By Rebecca Mitchell and Dennis DeBay

Get Real

AUGMENTED REALITY FOR THE CLASSROOM

Kids love AR simulations because they are like real-life video games. Teachers love them because they can differentiate instruction and engage even the most reticent learners in mastering any type of content while practicing digital age skills. And they're easier to create than you think!

Imagine a video game that takes place in the real world—right outside your classroom! In this game, the players learn that an alien spaceship has crashed on their school grounds, and they must solve a mystery: What are the aliens' intentions toward Earth?

Each of the players, working in a team of four, has a role to play: chemist, cryptologist, computer hacker, or FBI agent. And each gets his or her own GPS-enabled mobile device, such as a smartphone or tablet, displaying a map of the school grounds with digital markers tracking each player's location as well as the locations of virtual people and artifacts. Players must walk to and inspect these markers to gather evidence that will ultimately help them solve the mystery.

Would some of your students be more interested in playing a game like this than in doing math problems? What if they could do both? With augmented reality (AR) simulations, they can!

AR simulations allow students to learn content while collaborating face to face and interacting with a multimedia-enhanced version of the world around them. Although the technology may seem advanced, AR software makes it easy to develop content-based simulations that will captivate your students while teaching them standards-based content. (See the "Building the Program" section beginning on page 19 for information about AR software.)

The scenario above describes an actual classroom lesson using Alien Contact, a middle school mathematics AR simulation (tinyurl.com/3bvow7) that focuses on the mathematical concept of proportional reasoning. However, AR can work for any content area. In fact, we also developed an English language arts version and a combined math/language arts version of Alien Contact.

After conducting 17 implementations, mostly at urban public middle schools in or around Boston, Massachusetts, USA, during the 2007–08 school year, we determined that AR increases academic engagement by tapping students' interest in mobile devices, differentiates instruction by personalizing information or tasks for students, and creates situated learning experiences. Here is the process we used and some things to keep in mind if you want to create your own AR simulations to use with your students.

Concept Development

Before you start building your AR simulation using software, you will want to plan out the storyline, activities, and curriculum.

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Storyline. To conceive an AR learning simulation, you could start with an authentic problem, an engaging storyline from which content-based tasks can emerge, specific content, or some combination of these. Because AR enhances reality, we recommend beginning with an authentic problem, which allows you to nest content within an engaging story. MIT, for example, created a game where students determine a source of polluted drinking water, using the nearby Charles River as their game space. At some locations, students viewed digital interviews with scientists, and at others they virtually tested water samples.

To develop Alien Contact, we began with a storyline (an alien crash), content goals (proportional reasoning), and digital age skills (collaboration, communication, and problem solving). It was challenging to develop mathematical tasks that simultaneously furthered the storyline, supported student content learning and digital age skill development, and engaged students in the simulation. So, to keep content central, we created a document that provided overarching learning goals and detailed the tasks and learning goals for each day of the unit.

Role differentiation. AR lets you personalize the game for different students or groups of students by storyline, information, and content-based tasks. Although complex to design, simulations with differentiated roles can make the content accessible and challenging while strengthening communication and collaboration skills for all learners. Roles can allow for a jigsaw approach, with each student receiving different information that they must share for the group to proceed in the game.

AR software allowed us to create up to four versions of our simulation using different scripts for each role that correspond with each student's skill level (although we later found that groups of three are easier to manage). For example, the chemist received more challenging mathematical tasks, and the hacker received more guided tasks. At one school, we developed an audio version of the game for a visually impaired student.

To ease the planning of role differentiation, use tables to storyboard the content and narrative contributions of each role, and consider using self-contained activities, such as the Wing Model task described below.

Tasks. Alien Contact included a number of tasks designed to engage students in a virtual mystery while motivating them to practice proportional reasoning skills. For example, in the Wing Model task, teams track a digital marker on their mobile devices to a wing model, which is actually a latex triangle on the ground (see "Wing Model Task" on page 18). Once a team finds the model, the computer hacker's device displays a document offering a math problem that, when solved, will allow her to "hack" into a CIA database. She learns that, if the ratio of the hypotenuse of the wing to its shortest side is 5:3, the wing belongs to a military craft. From his mobile device, the chemist learns that the wing model has been measured with safety pins that are 1.5 inches long. The group studies the markings on the model itself to determine the dimensions of the wing and compare it with the given ratio.

