DreamBox Learning

Using technology to provide individualized learning

Executive summary

DreamBox Learning is an effective online math program that teaches and adapts to provide an individualized learning experience. DreamBox goes beyond the right or wrong answer. By using advanced technology and interactive virtual manipulatives, DreamBox is able to capture and assess data on about 60 behaviors as a learner works on a single answer, including the strategy a learner uses to construct their answer. Using this data DreamBox rapidly responds by adjusting lessons, hints, and manipulatives to the needs of the learner.

DreamBox is the next generation of individualized learning. DreamBox learning’s detailed data mining and analysis not only continuously adapts to the learner within a given lesson, but adapts the sequence of lessons as well. A seven year old using DreamBox might be working on first grade curriculum for the addition and subtraction unit, and concurrently be in the second grade curriculum for place value since they’ve already mastered the first grades for that concept. In contrast, other online programs use only a linear sequence of lessons that each student must do in specific order.

In this way DreamBox is ideal for all learners—including intervention and advanced—because it takes them where they are in their learning and advances them at their own pace and ability.

DreamBox also empowers students by making the whole experience engaging and giving them many choices. The DreamBox lessons are wrapped in game-like adventures, and students choose their persona and framing story. In addition, DreamBox provides each student with choices for lessons and manipulatives, all of which are appropriate for their learning, ability, and curriculum needs.

By using formative, embedded assessments DreamBox can provide teachers, educational leaders, and parents with informative and detailed progress reports. DreamBox technology works to support and enhance what already happens in the classroom by combining a rigorous curriculum that meets the NCTM Focal Points with individualized learning.
Introduction

DreamBox Learning does what great teachers do every day in the classroom by providing individualized learning experiences. By integrating advanced technology with solid educational research, DreamBox can deliver the kinds of educational experiences that the best teachers aspire to and all educators want for their learners. DreamBox doesn’t remove the teacher from a child’s learning, but instead acts as a collaborator by enhancing classroom instruction and providing accurate, timely reports that facilitate differentiated instruction and improve educational practices.

Individualized learning

Definition
There are many terms that may be used in reference to working with a learner at their instructional level and ability, such as individualized learning, differentiated instruction, negotiated curriculum, personalized learning, or personal learning plans.

“Individualized learning” best describes what DreamBox provides; DreamBox Learning teaches a robust curriculum to the individual learner at their ability, through continuous assessment and adaptation.

Individualized learning is most recognizable whenever you see a mentor, tutor, or coach work one-on-one with a learner. It happens most often in subjects like music, art, sports, and even the “behind-the-wheel” portion of Driver’s Education. The expert assesses the learner’s knowledge, proceeds to teach specific skills or curriculum, and can easily adapt the material as they work with and observe the learner.

We propose a functional definition. Individualized learning:

- **Adapts** to each learner.
- **Builds on** each learner’s prior personal knowledge and goals.
- **Empowers** learners to make self-directed choices.
- **Assesses** to form an increasingly rich mental model of the learner.
- **Utilizes** the assessment to modify and adjust instruction appropriately.

How DreamBox teaches

DreamBox Learning is an online math program that delivers a deep, individualized learning experience that simultaneously develops conceptual understanding, computational fluency, and problem-solving ability. Lessons, hints, level of difficulty, pace, sequence, instructional tools, and many other aspects of the experience are tailored to help each student learn.

One of the first games a student plays is actually a placement lesson. Placement lessons assess a student’s existing knowledge and place him/her at an appropriate place in the DreamBox curriculum. Students who already know a particular concept will pass a placement lesson, and then immediately skip over the entire group of lessons for that concept.

Unlike other learning products, DreamBox Learning goes beyond right and wrong answers by assessing the strategy a student used with the interactive manipulatives to answer a question, how quickly a student answered the question, if extra help was needed, and if there was improvement. Using this data our technology adapts the lesson appropriately. There are millions of different paths through our curriculum, based on a child’s needs and interests.
If a student “fails” an objective, reinforcement is needed. For example, the lesson problems get easier, more hints or scaffolding are introduced, and/or a correct answer is demonstrated. In addition, the lesson sequence is adjusted to provide either additional or parallel lessons that approach the concept in a different way, and then more practice-based lessons are introduced as necessary. If the student continues to struggle, a prior objective might be reintroduced and practiced before moving back to the challenging one.

