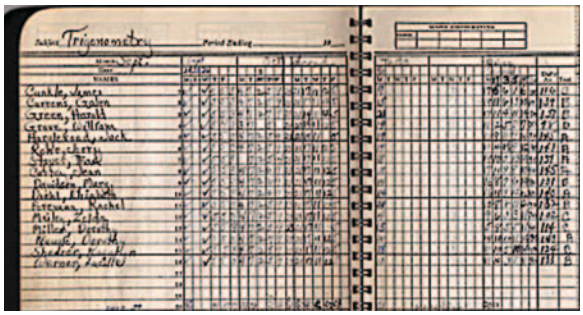
More than child's play: Games have potential learning and assessment tools

We have the technology, experience, and understanding to engineer simulations and games that are assessments for learning (formative assessments), assessments of learning (summative assessments), and potentially even assessments as learning tools.

By Vicki Phillips and Zoran Popović

Over the past 25 years, teachers' records of student progress have moved from printed grade books to spreadsheets. They used to look something like this:

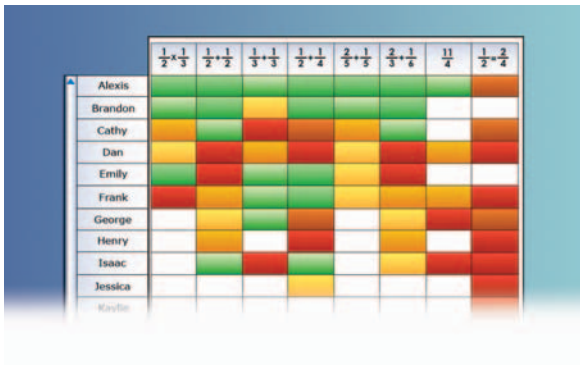


Now, thanks to technology, they often look something like this:

	A	B	C	D	E	F	G	H	I	J
1	Mathematics									
2	Name	Test 1	Test 2	Test 3	Test Avg	HW 1	HW 2	HW 3	HW Avg	Final Avg
3	Andy	56			56	48			48	52.8
4	Barbara	78			78	84			84	80.4
5	Bill	87			87	87			87	87.0
6	Carol	98			98	78			78	90.0
7	Cathy	97			97	94			94	95.8
8	Fred	89			89	98			98	92.6
9	Grady	90			90	99			99	93.6
10	Jim	93			93	96			96	94.2
11	Joe	98			98	89			89	94.4
12	John	89			89	88			88	88.6
13	Jose	97			97	85			85	92.2
14	Judy	97			97	86			86	92.6
15	Julie	96			96	86			86	92.0
16	Mary	93			93	85			85	89.8
17	Peter	92			92	89			89	90.8
18	Sam	100			100	90			90	96.0
19	Sandy	96			96	95			95	95.6
20	Tom	99			99	99			99	99.0

Teachers are tracking the same information — homework, projects, and tests — after a lesson or section has been completed. While teachers spend a fair amount of time on them, tests often don't provide the kind of granular information or feedback that helps teachers differentiate instruction or identify how to help a student improve.

But, what if a teacher could simply electronically access detailed information on how students are progressing on specific objectives? It might look like this:



This is the teacher dashboard of the educational game Refraction, which allows teachers to clearly identify how students are progressing on key skills as they play.

New research shows that games have enormous potential to serve as assessments. We have the technology, experience, and understanding to engineer simulations and games that incorporate assessments *for* learning (formative assessments), assessments *of* learning (summative assessments), and potentially

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Oldest gradebook image courtesy www.papergreat.com

even assessments as learning tools. Game-based assessment helps teachers:

- Personalize learning;
- Instill conceptual understanding and knowledge transfer; and
- Motivate students to develop the persistence they need to achieve mastery.

A new generation of educational games will liberate teachers from the need to administer a separate test. They can embed assessments within next-generation games and capture real-time data on student progress. The dashboard can help teachers see where individual students are struggling or where the whole class needs help. Teachers can use this to provide all students with tailored guidance and personalized instruction, which is crucial to student achievement. With enough time, access, guidance, and motivation, all students can learn.

