Intelligent Adaptive Learning: The Next Generation Technology
Executive Summary

DreamBox Learning is an elementary math program driven by an intelligent adaptive engine that creates truly individualized learning experiences for every student. Using advanced technology and interactive virtual manipulatives, DreamBox teaches math concepts for understanding and builds fluency by capturing and assessing data on about 60 behaviors as a learner works on a single problem, including the strategies used to construct the answer to the problem. Using this data, DreamBox rapidly responds by adjusting lessons, providing scaffolding and hints, and selecting appropriate manipulatives to support students towards mastery.

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 while concurrently using the second grade curriculum for place value since he/she has already mastered the first grade curriculum for that concept. In contrast, other online programs use only a linear sequence of lessons that each student must complete in specific order.
This “behind the scenes” system truly transforms the way students engage with math, ensuring that all students work at their optimal level of instruction resulting in a dramatic improvement in proficiency. Perhaps best of all, DreamBox Learning leverages the “gaming” environment that is so engaging to today’s students — in other words, students love it!

In this way, DreamBox Learning is ideal for all learners — from grade level to intervention to gifted — because it meets them where they are in their learning and helps them advance in the way they learn best.

DreamBox also empowers students by giving them choices and making the learning experience highly engaging. DreamBox lessons are wrapped in adventures, and students choose their personas and framing stories. In addition, students choose from lessons and manipulatives, all of which are appropriate for their abilities and curriculum needs.

By using continuous, embedded formative assessments throughout the program, DreamBox adapts accordingly to meet learners’ needs while simultaneously providing teachers, administrators, and parents with informative and detailed progress reports. Both the teacher reports and the administrator reports provide easy access to the data to see exactly where each student is struggling or performing. This information is crucial to planning effective classroom instruction. DreamBox Learning is a supportive program that can work in every classroom. The program is built upon a rigorous curriculum that aligns with the Common Core State Standards for Mathematics and the National Council of Teachers of Mathematics (NCTM) Focal Points.

Introduction

DreamBox Learning does what great teachers do every day in the classroom by providing adaptive learning experiences. By integrating sophisticated, patented adaptive technology with solid educational research, DreamBox delivers the kinds of learning experiences that the best teachers aspire to and all educators want for their learners. DreamBox doesn’t remove teachers from students’ learning, but instead supports teachers by enhancing classroom instruction and providing accurate, timely reports that facilitate differentiated instruction and provide insight into student progress and proficiency.

Intelligent Adaptive Learning

DEFINITION

There are many terms that may be used in reference to working with students at their individual instructional levels and abilities: adaptive learning, individualized learning, differentiated instruction, negotiated curriculum, personalized learning, personal learning plans.

“Intelligent adaptive learning” best describes what DreamBox provides: a robust curriculum adapted to each individual student through continuous, embedded formative assessment.

You might recognize adaptive learning when you see a mentor, tutor, or coach work one-on-one with a learner. It happens often in subjects such as music, art, sports, and even the behind-the-wheel portion of driver’s education. Experts assess learners’ knowledge, proceed to teach specific skills or curriculum, and can easily adapt the material as they work with and observe the learners.
DreamBox proposes a functional definition. Intelligent adaptive learning:

- **Adapts** to each learner
- **Builds** on each learner’s prior personal knowledge and goals.
- **Empowers** learners to make self-directed choices
- **Continually assesses** to form an increasingly rich mental model of the learner
- **Continuously utilizes** assessment data to individualize instruction appropriately

**How DreamBox Works**

DreamBox Learning is an online math program that delivers a deep, adaptive learning experience to ensure the development of conceptual understanding and computational fluency. Lessons, hints, level of difficulty, pace, sequence, instructional tools, and many other aspects of the experience are ways the program adapts—tailored for each student personally for powerful learning.

Students begin the DreamBox program by completing a unit pretest, which assesses a student’s existing knowledge and places him/her at the appropriate level in the DreamBox curriculum. Students who already know a particular concept will pass the placement lesson and skip the entire group of lessons for that concept.

