

Video Games and the Second Life of Science Class

Can video games and computer simulations revive science education in the US? Amy Maxmen has the story.

This March, for the first time, a member of the White House spoke at the Game Developers Conference (GDC) in San Francisco, where video game programmers, producers, and designers gathered to discuss the lucrative future of the video game industry (<http://www.gdconf.com>). Kumar Garg, a policy analyst for the White House Office of Science and Technology Policy (OSTP), presented to the conference attendees a challenge handed down from President Obama regarding the dilemma the US faces in science, technology, engineering, and math (STEM) education. "Now the hard truth is that for decades we've been losing ground. One assessment shows American 15-year-olds now rank 21st in science and 25th in math when compared to their peers around the world. And this isn't news. We've seen worrying statistics like this for years," Obama remarked on November 23rd as part of his "Educate to Innovate" campaign (<http://www.whitehouse.gov/the-press-office/remarks-president-education-innovate-campaign>). "And that's why I'm committed to moving our country from the middle to the top of the pack in science and math education over the next decade."

Not only OSTP but also the National Institutes of Health (NIH) and the National Science Foundation (NSF) have been concentrating on ways to make good on Obama's commitment. And video games, they hope, may be one solution. "The trend is that we are going to have more games and more types of games," says Garg. "It's an important time to talk about the role of games that serve the public interest." He explains, "I work on STEM education, and the challenges that the games community works on could be hugely relevant." By immersing players in a virtual world, video games and computer simulations force people to solve problems they don't normally

face. Completing a level relies on learning skills programmed into the game—be those skills stealing cars or engulfing invading bacteria. As in school, skills are attained gradually as the player moves on to higher levels of difficulty in the game. Garg says, "As one person at GDC put it, game developers think a lot about level one. If you mess up level one, you haven't created a good game. So they think about what experiences keep people going...it must be hard enough so that there's a continuous path of improvement, but not so hard that it stops being engaging. And that's important in learning."

For years, computer simulations have been giving soldiers, surgeons, and racecar drivers lessons to prepare them for their careers. Now, game developers have been challenged to show that video games and simulations can train kids to think like scientists, mathematicians, and engineers. Furthermore, games allow teachers, parents, and funding agencies to observe how students learn as they play. In fact, science-related games embedded with assessment software can even act as alternatives to paper exams for testing critical thinking. What the current administration has realized is that reforming science education means more than memorizing facts and bolstering exam grades. If America is to maintain its competitive edge, the type of critical scientific thinking that comes with experience must be nurtured. More than 50 years ago, educational philosopher John Dewey emphasized the role of human experience in learning. His opinions appear to be making a comeback.

"We wouldn't teach football from a textbook. It is even more important that America's youth have the opportunity to learn math and science by doing," said John Holdren, Science Advisor to President Obama, as he introduced a new

STEM education project called National Lab Day (<http://www.nationallabday.org>). National Lab Day is a nationwide effort to bring experiment-based learning to children across the US, and although there will be an actual "day"—celebrated across the country on May 12th—activities and the website operate year round. Like a dating service, the website automatically matches volunteers from the private and public sectors to requests from teachers who want to give their students hands-on learning experiences in science, technology, engineering, and math. Among the requests are four "teacher seeking video game designer" advertisements. The NSF, NIH, Bill and Melinda Gates Foundation, Microsoft Corporation, AT&T, and others have pledged to support National Lab Day. At OSTP's urging, the MacArthur Foundation aligned its \$2 million "Game Changer" competition to design compelling science-related video games with the announcement of National Lab Day. Winners will receive awards ranging from \$5,000 to \$50,000, as well as recognition from the game industry companies Sony and Electronic Arts.