Well-designed games can serve as next-generation assessments that engage students in a seamless learning experience and assess their learning without their even realizing it. By requiring students to demonstrate mastery before moving to the next level, games cultivate student persistence, an essential component of learning.

Assessments

Until now, standards, instruction, and assessments have been only loosely linked. States develop tests. Districts develop their own curriculum. Teachers develop their own instruction.

Many reformers hoped that requiring accountability would improve performance. In reality, it has increased the importance of statewide high-stakes summative tests that tend to be less connected to daily classroom activities.

With the adoption of the new Common Core State Standards, we're now able to develop better assessments and instructional tools that provide ongoing feedback to help teachers and students improve. One way to do this is by developing games that incorporate effective formative assessments.

The power of games

Gaming technology has some clear advantages over traditional learning and assessment tools.

Engaging students

A great game makes you want to play it over and over. Ninety-seven percent of children aged 8-17 play video games. That obsession, that desire to stick with a game, has a learning advantage. Recent neuroscience research shows that games stimulate the brain's reward system to produce the chemical dopamine, which helps make connections between neurons — the physical act of learning. Rewarding experience drives students to focus and spend more time learning each concept.

Schools generally use extrinsic motivation — grades and diplomas — to get students learning. But, games can instill intrinsic motivation by engaging students in enjoyable experiences. A good game can give students a desire to pursue that subject independently and carry that interest into new challenges.

Games also have the potential to affect the nature of how students approach challenges in learning and life. Studies show that students who see learning as a continuous process of improvement routinely outperform even students who think themselves "gifted" in an area, because the former persist through more advanced learning challenges (Dweck, 2006). Games alter the reward structure to promote persistence and tenacity. This can have a profound effect on a student's lifelong learning process.

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Games can serve as an entry point that enables teachers to reach students in more effective ways and transform the way teachers and students look at assessments. In a survey by the Joan Ganz Cooney Center, 60% of K-8 teachers who use digital games said that since integrating digital games into the classroom their students had become better collaborators and paid greater attention to specific tasks. Fifty-six percent said lower-performing students were now more engaged with the content.

Real-time feedback enables differentiated instruction

In a Bill & Melinda Gates Foundation/Scholastic survey of 40,000 teachers, 92% said formative assessments are important in measuring student academic achievement. While feedback and assessment help teachers differentiate instruction and reteach material according to each student's needs, too often they lack the tools or time to get that information. As one elementary school teacher reported, "Just thinking about the time it takes to review student data and prepare for and deliver instruction to growing numbers of students, who all require ongoing formative assessments and differentiated instruction, leaves me breathless." Gaming technology can enable personalized learning by immediately showing students where they've gone wrong and repeating

Images courtesy the authors

levels as necessary.

Games can collect enormous amounts of data from players to change the gaming environment depending on student needs. At the same time, games give teachers immediate feedback on students' learning trajectories for use in differentiating instruction. According to the Cooney survey, 62% of surveyed teachers said digital games made it easier for them to teach students of different abilities and to personalize instruction.

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For example, Refraction is a free, online game that allows students to create fractions, find common denominators, and add and multiply fractions in an addictive way. The game's goal is to rescue different animals stuck in outer space. To get through each level, students must apply their knowledge of fractions and spatial reasoning to split spaceships' power into the right fraction. Teachers can input the equations they want students to work on.

Then, they can track how each student is doing through the dashboard, identify which concepts are stumping students, and adjust instruction accordingly. Game environments can also help identify student misconceptions.

For a long time, we've been asking teachers to differentiate their instruction without giving them an effective way to do so. Game environments give teachers revolutionary control over individualized learning, combined with data and immediate feedback.

Conceptual understanding and skill transfer

Formative assessments can help students gain a deeper knowledge of subjects and the ability to transfer that knowledge to different contexts. However, traditional static assessments don't lend themselves to this type of knowledge transfer.

Computerized learning is more than glorified digital worksheets for drills. Well-designed games offer a huge opportunity for conceptual understanding by challenging students to apply concepts they've learned in different contexts. Games with assessment components give teachers the opportunity to assess more complex skills than traditional tests can capture and give a more comprehensive understanding of what students know.