After collecting data outside, the students move inside to analyze it. This is when they determine the aliens' intentions, justifying their position with mathematical evidence.

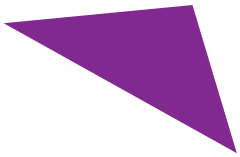
Content. Including thoughtfully developed curriculum content transforms a merely engaging activity into a positive student learning environment. The Alien Contact curriculum guide provides daily mathematical and digital age skill objectives, a solution key, and teaching suggestions, such as advising students to share strategies.

It is important for teachers to emphasize content and provide adequate time for students to think about it. If you are developing a game for teachers, elicit their feedback about the quality and accessibility of the content-based tasks so you can make improvements for future classes. In

This AR display from a student's mobile device shows his location as well as some of the digital objects he is trying to locate on the school grounds.

Wing Model Task

Outdoor Component



Wing Model

Federal investigators found a wing at this exact spot on the crash site. The FBI took the wing but left a scale model for us to look at. The weight of the uranium in pounds, a three-digit number, is the code to access this piece of evidence.

Chemist	Cryptologist	Computer Hacker	FBI Agent
Locate the purple triangle on the ground. This is the scale model of the spaceship wing. You can see the markings where someone measured it using a safety pin. The safety pin was 3/2 (or 1.5) inches long.	As a team, figure out the measurements of the side lengths of the wing. When you are done, write your answer on the paper you were given. The largest of the three measurements is the code to access your next piece of evidence.	We hacked into a government computer and found this: **Data on Military Spacecraft** *** Top Secret *** According to CIA data, in a military spacecraft, the ratio of longest side to shortest side has to make a fraction that reduces to 5/3. In other words, if you have a military craft: $\frac{\text{Longest side}}{\text{Shortest Side}} = \frac{5}{3}$ Write this proportion down for later.	Locate the purple triangle on the ground. This is the scale model of the spaceship wing. You can see the markings where someone measured it using a safety pin. Use what you remember from your training to help your team complete this task.

Indoor Component

- Using proportions, check whether the spacecraft we found was a military alien ship.
- Which strategy (additive, unit rate, scale factor/equivalent fractions, cross multiply) is the best or easiest to solve this proportion? Why?
- Another group measured the scale model of the wing using paper clips. They found the wing model to be 12 paper clips by 15 paper clips by 20 paper clips.
- Are their measurements accurate? How do you know?

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our early pilots, we discovered that students would rush to find the characters without doing the mathematical tasks. So we started programming the answers to each math problem to serve as access codes that the students would need to receive information at the next location.

Place independence versus dependence. AR programs use GPS coordinates to create game spaces anywhere on the planet. As our target demographic was urban public schools that had no money for field trips, our simulations were place independent so that students could play them directly outside any school. If you develop a place-independent simulation, using real objects in the game space will help students interact more productively.

However, one of the coolest things about AR technology is that it can augment students' learning experiences within a meaningful context, which can include location. Simulations with tasks that relate to a specific location—such as giving students measurement data about their own school and asking them to calculate its height—take better advantage of this benefit. Think about how nearby geographical areas might lend themselves to tasks that further student understanding of your content focus.

For example, Harvard graduate students have been developing a simulation for the Black Heritage Trail in Boston, Massachusetts, USA, to help K–12 students experience what it might have been like to be a self-liberated slave in Boston. At locations on the actual trail, the students will access historic documents, hear from significant people detailing their experiences in Boston in the 1700s and 1800s, encounter setbacks that self-emancipated slaves would have encountered, and receive financial assistance and employment, all via AR.

Building the Program

A University of Wisconsin–Madison team developed the free ARIS AR platform (arisgames.org) for iPhone and iPad. On the program's map screen, you determine the game space using Google Maps, and the object screen allows you to create characters and items, which you then place on the game space by dragging them over. You can easily upload images, video, audio, or other multimedia files for students to view during the game. ARIS is user friendly, and we were able to create a sample game in 30 minutes.