Research on how children learn math has shown that it’s not a simple, linear process. Rather, learning grows like a web through a range of experiences. Our unique lesson sequencing technology allows us to maximize a student’s learning potential in all areas of the curriculum. Because of this, a student could be working in two grade levels at one time. For example, a student could be working in the first grade curriculum for addition and subtraction, but be in the second grade curriculum for place value.

**DreamBox technology**

The following are key technologies within DreamBox.

- **Rich, interactive manipulatives** allow the same tools that deliver instructional examples to track every move and gather constructed-response data. Unlike traditional directed-response questions (e.g. true/false, multiple-choice, multiple-answer, fill-in-the-blank, etc.), the manipulatives present a lightly-constrained micro-world. Kids recognize these as game-like—and they respond accordingly. Discovering the rules of the game by playing is how they learn.
  
  Example: Using the two-wire mathrack virtual manipulative (shown here), a student can be asked to construct 14. Some students will count beads individually until they move 14 beads. Others will slide two groups of 5 and then count 4 more beads. Others will slide 10 beads, 5 beads, and then slide back a single bead (e.g. 10+5-1). A particularly insightful student might tip the whole rack and then move 6 beads back (20-6).

- **A lesson run-time environment** whose components continually observe, analyze, and assess every student interaction. This run-time can work on any connected device, providing the constant alertness you’d expect from the most patient mentor, and its current implementation only requires a Flash-enabled browser.

- **GuideRight™** is a heuristics-based adaptation engine that creates fine-, medium-, and course-grained individualized adaptations based on the embedded continual assessment provided by the lesson run-time environment, as well as relevant cohort analysis of previous students. This technology questions, remembers, follows up, and moves towards a definite end at a pace appropriate for each student. GuideRight runs in the “cloud”—on DreamBox servers—and is available to guide learners whether they are in a home, school, library, or anywhere else with a computer and internet connection. GuideRight’s analysis feeds the lesson run-time environment with the data it needs to deliver the right next challenge to the student.

- **Content creation tools** that allow DreamBox domain experts to efficiently and effectively design products that teach (without worrying about programming or technical details). This not only puts the emphasis on writing lessons and formative assessments that are effective, but
allows for writing lessons that are sensitive to the data flowing back from learners. These tools capture the insight of National Board Certified educators and the anticipated behaviors from students so DreamBox can respond in real time.

- **Deep data analytics** tied to GuideRight allow DreamBox domain experts to look at patterns across thousands to millions of student interactions. This insight is used to tune, improve, and redeploy lessons in the course of a couple of days (as opposed to the multiple years required to revise a lesson in a traditional basal program). This allows DreamBox expert teachers to reflect on the actual effectiveness of lessons and improve them.

- **Dashboards and emails** for teachers, administrators, and parents provide an actionable summary of how learners are progressing. Specifically it shows what skills and knowledge the student has been able to skip over due to prior knowledge and what concepts they are currently working on. This information allows teachers and parents to not only feel confident that learning is happening, but may identify areas where learners need additional support in the classroom or at home.

**Educational challenges**
The educational setting provides many challenges to the ideal of providing individualized learning to all students.

- **Large class sizes:** No matter the size of the classroom, there are always more students than teachers. The spectrum of learning can be overwhelming—from well-below to well-above grade level. Trying to reach all learners where they are at is a problem that has always faced educators. DreamBox Learning does well with all children—from intervention to advanced—by customizing the instruction for each learner.

- **Lack of resources:** Classroom teachers are always searching for appropriate materials for all levels of learners, as well as finding the time to assess and then effectively use the assessments to improve instruction. DreamBox adapts to each learner, providing the exact instruction that is needed. It uses formative, embedded assessments that benefit the learner as they are using the program, but also supports the teacher by providing detailed summaries of what the learner has mastered and the skills they are currently working on.