This requires game designers to work with education and assessment experts to create games that lead to conceptual understanding and transfer. Games should be designed to provide students with skills and understanding that can be applied outside of the game.

Motivation and mastery

Almost every child has mastered something — a hobby, game, dinosaur names, or song lyrics. The question for educators is to translate that enthusiasm for mastery into school subjects.

In her book, *Fires in the Mind* (Jossey-Bass, 2010), Kathleen Cushman worked with a group of young people to understand how they became motivated to get good at whatever they were good at — whether it was computer programming, knitting, or drumming. After some exploration, students figured out it takes an initial spark of interest, followed by practice, then seeing progress (so they would keep going even as things got tougher) followed by more practice. Recent research agrees: In addition to academic knowledge and skills, students need a stick-to-itiveness to solve problems — academic tenacity — and intrinsic motivation.

In fact, University of Pennsylvania psychologist Angela Lee Duckworth agrees this tenacity, or "grit," may be as important to success as intelligence. What's amazing about grit is that it is teachable. Students can learn it by playing games that require a level of persistence to advance.

For instance, one of the coauthors of this article, Zoran Popović, helped create the game Foldit for a group of biochemists working on how the complex chemical structures known as proteins fold. Not even the fastest computers have been able to solve some protein-folding problems, so biologists wanted to see if they could be answered by nonbiologists using gaming.

Three years later, Foldit has exceeded expectations. Incredibly, nonscientists (even schoolchildren) have beat professional biochemists at their own game, and have even published several scientific papers on protein folding. Through the work of these Foldit gamers, scientists have discovered new

protein structures, including a protein important to understanding AIDS in humans. The problem was posed to Foldit players, and, in 10 days, they solved what scientists hadn't been able to do in 15 years.

Games have a unique power to enhance an intrinsic motivation to learn. The Center for Game Science, housed at the University of Washington and supported in part by the Gates foundation, focuses on developing learning games, including Refraction. It is working on automating the principles that led to Foldit and directly applying them to early math concepts that give students the most trouble, like fractions.

Games can also be a powerful social learning platform. Social aspects of a game — including competing against and helping others — often provide intrinsic motivation. In the Foldit community, highly successful players invested time helping newcomers become team collaborators. In fact, every key discovery produced by Foldit play was a product of collaborations. Games show how collaborative learning and exploration can produce better outcomes than a single learner could achieve alone.

These lessons about motivation and mastery were incorporated into Refraction. For example, a student who masters fractions can go into "angel" mode and help other players with hints. This peer-to-peer tutoring not only helps the struggling student, but also deepens the angel student's understanding through the act of teaching someone else.

Harnessing game power

While games are an immensely promising new learning vehicle, developing effective games is still difficult. For instance, a game may not be optimized to engage all students, may promote learning that doesn't translate well to real-world tasks, or may increase students' frustration with a topic. Presenting concepts through games does not guarantee effective learning.

To be effective, learning games must adopt a key set of design principles:

- Stay true to learning science principles, not just game design principles;
- Optimize engagement and learning transfer simultaneously and avoid creating an uninteresting game or one with little learning;
- Continuously improve over time — the initial design of a game cannot be permanent;
- Include continuous in-game assessment, including assessing its own effectiveness for all learners; and
- Be optimized for multiple learning audiences: teachers and students in classrooms, parent-child learning, peer play and individual play.

There are also several major barriers to the widespread development and adoption of game-based learning.

First, most schools don't have the infrastructure to use even basic technology, let alone games. We're seeing some significant improvements. The Common Core assessment consortia have committed to developing digital assessments by 2014, and they've begun to look at technology readiness in the states. At the same time, the Gates foundation has made a major investment in a shared learning infrastructure, an open-source technology that will allow states and districts to integrate student data from different places and formats with content and applications from many providers. This will reduce costs and free up resources for great personalized learning tools. But, there's still a long way to go.

Second, more research is needed on how games affect learning, specifically their ability to assess complex skills and academic tenacity. Preliminary findings suggest that games can advance both learning and assessment, but the foundation is supporting further inquiry.

