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FUSE for STEM Learning and Interest Development

An interview with Reed Stevens, a professor of the Learning Sciences at Northwestern University about his work to support STEAM exploration in a student-centered, choice-driven studio environment. See FUSE – Our Story for more information.

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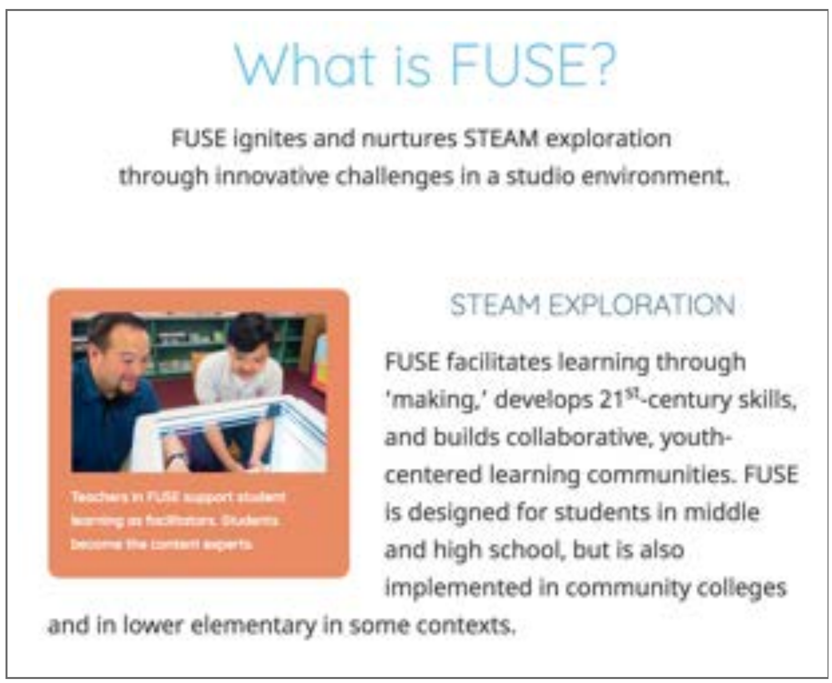
What is the big idea of your project?

FUSE is an interest-driven exploration program that engages youth ages 10-18 in science, technology, engineering, arts/design and mathematics (STEAM) topics while fostering the development of important 21st century skills. Students choose challenges they want to work on and who they work with, alone or collaboratively. The challenges are designed around student interests in areas such as music, design, fashion, and the environment. FUSE prepares educators to support students with guiding questions and youth-centered classroom management.



How has program evolved over the years?

FUSE has been around since 2011, our pilot year. We came up with the idea and gave it a test with here at Northwestern. It seemed pretty promising. And then we started taking it out into the commu

Initially, I had not intended for it to be an in-school experience. We were modeling it after what my friend and colleague, Nichole Pinkard, had done with her YouMedia project and we had aimed for community centers and libraries. But in 2013, a local school district west of Chicago, that had heard about FUSE, came to us, and we began a conversation with them that led to us piloting it in some of their schools. And not long after, a variety of forces in that district led them them to ask us to expand to more of their schools.

Long story short, in that district, over a few years it went from being in a couple schools to being in every middle school. Every 5th and 6th grader was participating in FUSE for two years. And it is a pretty big district. So that was where we grew initially. Now, as of this Fall 2018, FUSE is going to be in approximately 190 locations. Almost all of these are schools.

In terms of the number of kids participating in FUSE, it's about 25,000 students. And so the growth over the last couple of years has been really significant. It caught fire and has become more widely known. So, over the last two years, we have grown by more than 120%. As far as the source of such growth, there have been a number of factors. First, it seems like the schools have increasingly opened themselves up to different kinds of learning experiences and environments for kids. But we have also developed a number of funding streams, and I created a novel FUSE grant program where I give money to cover the costs of FUSE for the neediest schools, money that comes directly to me in terms of gifts and grants.

This is all done out of Northwestern, and it is interesting that we've done all of this without any marketing or sales. Of course, I go around and give talks and so does my project director. But there has not been any formal associated marketing or sales programs.

When a new school or district comes to you, do you now have set options in terms of classroom integration? Or is it still largely at the discretion of the partnering school or district?"