Meanwhile, the Siemens Corporation has kicked off another nationwide initiative, called the Siemens STEM Academy (<http://stem.discoveryeducation.com>), to immerse students in activities related to careers in STEM. "The main thing that's on our minds is how do you get enough kids interested in STEM to fulfill what turns out to be a big gap in our employee base. We have over 600 openings in the US for engineers, and the demand is going up. True, there are probably more than 600 engineers in the US looking for jobs, but we are very selective," says Siemens Corporate Research division President Paul Camuti. "We have to be worried about the STEM education base in the US. It's a fundamental problem, so



Figure 1. Fantastic Voyage Goes Digital

In level 5 of the video game *Immune Attack*, a player navigates a nanobot drone (white) over the surface of a macrophage (blue) in search of a cytokine emitter (brown) that when struck by the nanobot's ray gun will stimulate the macrophage to release a cytokine called CXCL8 (interleukin 8). This cytokine entices other white blood cells (neutrophils) to join macrophages in the fight against invading bacterial pathogens. Image courtesy of the Federation of American Scientists, Educational Technologies Program.

we think we need to connect with kids in a different way than we used to, using the technology available today."

The Value of the Virtual Experience

Educational video games have been around since the 1970s, but most have faded into obscurity. According to education expert James Paul Gee at Arizona State University, the problem is that many games simply present textbook-like questions on a flashy background. "It's what I call chocolate-covered broccoli," says Gee. "These games only sugar-coated content that was just old skill and drill. But that industry has sort of fallen apart. Now we instead want to put people in problem solving space. Games today can give you experiences and understandings you could have never gotten before." For example, students can manipulate electromagnetic fields before looking at a formula. Outside of school, people learn through experiences. And new words come with situations attached. That's why manuals make more sense after playing a video game, fixing a bicycle, or cloning a gene than they do

before. Likewise, Gee explains, playing a video game before opening a book can facilitate learning.

In 2004, the Federation of American Scientists (FAS) set out to prove that video games can boost the ability of 7th through 12th graders to learn science. In an informal survey of high school teachers, immunology had been voted the hardest subject to teach, and so FAS created a video game called *Immune Attack* (<http://fas.org/immuneattack>). "Prepare to visit an alien world that is closer than you think," warns the game trailer as the video zooms through a pulsating, three-dimensional universe of cells and molecules. *Immune Attack* took a cue from award-winning, third-person shooter games like *Resident Evil 4*, in which the player's character is visible on the screen. Players travel inside a patient afflicted by a dysfunctional immune system in a "nanobot" and perform feats that eventually save the patient from succumbing to the disease, like teaching white blood cells to locate an infection by following a cytokine cloud (Figure 1). Since its release in March 2008, *Immune Attack* has been downloaded 12,000 times and

600 teachers have agreed to evaluate the game for FAS in their classrooms. Melanie Stegman, FAS program director for educational technologies, came to FAS after a postdoc in the Department of Microbiology and Immunology at Weill Cornell Medical College. She tries her hardest to keep the game scientifically sound and even has the game peer-reviewed. "Blood flow happens accurately, molecules crowd accurately—the fun thing is that the complexity of the science makes the game challenging," Stegman says.

Immunologist Bill Muller at Northwestern University in Chicago reviewed the game's introduction on immune cells. He says, "I like the idea of making science accessible but you don't want to dumb it down. If everything is simple, then people may start to wonder, 'Well, if it's so simple, then why can't scientists cure cancer and tuberculosis?'" Moreover, Muller adds that intrigue inspires interest. "If you want people to go into science, you should let them know that there are many big, important questions to be answered by the next generation of scientists." In the second version of *Immune Attack*, slated for release this summer, players can link to real images of cells and proteins, as well as to researchers' websites. Importantly, this information will not interfere with game play. FAS is currently assessing what students learn from *Immune Attack*. Thus far, student game players perform better on immunology multiple choice tests than students who have never played the game, plus they are more confident. "If a student feels like immune cells are something they are familiar with, not something that only 'smart people' know about, then they will be more confident in their ability to understand what the teacher is presenting," says Stegman. In addition, FAS hopes the game might be played by people of all ages so that they might better comprehend articles on public health, environmental contaminants, and other news related to cell and molecular biology. The NIH has recently awarded the project a 5 year, \$750,000 grant.