Unlike other learning products, DreamBox Learning goes beyond right and wrong answers by assessing the strategy students use to answer a question, how quickly students answer the question, if extra help is needed, if there is improvement, and other dimensions. Using this data, DreamBox technology adapts the learning experience appropriately. There are millions of different paths through DreamBox curriculum, based on each student’s needs and interests.

If a student “fails” an objective, DreamBox provides the student with differentiated instruction. For example, the lesson problems get easier, progressive scaffolding is introduced, and a correct answer may be demonstrated. In addition, the lesson sequence is adjusted to provide 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, the program might reintroduce a prior objective, enabling the student to practice it before moving back to the challenging one.

Research on how children learn has shown that it’s not a simple, linear process. Rather, learning grows like a web through a range of experiences. DreamBox Learning’s unique lesson sequencing technology enables us to maximize each student’s learning potential in all areas of the curriculum. Therefore, students can work in more than one grade level at one time. For example, a student could be working in the first grade curriculum for addition and subtraction, but in the second grade curriculum for place value.

**DREAMBOX LEARNING TECHNOLOGY**

These are the key technologies within the DreamBox program:

- **Rich, interactive manipulatives** allow the same tools that deliver instruction 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 microworld. Students recognize these as game-like,
and they respond accordingly. Exploring to solve a problem is how they learn and develop critical thinking and problem-solving skills.

- **A lesson run-time environment** contains components that 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. The current implementation requires only an Adobe® 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 on 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 lives 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 most appropriate next challenge to the student.

- **Content creation tools** allow DreamBox domain experts to efficiently and effectively design products that teach (without worrying about programming or technical knowledge). Domain experts can then focus on writing lessons and formative assessments that are effective and 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 few days (as opposed to the multiple years required to revise a lesson in a traditional basal program). DreamBox expert teachers can then analyze the effectiveness of lessons and improve them.

- **Dashboards and emails** for teachers, administrators, and parents provide an actionable summary of how learners are progressing. Specifically, they show what skills and knowledge students have skipped based on comprehension, and what concepts they are currently working on. This information allows teachers and parents to feel confident that students are gaining proficiency, and it identifies areas where learners may need additional support in the classroom or at home.

EDUCATIONAL CHALLENGES

The educational setting provides many challenges to the ideal of providing adaptive learning to all students:

- **Large class sizes.** Regardless of the size of the classroom, there are always more students than teachers. The spectrum of learning can be very broad — from well below to well above grade level. Trying to support all learners’ needs is a problem that has always faced educators. DreamBox Learning helps all students — from intervention to gifted — by customizing the instruction for each learner.
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- **Lack of resources.** Classroom teachers are always searching for appropriate materials for all levels of students, and then trying to find the time to assess them and effectively use the assessments to improve instruction. DreamBox adapts to each learner, providing the exact instruction that is needed moment by moment. It uses embedded formative assessments that benefit learners as they use the program, but it also supports teachers by providing detailed insight into where students have gained proficiency and the skills they are currently working on.

- **Hybrid learning modules.** Schools and districts using a blend of online learning and in-classroom instruction use DreamBox to take advantage of this model: enabling teachers to foster classroom interaction while providing online differentiated instruction and support for a diverse group of learners when those students need it most.

- **Computer lab staffing.** Using a computer lab efficiently and effectively in a way that benefits the most students is the goal of many schools. Computer labs can be staffed by a certified technology specialist, non-certified staff, or a classroom teacher whose students are using the lab. 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.

**COMPARISONS TO DREAMBOX**
Here are some alternatives and how they compare to DreamBox Learning:

- **Other online educational programs** generally fail to meet one or more aspects of the functional definition of intelligent adaptive learning.
  - Some are decorated multiple choice quizzes with limited (or no) branching logic; the decorations may motivate, but the quiz questions can’t detect how learners arrive at answers. The software fails to build and refine models of what learners are thinking — so it can’t provide dynamic scaffolding to assist learners.
  - Some have decent “casual” (puzzle-like) games, but the games don’t generate (or adapt to) data from multiple sessions from multiple learners or cohorts. The games have levels, but they can’t differentiate between a learner who is lucky and a learner who is ready to move on.
  - Some solutions (most often found at the high school level) attempt to adapt to students. Unfortunately, the learning model is often static — 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
The Next Generation of Adaptive Learning

DreamBox Learning continuously strives for new levels of effective, high-quality instruction by using the most advanced technology to gain deeper insight into how students learn. DreamBox mines the data, micro-analyzes it, and responds quickly.