I would say it's somewhere in between. There are two general routes that schools take. Schools are not completely unique from each other. Once we get to know a district and form a partnership with them, we consider their schools and where there are similarities in terms of scheduling and curricula with prior implementations. This has spurred growth. The second approach is more intensive and represents what we have been writing about from the research side. We've been generously funded—especially by the National Science Foundation—over the past six years. With the second approach, we let individual schools and districts adopt the FUSE program, follow and analyze the adjustments they make, and then assess how our partnership has evolved to help them meet their learning needs. Of course throughout, we also work to maintain an integrity of implementation that aligns with the core principles of FUSE.

In terms of teacher professional development (PD), the program often asks teachers to reconceive the teaching process. Facilitating a FUSE class is not a "stand and

deliver" type of approach to instruction where the teacher is on one side of the room and the children are on the other?

Not at all. Initially, when things were just getting started, we would have a couple hours of teacher PD to introduce teachers to the program and take their questions. Over the years, our PD has developed into something a lot more substantive, especially in terms of articulating a pretty wide range of approaches to classroom implementation. Four years ago, my research team was in seven classrooms for the entire academic year, and the teachers participating in our study were different in the way they approached teaching, by design. What I mean by that is that we worked with the FUSE coach in that district to select teachers to participate in our research who had different approaches, so we would could learn how those differences might matter for what happens for kids' experiences. Consequently, through our research, we really gained a strong sense of the trajectory of experience for teachers with different approaches and styles. We've asked, and incorporated answers that we've found to questions like these: What were different teachers' initial struggles? What were their confusions? How does teaching in FUSE change over a first year for a new FUSE teachers? As you said, this is a very different way of teaching than the front of the classroom approach.

So, over the last three years, we have gone from a shorter half-day PD experience to what is now an experience that extends over two days and one that often includes not only teachers but school administrators and tech personnel in the school. These have been led—almost in every case—by my project director, Henry Mann. And teachers find it to be a tremendously positive experience. Frankly, teachers don't always have that positive of an experience with on-the-job PD. But we've had genuinely positive responses to our approach, because many of these teachers still teach in the more traditional way most of the day. Then they do this. And one of the things our research has shown is that participating teachers get the opportunity to see kids be very different learners than what they've seen before. Kids who aren't necessarily successful in the traditional classroom environment often turn out to be really successful in FUSE. And this is a really positive thing for teachers to see and appreciate firsthand.

NSF Project Information

Title: Scaling up an innovative STEAM (Science, Technology, Engineering, Arts, & Mathematics) learning environment through two partnership models with industry and schools (Award Details)
Investigator: Reed Stevens

Title: FUSE Studios: A New, Interest-Driven Model for Engaging Youth In STEM and Career Development Through Challenges and Partnership with Industry (Award Details)
Investigators: Reed Stevens, Kemi Jona

Title FUSE Studios: An Alternative Infrastructure for STEM Learning and Interest Development (Award Details)
Investigators: Reed Stevens, Kemi Jona

One of the things that successful FUSE teachers do—and we call them **facilitators** for this reason—is that they really help kids find the expertise in the room and reflect on whether they themselves are on a trajectory to developing it. The kids really push themselves to develop it, because it turns out to be a winning formula.

It's two-fold. First, a young person experiences the self-esteem associated with feeling like an expert for other kids, their peers. Second, kids get the experience of having to figure out who in the room can help them and not just assuming it's the teacher. These are both valuable experiences for kids moving forward in life.

How do you assess student success in FUSE? When you're talking to administrators, how do you talk about student assessment? If a school principal has reservations about how well FUSE will meet wider district standards and assessments, how do you and your the team address these concerns?

The first thing we do is to make a distinction between standards and assessments. We've had really good and positive conversations with school districts around standards. For example, we have a significant footprint in CPS, the Chicago Public Schools, and they have a district mandate that anything that comes in as science curricula (as FUSE did there) has to meet NGSS standards. Since we conceive of our work in terms of partnership, we work together to find a happy medium, one that meets the truly required standards of the district while also maintaining an integrity of implementation, so that a FUSE experience remains true to the core principles. What I've been happily surprised by is the amount of wiggle room that schools and districts will find in order to give their students this experience.