Taking It to Level 2

An increasing number of games have built-in tools for assessment that keep track of how a person plays. New software can aggregate these data and let evalu-

ators know how students go about solving scientific problems. Arlene de Strulle, NSF Program Director in the Division of Research on Learning, says, “Advances in technology now afford game developers with the capacity to embed sophisticated assessment tools into a game to understand the cognitive processes associated with learning through gameplay as it’s taking place. Through games, teachers can assess student progress and track student decision-making, and students are enabled to scaffold their own learning processes.”

Chris Dede, a professor of learning technologies at the Harvard Graduate School of Education, is working on “virtual performance assessments,” game-like simulations that teach and test skills of scientific inquiry, like making observations and forming hypotheses. In one of Dede’s games, students roam two virtual Alaskan coastlines and ask questions about why kelp on one coast is healthier than that on the other. “Paper and pencil tests aren’t valid for measuring higher order thinking or collaborative skills. Failing a pencil and paper test may indicate that the student is a poor reader, even when they have good skills of scientific inquiry,” Dede explains. The danger in failing is that a student who enjoys science may become frustrated with the subject for the wrong reasons.

Diane Jass Ketelhut, a professor of science education at Temple University in Philadelphia, is developing SAVE Science (short for “Situation Assessment using Virtual Environments” of scientific content and inquiry) to test comprehension of scientific principles. In one SAVE

Science game called *Sheep Trouble*, players observe a farmer’s flocks and propose experiments to determine why one flock isn’t doing well. “Teachers can follow what parts of concepts like adaptation students don’t understand and they can also use that information to give a grade,” explains Ketelhut. “On a normal test, you tell students what to do. Here, they decide. Plus, when we tested it out on kids, they seemed to have a good time. They said, ‘Make it harder! We know it’s a test, but make it harder!’”

“When you log into a new virtual world, you never know what the goal is right away. So you learn how to explore, what to explore first, and how to deal with overcoming challenges,” explains epidemiologist Nina Fefferman at Rutgers University in New Jersey. When the flu-like Whypox sweeps through the virtual world of *Whyville* (<http://www.whyville.net>), students take measures to control the outbreak as it rapidly interrupts their ability to socialize with other avatars online. Fefferman and her colleagues observe how players react to this and other outbreaks, and they’ve encountered unexpected reactions. For instance, a number of students feigned illness to fit in with their peers, others sold fake cures for virtual profit, and some systematically took surveys to understand the symptoms, severity, and virulence of the disease. Students also went to *Whyville*’s Center for Disease Control (CDC), where they could model the time course of diseases and get vaccinated for Whypox. New additions to the game allow kids to design their own vaccines to protect against new infec-

tious diseases as they occur. Further, the line between reality and *Whyville* has blurred. Computational neuroscientist and *Whyville* creator Jim Bower says, “During the SARS and H1N1 outbreaks, kids went into our CDC to try to predict what might happen on their own.”

Technology today allows for virtual experiences unlike those of a decade ago. Yet the challenge of creating a storyline that both entertains and teaches remains the same. Americans ages 25–40 may fondly remember *Oregon Trail*, an educational game about 19th century pioneer life released on floppy disk in 1971. “The ideal game sets up an experience where students learn in spite of themselves,” says one of the three *Oregon Trail* creators, Don Rawitsch. “I think science is a rich opportunity for computer simulations. It’s an opportunity to teach kids about how to approach investigations, how to think logically, and how to draw conclusions. These are skills that are useful whether the student takes up a career in science or not.”

President Obama said in his address on STEM education, “Everyone in this room understands how important science and math can be. And it goes beyond the facts in a biology textbook or the questions on an algebra quiz. It’s about the ability to understand our world, to harness and train that human capacity to solve problems and think critically, a set of skills that informs the decisions we make throughout our lives.” Ironically, the video games that kids have been neglecting their science homework to play can now be harnessed to make science—and scientific thinking—fun again.

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