- **Computer lab staffing:** Using the computer lab efficiently and effectively in a way that benefits the most students is the goal of most schools. How computer labs are staffed can range from a certified technology specialist to non-certified staff to only the classroom teacher bringing in a class. DreamBox works with any model that is already in place, because it automatically adapts to each student, and does not require real-time intervention from a certified teacher. Students are engaged and learning.

- **Hybrid learning modules:** Educators using a blend of on-line learning and in-classroom learning can use DreamBox effectively as part of their experience.

**Alternatives to DreamBox**

- **Other online educational games** generally fail to meet one or more of the aspects of the functional definition of individualized learning.
  - Some are merely decorated multiple choice quizzes with limited (or no) branching logic; the decorations may motivate, but the quiz questions cannot detect how the learner arrives at an answer. The software fails to build and refine a model of what the learner is thinking—so it can’t provide dynamic scaffolding to assist the learner.
Some have decent “casual” (puzzle-like) games, but the games do not generate (nor do they adapt to) data from multiple sessions from multiple learners or cohorts. The games have levels, but can’t differentiate between a learner who was lucky and a learner who is ready to move on.

Finally, some interesting solutions (most often found at the high school level) attempt to adapt to the student. Unfortunately, the learning model is often a static one—with a single “recipe” for scaffolding - or the solution favors only one or two visual representations that fail to address the learning styles of all learners. The choice of questions is personalized, but the questions themselves don’t adapt (and don’t teach) if the student is fuzzy on the concepts. They simply reiterate the recipe more slowly and in more steps.

- **Online tutoring services** typically cost $35/hour and up and may or may not use certified teachers. These services use electronic whiteboards and voice or text messages as the primary communication model. They are best suited to assist a student in learning how to mimic a particular computational technique. They aren’t designed to measure and improve the nature of the learning across a wide range of students operating at a wide range of levels.
- **Personal tutoring** can range from the teenager next door to a full-time private instructor. Prices can range from $10/hour to $50,000/year, and is dependent on the resources available in your area.
- **Tracked classes** work for the wide differences among students, but doesn’t allow for fine-grained differences. It also fails students who are in the midst of rapid learning transitions and might have to jump back-and-forth between tracks on a concept-by-concept basis. Tracked classes ease differentiated instruction for groups, but don’t really personalize education.
- **Pull-out programs** also work to lessen the differences among students by pulling out the students working above or below grade level, but can break learning continuity and group work. In addition, scheduling so that students don’t miss another subject can be extremely difficult.

**The next generation of individualized learning**

DreamBox Learning continuously strives for a new level of effective, high quality teaching and learning. DreamBox does this by using the most advanced technology to gain a deeper look at the learner. We mine the data, micro-analyze it, and respond immediately.

**Data mining**

In order to achieve individualized learning for a wide set of learners, one needs to observe the full scope of students with all their varied backgrounds, learning styles, and abilities. Let’s see how difficult this is without using technology.

A classroom teacher will have close interaction with about 1,300 students in the course of a 40-year career. A principal will evaluate few dozen teachers (at most) once or twice a year. A roving Math Specialist might closely interact (rarely) with up to 10,000 students in a 40-year career. A Master Teacher or PD trainer might get “impressions” from a few thousand teachers representing a few hundred thousand students. A textbook publisher might get “requirements” from a few dozen state and district boards. In short you have a tradeoff between detailed observational data on a few students (tens per year for a classroom teacher) or progressively more vague generalizations for progressively larger populations. Attempting to scale this way means necessarily aiming for the squishy middle with fairly averaged and inflexible materials. It also means that teachers are left to sink or swim when
dealing with the rare students who are two or three (or more) standard deviations from the mean. They simply don’t see enough of them to create effective strategies.