Here we also can go back to one of your earlier questions about integration. Because FUSE is flexible in terms of how it is implemented, different schools can fit it into their school day curricula in different ways. For some schools it's in science, for some schools it's an amalgamated STEM course, and for some schools, it's a technology course. All of these present different issues relative to standards and assessments. Of these different ways to fit FUSE into the school day, this last one, the technology course, often works the best because technology education in schools is often pretty far behind the times. I mean some schools are still teaching kids to use computers as little more than word processors, and the kids are light years ahead. So, there's a real opportunity for FUSE to provide a refresh in schools around a contemporary and compelling technology-centered course.

But returning to your question, and taking CPS as an example, teachers there are responsible for aligning the lessons to academic standards and we and they were able to demonstrate that alignment. This addresses the standards component. But in terms of assessment, familiar, uniform assessments just don't work in FUSE. The pathways that different kids take through this experience are far too varied and far less uniform than within a standard curriculum, so expecting a single right way that can be assessed across the board is not only unrealistic but antithetical to the program itself. In general, I would say teachers find, often through conversation with us, ways to assess that meets the expectations and rules of their school and district, while preserving the core qualities of the FUSE experience. I would also say that one of our successes has been with the conversations we have had with teachers and developing some real skepticism among them about standardized assessments. Maybe they had this skepticism all along, but with FUSE, they can see the real dangers of taking the one size fits all, impersonal approach to assessments. As I mentioned before, we've had success with schools finding some wiggle room in how they assess FUSE. One of the things we have been associated with has been the broad (and not always very well formed but important) category of what are called 21st century skills. FUSE excels here. We do really good with kids learning to collaborate, with learning to be adaptive and solve problems in new and creative ways.

Whenever a program expands as much as FUSE has expanded, there's always going be new challenges. What, in your estimation, are the main challenges going forward?

Over the years I've been in this line of work, I have seen so many innovative, well-funded educational research projects. But too often these projects don't last. Many programs don't sustain themselves after a few research funded years of innovation, and they do not continue beyond the initial enthusiasm of energetic professors and graduate students who go into schools for the duration of a grant. So for me, it was really important to create something that could be sustainable. That was one of the reasons why we really let schools come to us rather than the more familiar approach of going to schools and asking, "Will you let us try this in your school or classroom?" And with this approach, often researchers will pay teachers extra to be try their innovations. There are obviously good reasons to do that. But in my view, that model turns out to be less sustainable. So, we really thought about sustainability from the outset, and one of the things we talked about at the beginning was creating a program that is genuinely flexible and adaptable to local circumstances. And most of all, something that would provide kids with a different kind of learning environment, which we knew if successful, would resonate with teachers.

In this regard, Michael Cole, now a retired professor from the University of California at San Diego, has been an inspiration to me in the way that he coupled research and the development of a program. In his case, it was called the Fifth Dimension. And one of the things that Mike said in an early advisory board meeting was that one of the things he liked about FUSE was its "half-baked" nature. This got a laugh. Usually describing something as "half-baked" is a criticism, but Mike went on to explain that what he was referring to was the designed flexibility of FUSE, so that the program can be fitted to distinct contexts. His Fifth Dimension model was quite similar in this regard and has been one we've revisited and continued to draw inspiration from over the years.

So returning to your question about expansion, in the last few months, as my team and I have been out talking about next steps, here is part of what occupies our discussions. How do we balance the integrity of implementation so that core programmatic features are not compromised, while also allowing the program to be what it needs to be for the people who are actually using it and as it gets implemented further from our direct daily contact with those implementations? That's the key balance we are trying to strike. I think one of the challenges going forward will be bigger adoptions. Whole school districts may decide to adopt FUSE across all their schools. And then I think we will be interacting with a different institutional scale. And I hope it will work just as well. We've planned for it as a new challenge.

And this likewise connects to what we just were talking about with assessment. More broadly, how can we effectively coordinate with a wide range of schools, teachers, and administrators to document the positive and also the less positive things that are happening with assessment? This is particularly important, because it gives the whole community a chance to potentially rethink some of the questions and assumptions we have long made and operationalized about student assessment.