An enticing storyline, a game that takes place outside, authentic problems to solve, and mobile devices with multimedia content all converge to make this AR math simulation the best class of the day for these middle school students.

MIT has also recently developed TaleBlazer (education.mit.edu/projects/taleblazer), a web-based AR game development tool similar to ARIS, for teachers and students to make and share games using iPad, iPhone, or Android smartphones.

Time to Play

So you've created your AR game and are ready to unveil it to your students! Yes, it will be fun, but there are also some things you'll want to keep in mind:

Student engagement. Students were highly engaged during Alien Contact. One teacher noted, "My classes … love to chit-chat and talk, but throughout this entire week and a half, they were focused, they were really engaged, they really wanted to figure out what the problem was." Students especially liked working in teams while maintaining their own role expertise. Other appealing aspects of the simulation that students mentioned include using multimedia, being outdoors, using mobile devices, using GPS to track students' movements, collaborating, and engaging in tasks that they perceive as authentic. Teachers often noted with surprise that their least motivated and successful students were the most engaged with Alien Contact.

Technical issues. At times, however, technology can temper student engagement. For example, students in our simulations often had to refresh their devices because of disruptions in GPS signals. Additionally, due to built-in GPS inaccuracies, students would access the same character at slightly different locations. As a result, we had to provide physical, along with virtual, location markers for tasks requiring precision, which required students to measure the distance from the virtual impact crater to the furthest piece of debris. Also, some devices' screens and speakers are not intended for outside use. Our students would sometimes have to hold their machines to their ears to hear videos, which caused them to lose key visual information, or they would have to squint to see the images in the sun's glare.

AR technology has already evolved since we conducted the Alien Contact simulations. For instance, the mobile map technology has advanced from a flat, bird's-eye view to a 3D street view. As GPS becomes more accurate and mobile devices acquire the ability to project images onto walls, many issues will decrease significantly or even disappear. For now, we recommend recruiting technology support during implementations.

If you are developing AR simulations for other teachers, be cognizant that some may be uncomfortable with the technology and with feeling less fluent with the tools than their students. Students may also get distracted by trying to gain internet access or play the videos at high speed. Allow sufficient time for teachers to become familiar with the tools, and build in student playtime as well, as play is an important part of learning to use any new tool. One teacher suggested training student leaders beforehand to become technical experts for their peers.

Management. It is important to prepare for management issues with both materials and people. Alien Contact required a teacher and two other adults to pass out hardware and assist with technological and navigational issues. One teacher used college student volunteers, but he told his class they were FBI agents, resulting in logistic support that also enhanced the game context. Materials should become easier to manage as technology improves.

During game-space exploration, teachers also often had to remind students to regroup. This can be mediated by developing a game where students complete tasks individually, then share their findings with their group. Teachers also often had to help students read their maps and navigate the game space.

At other times, students might be too focused on their devices and need reminders to stay aware of their physical surroundings, especially near streets. And if students are not accustomed to working in groups, teachers will need to help them negotiate group dynamics.

Content considerations. Student engagement, technology issues, and management complexity can potentially distract from content learning. While forcing students to solve the math

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problems to access the next character helped focus more attention on the content, technology and management concerns shifted the focus away from the mathematics learning. Content must remain the focus for any AR learning simulation. We suggest developing easier content tasks for students to work with initially to allow teachers and students to get comfortable with the simulation before delving into more complex content.

Despite the inevitable difficulties, we believe that AR is well worth the trouble. We have found that these simulations engage students who are typically disengaged in mathematics classrooms, encourage collaboration, allow for differentiation of instruction, and stimulate authentic learning. The teachers we worked with also appreciated that students were learning to collaborate and use evidence to support their thinking and were able to transfer their proportional reasoning skills to standardized testing contexts. Given that the simulations are easy to create and that advancements in technology are making it even easier as time goes by, it seems that AR is an educational approach whose time has come.

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