DreamBox, on the other hand, can aggregate detailed data across millions of students. Unlike the teacher who sees the “one-in-a-thousand” student once or twice in a career, DreamBox sees them every day. Using industrial-strength data-mining algorithms for segmentation and prediction DreamBox can identify the groupings (cohort analysis and identification) that actually exist among students and make informed guesses as to which cohort a student belongs to. This analysis is on a concept-by-concept basis and dynamically adjusts as more data is gathered for the individual student and across the set of all students! It starts with a priori assumptions using the best thinking of the board-certified teachers who construct lessons; it continually applies a posteriori analysis to determine which sequencing (transitions between lessons) or alternative approach (e.g. mathrack vs. tenframe vs. skip counting) is most effective to offer to a given student. DreamBox also uses outlier analysis to automatically adjust lesson pacing to keep students from getting frustrated or bored.

In addition to the ongoing automatic data analysis and automatic lesson tuning for learners, DreamBox applies its analysis tools to the overall structure and connections between the lessons themselves. In one case (during DreamBox Learning’s K-2 beta testing) the data from less than 1,000 students was sufficient to detect a “gap” in the lessons where an unusual number of students were failing to progress. The lesson author had simply generalized “too soon”—sound pedagogy, but a slight lapse in pacing. It only took one-to-two days to recognize this issue, two days to gather the lesson writers and designers and implement lessons to fill the gap, and a couple days to test and deploy them. The students were immediately able to proceed. From their point of view, they simply became “unstuck” because DreamBox offered another path to the students who needed it. The students who didn’t get stuck weren’t forced through these new lessons unnecessarily.

If this had been a textbook, the issue might never have been noticed. It might have taken months before a problem would be recognized (via flat or declining scores in a high-stakes assessment) and years before a new edition would be delivered. Again, since the textbook targets the squishy middle the “fix” might be insufficient for a large number of “non-average” students—or might have bored the students who didn’t need another lesson belaboring the point.

**Fine-grained observations**

A directed-response question (T/F, multiple choice, etc.) has a very limited number of discrete choices (distractors). Typically, only one answer is right; the rest are wrong. The wrong answers might give some limited insight into the nature of a student’s error, but there is no visibility into student thinking about how they arrive at the answer.

Since DreamBox uses virtual manipulatives to present concepts and ask constructed-response questions, each learner is presented with situations with many ways to get a “right” answer (and many ways to get a “wrong” answer). Unlike directed-response questions, the challenges posed by DreamBox generate a lot of data. Different right answers show different strategies being employed by the learner (e.g. counting vs. grouping); different wrong answers show different deficiencies in the mental model and therefore might require different remediation by DreamBox.

In addition to the inherent ability of lessons and questions to elicit responses that provide insight into the student’s problem-solving strategy (and “grip” on concepts), the DreamBox lesson run-time environment captures all mouse movements and timings. (In fact, DreamBox captures about 60 behavioral data points as a learner works on a single “answer”.) For example, DreamBox captures think time, prep time, and act time. An older or introspective learner might have longer think time and then act quickly once they have thought; a younger or physical-kinetic learner might “fiddle” with the
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Manipulatives to work out their response and would therefore have less think time and more act time. This data can be used to dynamically tune responses and further challenges for each learner.

No teacher has the endurance or precision to measure timings and mouse movements and make detailed notes about how one learner responds to a challenge, let alone for all of the learners in their classroom. DreamBox is indefatigable and captures fine-grained data for each student—with accuracy and uniform quality. Combined with the sheer number of learners this allows the DreamBox platform to become a high-quality research base for investigating the effects of any lesson or question.

**Rapid response to students**

Making the most of “teachable moments” requires not only correctly determining what the student is thinking and sorting among the best responses, but it also requires responding quickly. Consider these typical response times:

- **Teacher tutoring 1-on-1**: Minutes. However, all the other students are either waiting or not benefiting from the individual tutoring.
- **Whole-class instruction**: Hours to days. This is dependent on how long it takes to grade a worksheet, deliver and grade a quiz, or correct homework.
- **Reflection on the lesson itself**: Weeks to months.
- **Program evaluation**: Months to years. In the case of a printed basal, it can take half a decade or more!