So those are the two things I see as core ongoing challenges: first, scale—even though the organic scaling we've been doing over the last few years has been going quite well. And second, assessment. I think FUSE has the possibility, as it scales, to disrupt the time-worn assumptions about assessment and to help education see that we need new ways to assess, especially in assessing what students can do, not what they can't, and in making assessment do the job it really should have been doing all along, which is to be formative, to shape future action and learning, not to be a sorting mechanism, as some educational scholars have described it.

This returns to one of the most compelling elements of FUSE—namely, how has the program changed teachers' perceptions of their roles in the classroom?

Yes, let me just say one more thing in this regard. I was a high school math teacher. You were once a high school English teacher. What really excited me as a teacher—and still does teaching at the college level to undergraduates and graduate students—is when you see your students really get into something in a deep way. And when that happens and you know you've done something to help make deep learning experiences happen, it makes teaching gratifying. And FUSE gives teachers a lot to work with in facilitating these kinds of experiences for their students.

← Learning Analytics Goes to School

How K-8 Teachers Are Using Virtual and Augmented Reality in Classrooms Today →

This material is based upon work supported by the National Science Foundation under grants 1837463 and 1233722. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Learning Trajectories for Grades 6-8 Rational Number Reasoning

An interview with Jere Confrey about her Gates Foundation and NSF-funded project to build and validate learning trajectories (LTs) for grades 6-8 mathematics around rational number reasoning.

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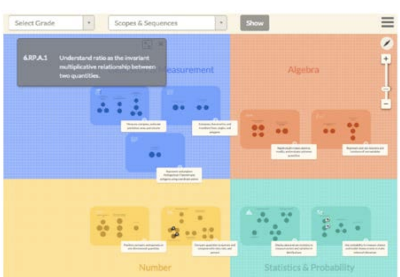
What is the big idea of your project work?



Our team is working on an interactive learning map in for middle school math. This work is part of our Scaling Up Digital Design Studies (SUDDS) project work, with funding from NSF and the Bill & Melinda Gates Foundation.

A learning map, in contrast to a straight disciplinary map, is a map that is based on research on learning and tries to delineate the landmarks/or obstacles that are essential to understanding a big idea. Our learning map helps teachers create personalized learning resources for students in middle grades math in a coherent way. It supports flexible grouping based on students' choices, paths, and performance.

What does the interactive learning map cover and how does it work?

Our middle school map covers 4 fields: Geometry & Measurement, Algebra, Number, and Statistics & Probability (see Figure 1). Within each field you see boxes, which we call regions or "big ideas" of learning math. There are 9 big ideas across the fields. If you click on a region label, you can see what it stan[…] Numbers, the two big ideas around middle grades are one-dimensional number (how do you locate[…] the number line, what's bigger/smaller, what's the order of fractions and decimals); and the second rate and percent. In Statistics & Probability, there is displaying data using statistics around centered variation, and probability and inference.

