucial insights for important instructional decisions. By itself, technology is not necessarily good or effective. In fact, most products are not. But the potential is there, and with careful evaluation, one can find great products that effectively improve education. Online shopping sites notify users of recommendations for other items of interest on the basis of purchase history and what similar buyers bought and enjoyed. Imagine an educational system that identifies a student's strengths and weaknesses and notifies the teacher. Now imagine that system recommending techniques, curricula, and instructional approaches that may benefit that struggling student, again on the basis of data from other students across the globe with similar profiles. Imagine the computer as an assistant teacher providing differentiation in every classroom, freeing up teachers to involve students in rich, open-ended investigations and projects in class. Once technology has surpassed its earlier position as the computer in the corner of the classroom and become the nucleus of the profession, how might this reweaving of the educational tapestry affect intervention? Would we even need intervention?

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