Alternately, DreamBox is able to respond to a student’s answer immediately. First, DreamBox analyzes the answers from virtual manipulatives and 60+ other variables captured from the learner. DreamBox instantly determines the answers to questions such as:

- Does scaffolding need to turn on right now for this problem to keep the learner from getting stuck?
- Does the learner understand this idea enough to move on?
- Is the learner having a problem?
- What kind of learner is she/he?
- Where do we go next?

This instantaneous formative assessment and lesson response is not something that easily happens for learners very often.

**Expressive and concise language for lesson and assessment construction**

Most educational software suffers by forcing educators who don’t understand programming to communicate with programmers who don’t understand education. Not only does this lead to frequent miscommunication (leading to poorly implemented content), but it slows down the product development process even if communication is flawlessly correct. Adaptability becomes expensive or impossible because of these extra educator <-> programmer translation steps!

LessonScript™ (the DreamBox lesson scripting language) and related lesson development tools used by DreamBox Learning’s National Board Certified teachers are used to break this critical bottleneck.

DreamBox only requires educators and programmers to collaborate upfront on the design of a few manipulatives and parameters. Lesson and assessment design can then proceed without programmer intervention. This allows DreamBox educators to focus on the educational design and pedagogy and to
rapidly respond to the distilled data analysis from the complete DreamBox learner community. It really is possible (as mentioned above) to identify, design, create, test, and deploy a critically-needed lesson in a week. It’s also possible for a dozen archetypal manipulatives to support the authoring of hundreds of distinct lessons covering multiple years of standards-based curriculum for millions of students.

Analogy of how DreamBox works

DreamBox is applying the best leading-edge techniques of data analysis and data mining to instruction and formative assessment. For a parallel example, Amazon will collect data on pages viewed and books bought (personalized as well as aggregated, analyzed, and mined) and generate the following selections (among others) when it displays a book:

- **Frequently bought together**: Dynamically constructs product bundles to get you to buy two or more books that complement the book you are considering buying.
- **Customers who bought this item also bought**: Mined from billions of dollars of purchase transactions.
- **What do customers ultimately buy after viewing this item?**: Shows a percentage breakdown of products purchased by folks who bought something after viewing the page. This provides “digital serendipity” and can allow you to discover related books that others found worth buying.
- **Your recent history**: Shows the last few products you’ve looked at (whether it was today or last month).

DreamBox isn’t selling books or blenders, of course. However, the same type of analytical techniques that allow Amazon to create uncanny recommendations using only the two measurements “did I look at the page” and “did I buy the book” are used by DreamBox to analyze the answers from virtual manipulatives and other variables captured from the learner. There is far more richness in DreamBox educational measurements than in Amazon’s browsing and purchase measurements. Yet, DreamBox is only scratching the surface and as more lessons and assessments are authored for more subjects with more manipulatives, the insight into student learning will only become deeper.

Learner engagement

The primary means of engagement is to quickly meet the learner at his/her level and to draw them into directly manipulating the subject matter (e.g. mathracks, tenframes, function machines, etc.). Instead of talking at them (and possibly boring them or confusing them) DreamBox invites them to interact immediately. The “fun” comes from doing and succeeding—keeping the learner in the “zone of proximal development” (as opposed to the comfort or fear zones) and drawing them along. In addition, DreamBox provides the following features that are consistent with a definition of individualized learning that “…empowers learners to make self-directed choices.”

- **Choice of avatar**: This allows learners to place themselves within the DreamBox world.
- **Choice of framing story (skin)**: The story provides longer term narrative objectives. For example, math learners can choose pirates, dinosaurs, pixies, etc. These do not affect the cognitive mathematical content, but allows an appropriate affective engagement. Some kids
think pixies are silly; others think dinosaurs are icky. To each their own is a better approach than forcing all learners to use the same skin.