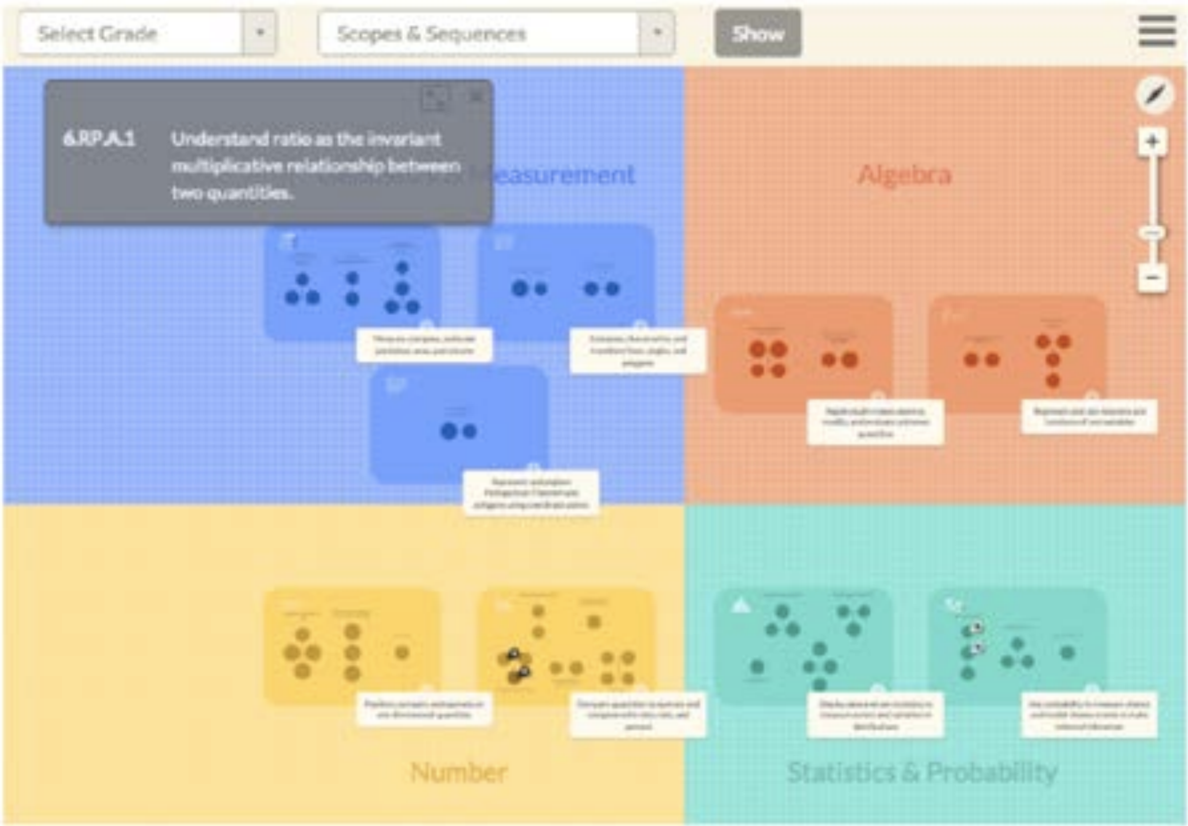


Figure 2. Middle school map covering 4 fields. Each field contains regions or big ideas, each of which contain clusters of constructs.

If you double click on a big idea, it zooms in and you can see circles that we call "clusters". The circles are constructs that go together to make up an idea. So if you look at key ratio relations, there's identifying ratio equivalents, finding base ratios, and finding unit ratios. The structure reflects that they first need to learn ratio equivalents, and then they can learn these other two in any order. The idea is that instead of big unidimensional learning trajectories, they are broken down into clusters. A learning trajectory at the level of a construct can still cross grades but they are more compact than in my previous work.

If you click on a construct within a cluster, like Identifying Ratio Equivalence, it will expand and show a window that we call a stack (see Figure 2). The stack is the delineation of the learning trajectory and shows that when you're learning ratio equivalence, the first thing you have to learn is that you can make more of something and maintain the same ratio, like in a recipe for lemonade that you double. When the numbers are even, it's easier for kids to do it than when the numbers are odd. As you go up the stack, you'll see that at 6th grade, students should learn all of these proficiency levels in that stack. If you click on CCSS-M at the bottom, it puts up the standards that are associated with this particular construct. And you can go the other way, too: when you click on a standard, it shows you what constructs it corresponds to on the map. Another major change from my prior work (turnonccmath.net) is that a standard can be associated with multiple locations on the map.

Figure 2. The Identifying Ratio Equivalence construct and corresponding stack and link to CCSS-M standard.

How do teachers use the map?

We think the map is useful to organize the mathematical space. We're designing it for teachers to use with classes, and home schoolers could also use it. One concern we have is that there's a drift on the web toward individualized learning and instruction. Our cyberlearning and science of learning community knows how important discourse and interaction are. So we are designing this to try to support teachers who want to do interactive classes but still respond to the diversity of needs among their students.

We also have a way that teachers can build a scope and sequence for the year based on which regions are taught or not taught, and in what kind of order, and then they can go in and order the clusters (see Figure 3). Below the clusters we don't let them order them because we want those things taught in a certain order as related learning concepts. From the concepts, we also link out to resources on the web. We are populating the map this summer.