DATA MINING

In order to deliver adaptive learning to a wide set of learners, one needs to observe the broad range of students with 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 a few dozen teachers (at most) once or twice a year. A roving math specialist might closely interact with up to 10,000 students in a 40-year career. A master teacher or professional development 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 trade off 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 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. Teachers don’t see enough of these students to create effective strategies.
"...the most advanced technology to gain deeper insight into how students learn”

DreamBox Learning, 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 sophisticated data-mining algorithms for segmentation and prediction, DreamBox can identify the groupings (cohort analysis and identification) that exist among students and make informed guesses as to which students belong in which cohort. This analysis is on a concept-by-concept basis and dynamically adjusts as more data is gathered for individual students 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 versus ten-frame versus 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 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 beta testing), the data from fewer 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 generalized “too soon”—sound pedagogy, but an issue of pacing. It took only 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 of days to test and deploy the lessons. 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 to complete these new lessons unnecessarily.

If DreamBox had been a textbook, the issue might never have been noticed. It might have taken months before a problem was recognized (via flat or declining scores in a high-stakes assessment) and years before a new edition was delivered. Because textbooks target the squishy middle, the “fix” might have been 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 (true/false, multiple choice, etc.) has a limited number of discrete choices. Typically, only one answer is right; the rest are wrong. The wrong answers might provide limited insight into the nature of students’ errors, but there is no visibility into student
thinking about how they arrive at the answers.

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 that the student is employing different strategies (e.g., counting versus grouping); different wrong answers show different deficiencies in the student’s mental model and therefore he/she might require different re-mediation by DreamBox.

In addition to the inherent ability of lessons and questions to elicit responses that provide insight into students’ problem-solving strategies (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 take longer to think about a problem, but might then act quickly; a younger or physical kinetic learner might “fiddle” with the manipulatives to work out his/her 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.

Most teachers don’t have the endurance or precision to measure timings and mouse movements and make detailed notes about how one student responds to a challenge, let alone all of the learners in the classroom. DreamBox is infinitely patient and captures fine-grained data for each student, with accuracy and uniform quality. When multiplied by the sheer number of learners, this captured data allows the DreamBox Learning 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 how each students is strategizing and sorting among the best responses, but also responding quickly. Consider these typical response times:

- **Teacher tutoring one-on-one.** Minutes. However, all the other students are either waiting or not benefiting from the individual tutoring.

- **Whole-class instruction.** Hours to days. This depends 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!

Alternatively, DreamBox is able to respond to a student’s answer immediately. First, DreamBox analyzes the answers from mouse clicks and potentially many other variables captured from the learner. DreamBox instantly determines the answers to questions such as:

- What sort of mistake (if any) did the student make? Have they made it, or something, similar recently?

- 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?
• What’s the right next hint, level of difficulty, lesson, or virtual manipulative?

The result is instantaneous formative assessment.

**EXPRESSION AND CONCISE LANGUAGE**

Most educational software development platforms force 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), it also 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 can break this critical bottleneck.

DreamBox only requires educators and programmers to collaborate up front 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. As mentioned previously, it really is possible 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.

**Learner Engagement**

The primary means of engagement is to quickly meet students at their level and draw them into directly manipulating the subject matter (by using mathracks, ten-frames, function machines, number lines, etc.). Instead of talking at learners (and possibly boring or confusing them), DreamBox invites them to interact immediately. The “fun” comes from doing and succeeding — keeping students in the zone of proximal development (as opposed to the comfort or fear zones) and drawing them along.