- **Note:** This capability is extremely useful for special needs and gifted-and-talented populations. As DreamBox extends to other grade levels, it will be able to offer pixies to first-graders even if they are working on fifth-grade content—and shredding skateboarders to eighth-graders working on second-grade content. By allowing the learner to pick the age-appropriate affect, DreamBox can pick the appropriate cognitive level. End result—the student learns what they need without being turned off by an inappropriate “skin.”

- **Choice of lessons and manipulatives:** Since concepts can be developed using more than one virtual manipulative, the student is often given a choice of two or three different lessons using different manipulatives. Some students get really excited about one or two and they can accelerate their learning by preferentially picking those.

Don’t worry—DreamBox can tell from the data if they need to be guided towards different manipulatives to deepen their understanding or prepare them for later topics. This is where DreamBox ensures students are always moving towards a definite end without hurrying them or overemphasizing one topic to the detriment of others.

By letting learners choose the virtual manipulatives that resonate with their learning style (and gently nudging them to expand their boundaries) DreamBox gives them a balanced diet without forcing the same portions in the same order be eaten in the same way. Some learners like to sample the different manipulatives; others want to push one to its limits with many lessons.

### Communicating with stakeholders

#### Teachers and educational leaders

DreamBox provides a concept-by-concept roadmap showing what a learner has already mastered (based on adaptive testing) and was able to test out of, what they have learned through learning modules, what they still need to learn, and the specific concepts most recently mastered (or currently puzzling over). It also provides alerts when a learner achieves critical educational milestones.

Teachers also get “at-a-glance” information on their whole class. This can assist in setting up student groups for differentiated instruction or guided math lessons.

Additionally, educational leaders can combine DreamBox data with their own demographic data systems to measure progress according to teacher, school, reporting subgroup, etc. Over time, DreamBox will respond to the market by providing the most useful tools and visualizations to support district-wide implementations.

#### Parents and guardians

DreamBox enables a meaningful school-to-home connection by providing parents the same concept-by-concept report that teachers receive. This gives the parent a real answer to “what did you do today in school” that’s far better than the usual (“nothing much, Mom/Dad”). It also allows parents to praise the child at the point of achievement when it’s most meaningful.

Even better, DreamBox provides timely suggestions to parents about fun activities that they can share with their children to reinforce and extend learning. Discussions between parent and child at home can
be based around the mutual enjoyment of learning the subject (and not merely a critique and angst concerning grades).

**Integrating DreamBox with the traditional classroom**

Since DreamBox created a standards-based curriculum and is designed to meet the NCTM Focal Points, it's possible to use any supplemental or basal materials that are aligned to the same standards in combination with DreamBox.

In addition to using DreamBox during the regular school day, after-school or summer school programming are also excellent uses for the program.

Not all learning happens on a computer. By allowing an accurate and timely bottom-up grouping of students, DreamBox supports teachers in differentiating instruction for their classroom. Since DreamBox assesses continuously, teachers can use the information to create flexible groupings of students for specific projects, remedial lessons with small group instruction, or enrichment activities for advanced students. Groups can be broken down and recombined several times during the year, providing for true flexible grouping of students.

Where a DreamBox virtual manipulatives is based on a common physical manipulatives, the teacher can use the actual manipulatives in the classroom for a smooth transition from what they see and do in the classroom to what they see and do on the computer.

Alternatively, DreamBox offers many of its virtual manipulatives for use on whiteboards. Even though this use isn’t individualized learning, it’s great visual tools for whole-group teaching. For classroom projects, the tools can be used by learners to present projects and demonstrations to the whole class.

DreamBox supports the school in providing communication tools for the home-school connection. The individualized reports include suggestions for home activities to allow parents to actively participate in their child’s learning.

**Conclusion**

DreamBox Learning is the next generation of individualized learning. By using innovative technology, we do what educators want for all students: to take students at their current ability and effectively advance them to the next level of knowledge, and have them engaged and enjoying the learning process.

For more information about DreamBox Learning K-3 Math, go to [www.dreambox.com](http://www.dreambox.com).

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