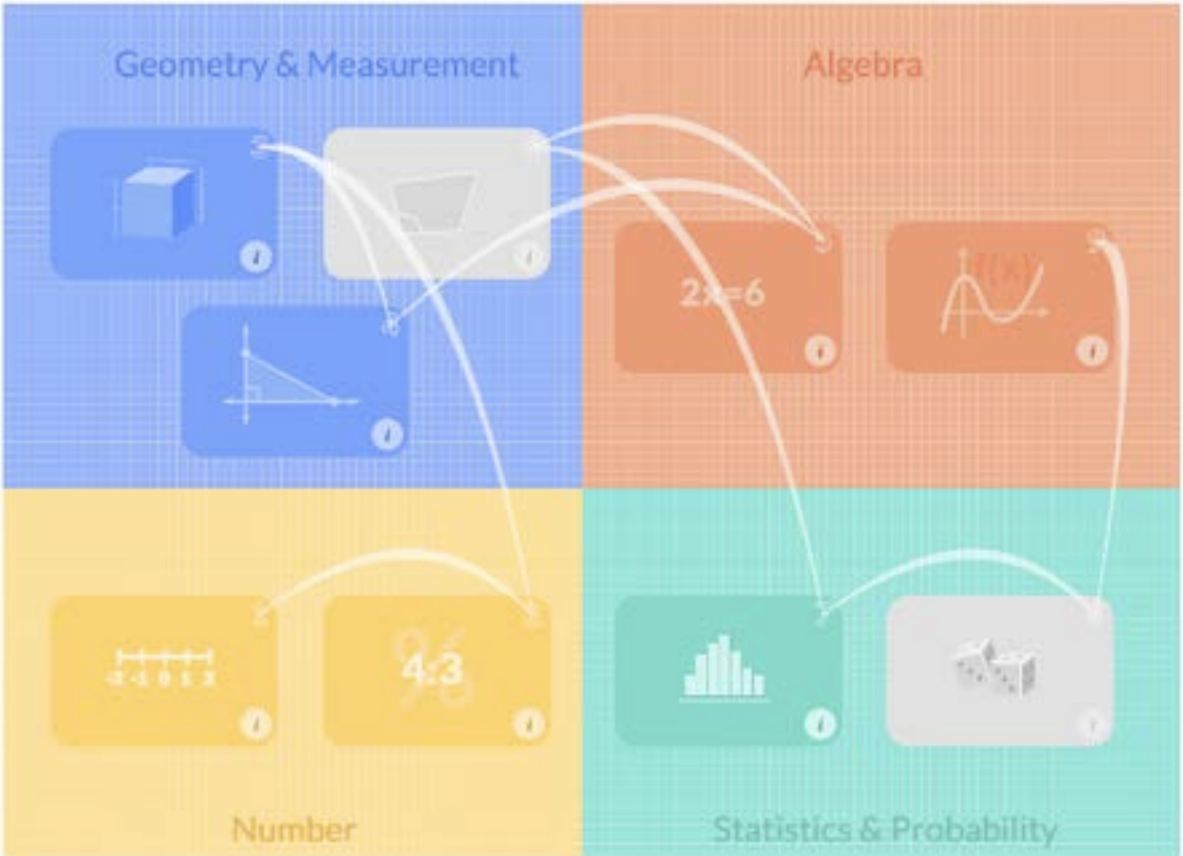


Figure 3. An example scope and sequence for a year that reflects what big ideas and constructs a teacher chooses to teach, and in what order.

So that's the notion of the learning map – being able to use web resources and getting teachers deep information about how kids think. In our NSF project, we are building diagnostics for each of the clusters so that when students finish a cluster, they can take an assessment and the assessment will give them feedback on how well they've learned the topics. Teachers can use this information to group students or students can use it to find other students to work with.

What do you sees as unique about your work?

I think of this whole thing as a digital learning system, and this is where I think the field's going to go. It's not complete now; this is really the bookends: The navigation and the information on the underlying concepts that kids need to learn and what it looks like when they've learned it. It also leverages visualization to make navigation of Common Core easy and intuitive. But you still need the middle part: how do you create a workspace where kids can use mathematical tools as they solve problems. All of that, and the backend analytics, would have to be built. But you're seeing two critical components.

NSF Project Information

Title: Completing, Validating, and Linking Learning Trajectories for K-8 Rational Number Reasoning Tied to the Common Core Standards

Award Details

Learn more about this work on the Scaling Up Digital Design Studies (SUDDS) project web site.

Investigators: Jere Confrey, Alan Maloney

← Interactive Robot for Learning Chinese

Making Microbiology Interactive and Available to Everyone →

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Interactive Robot for Learning Chinese

Based on a discussion with W. Lewis Johnson about his NSF-funded project to transform world language education using social robotics.