In addition, DreamBox provides the following feature set that “empowers the learner to make self-directed choices,” part of the definition of intelligent adaptive learning:

- **Choice of avatar.** Allows learners to place themselves within the DreamBox world.
- **Age-appropriate framing theme (skin).** The story provides longer-term narrative objectives. For example, younger math learners can choose a story theme, which doesn’t affect the cognitive mathematical content but allows an appropriate affective engagement. This capability is especially useful for special needs and gifted-and-talented populations. DreamBox also provides an age-appropriate engagement framework for older students.
- **Choice of lessons and manipulatives.** Since concepts can be developed using more than one virtual manipulative, students are often given a choice of two or three different lessons using different
Some learners like to sample the different manipulatives; others want to push one to its limits. DreamBox can tell from the data if students need to be guided toward different manipulatives to deepen their understanding or prepare them for later topics. DreamBox ensures students are always progressing forward without hurrying them or overemphasizing one topic to the detriment of others. By letting learners choose the manipulatives that resonate with their learning style (and encouraging them to expand their boundaries), DreamBox provides a balanced diet without forcing the same problems in the same order to be learned in the same way by every student. Some learners like to sample the different manipulatives; others want to push one to its limits.

Communicating with Stakeholders and Educators

DreamBox provides concept-level reports showing where students are proficient (based on embedded assessments), what they are currently learning or have learned through DreamBox lessons, and what they still need to learn. DreamBox also provides alerts when a student needs one-on-one help from the teacher, or when he/she is learning inefficiently.

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. And administrators get reports on concept proficiency classroom and school progress, DreamBox usage, and license utilization.

Additionally, educational leaders can export DreamBox data for use with their own demographic data systems to measure progress according to teacher, school, reporting subgroup, and so forth. 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 with the same concept-level view of their children’s progress that teachers receive. This gives parents a real answer to “what did you do today in school?” It also allows parents to give positive feedback to their children when it’s most meaningful.

DreamBox also provides timely suggestions to parents about activities that they can do together with their children to reinforce and extend learning. Discussions between parents and children at home can be based around the mutual enjoyment of learning the subject (and not merely criticism and angst concerning grades).
Integrating DreamBox Learning with the Traditional Classroom
Since DreamBox has created a standards-based supplemental curriculum aligned with Common Core State Standards, it’s possible to use any curricular materials in combination with DreamBox to align with these standards.

By allowing an accurate and timely bottom-up grouping of students, DreamBox supports teachers in differentiating instruction within their classrooms. Because DreamBox assesses continuously, teachers can use the information to create flexible groupings of students for specific projects, targeted small-group instruction, or enrichment activities for advanced students. Groups can be broken down and recombined as often as appropriate.

Where DreamBox virtual manipulatives are based on commonly used physical manipulatives, teachers can use the physical manipulatives in the classroom for a smooth transition from classroom to online instruction.

Furthermore, DreamBox offers some of its virtual manipulatives for use with interactive whiteboards and projectors. While these tools by themselves don’t provide intelligent adaptive learning, they are excellent visual tools for whole-group or small-group teaching. Students can use the tools to present projects and demonstrations to student groups.

DreamBox can be used before- and after-school, in summer school programs, and during the regular school days.

Conclusion
DreamBox Learning is the next generation of adaptive learning. Through innovative technology, the DreamBox intelligent adaptive learning program enables students of all abilities to achieve math proficiency, helping them excel in school and in life.

About DreamBox Learning
DreamBox Learning Math is changing the way students engage with and understand math. Through our innovative technology we deliver a phenomenal level of individualized math instruction. Dynamic adaptations, based not just on answers but on strategies, keep all learners, from struggling to advanced, in their optimal learning zone.

DreamBox Learning’s rigorous math curriculum is aligned with Common Core State Standards and builds conceptual understanding and fluency. Our integrated instruction and assessment, together with detailed reporting, give teachers and administrators actionable data on comprehension, proficiency, and academic progress. Just as important, we offer a highly engaging experience that teaches in a way that motivates today’s kids.

Founded in 2006 in Bellevue, Washington, DreamBox Learning’s award-winning products target students in kindergarten through fifth grade and deliver more than 600 core lessons with unlimited variations. More information can be found at www.dreambox.com.

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