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Third, while the education market is big and the commercial game market is even bigger, the two rarely overlap. Game developers haven't had an incentive to enter an educational market that is often monopolized by textbook publishers. Moreover, game designers haven't had many formal opportunities to work with assessment experts.

Finally, teachers aren't sure what technology offers them. A Gates foundation survey last fall of teachers in grades 6-12 found that most use some technology to support their teaching and believe it is a useful supplement to classroom teaching. But, they report facing serious barriers to using technology to its full potential. Many have limited access to computers and don't receive sufficient training on how best to use technology tools.

Perhaps most revealing, only 12% of teachers in the Cooney survey said games provide data for assessment. To make technology and games work, we need to help teachers understand how games can help in the classroom.

Gaming the system

Given the advantages of gaming and the challenges in developing and adopting games as an as-

sessment tool, the Gates foundation plans to invest in several key areas to help advance the field.

First, the Gates foundation is investing in game-based technologies, including new games aligned with the Common Core. We're looking for games that assess students' application of knowledge and skills, including complex skills like problem solving and tenacity, and that complement our existing work in teacher tools and supports.

To facilitate this work, we're investing in a project called Games, Learning, and Assessment (GLASS) that brings together some of the best game designers and assessment experts to build great new games. Many computer scientists and game developers are eager to get more involved in education. As one top game developer recently said of one of our investments, Formative Assessment Lessons in Math, "I have 20 years of experience in game design and not a day in teaching." This kind of collaboration can unleash untold creativity.

We're also looking to invest in four big areas of research: games as assessment tools; games and complex skills; games and their ability to transfer learning to other contexts; and the effect of games on the achievement of low-income and minority students.

We already have some preliminary, promising evidence that games are good assessments and can facilitate the transfer of learning. A pilot study of 35 elementary school students who played Refraction over seven weeks found they significantly improved on paper tests of fractions. Students became faster at solving assessments embedded in the game.

Next, we need to focus on implementation. What will it take for districts and schools to adopt gaming technology? Too often, teachers feel technology is something that must be bolted onto their classrooms. We want to invest in learning how teachers can best seamlessly integrate games into their classes.

Finally, we hope to invest in building this exciting new field through advocacy and through partnerships across industry, government, and the philanthropic community. In January 2011, for example, the Gates and MacArthur foundations cohosted a games, learning, and assessment conference. Over 80 assessment experts, game designers, and learning scientists came together, broke into teams, and created prototypes for 10 games-based assessment projects. In only two days, this group came up with some amazing ideas, including a fantasy horror-themed game called Undead Apocalypse that challenged students to think about systems and see the big picture by maintaining a proper balance of vampires, zombies, and werewolves.

One of the most exciting and profound aspects of this work is that game developers can see how players are doing, and then make immediate adjustments to the game. Correctly designed games like Foldit evolve to be more effective as more people play. Popović didn't need to wait to figure out what was and wasn't working and then make improvements to the game. The technology is such that these changes happen almost in real time.

Creating a generation of seekers

In his book, *Everything Bad is Good for You* (Riverhead Books, 2005), Steven Johnson recounts the story of playing the video game SimCity 2000 with his seven-year-old nephew. The game is a rather complex simulation in which players "build" a city as conditions change. At one point, his nephew suggested lowering the industrial tax rate.

If Johnson had, instead, started out by handing his nephew an industrial economics textbook, the child would most likely have walked away. He certainly would not have been as engaged and probably wouldn't have grasped the concept of industrial tax rates so quickly. After just an hour with a new game, this seven-year-old was learning — and he wanted more.

Johnson argues that what makes games so compelling and powerful is that they make people "seekers," where unlocking one door makes you want to unlock another one. People get hooked because of "the desire to see the next thing," which is fundamentally what learning is about.

Games are far from a silver bullet. But, if they could help us instill in all students that relentless desire to seek what's next, then we would ignite a love of learning that could last a lifetime. And that's a game worth playing — and an investment worth making. K

Reference

Dweck, C. (2006). *Mindset: The new psychology of success* (1st ed.). New York: Random House.