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The Robot-Assisted Language Learning in Education, or RALL-E, project, is designing a new social robot that has the potential to transform world language learning by giving learners new opportunities to practice their conversational skills.

The RALL-E robots are Chinese-speaking robots that create a safe environment for learners to practice their conversational skills. These robots create the experience of a conversation through a lifelike range of facial expressions and gestures coupled with innovative language acquisition-based dialog software.

Along with a cluster of cyberlearning projects that are exploring interaction with a virtual agent, this project is advancing our understanding of how modalities of interaction that get away from desktop, laptop, tablet and phone paradigms may engage social cognition in ways that strengthen learning. The RALL-E project aims to increase speaking competency in Chinese classrooms by providing students with a novel and motivating conversation experience. These robots will allow students to get the real

NSF Project Information

Title: EXP: Transforming World Language Education using Social Robotics)

Award Details

world experience of using a new language, without the anxieties that can come with using a new language, and empower teachers to bring the conversations they want into their classrooms.

PIs: William Johnson, Kino Coursey

Students are already playing with these robots in Chinese classrooms at the Thomas Jefferson High School for Science and Technology in Alexandria, VA. During a recent project-led focus group at Thomas Jefferson High School, students had this to say about the RALL-E robots:

"It was more interactive [than online courses and classroom activities] and… actually it's just more fun!"

"The facial expressions make it feel like you're talking to an actual person."

"If I make a mistake it's okay. I know that when I speak Chinese with my [in-class] speaking pal it's for a grade, but with the robot it's just practice where I'm free to learn and do whatever I need to do."

Thomas Jefferson High School for Science and Technology is excited to be offering this new technology to their students. Dr. Evan Glazer, Principal, says:

> "I think RALL-E has a lot of potential to build excitement for learning languages. Students have opportunities to practice their skills, and the robot responds to the dialogue as confirmation that he understands. The potential is great to support individual learning needs, particularly at introductory levels."

The RALL-E project is a collaboration between Alelo, Robokind, the Virginia Department of Education, and Curious Lab and is funded by a National Science Foundation Cyberlearning award #1321056.

Learn more about the RALL-E project.

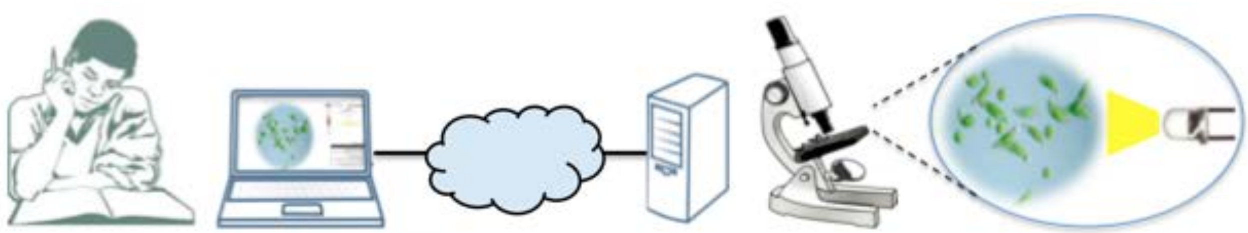
Image Credits: C. C. Ching

Making Microbiology Interactive and Available to Everyone

Back to Spotlights

An interview with Ingmar Riedel-Kruse and Paulo Blikstein about their NSF-funded project to build and evaluate a technological and curricular infrastructure to empower scalable, low-cost experimentations for undergraduates and K-12 students in the life sciences, combining them with computer models in real time.

What is the big idea of your project?



The big picture is: How can we make microbiology interactive and available to everyone? And how can we combine experimentation with computer modeling in real time? How can all ages, from child to adult, experience what microscopic life is like? Right now what we have in schools is microscopy, where students passively observe. It's hard to do experiments and for teachers to bring in biological organisms—harder than physics, for example, where you can put something back in a drawer at the end of the class.

So what we have been developing is different types of platforms to make easy two-way interaction between humans and microscopic organisms possible. We also believe that sensemaking is more powerful when experiments are tightly connected with models and simulations, instead of being separate activities are using the idea of Bifocal Modeling to combine our biological experiments and models in real tim example, we have an online platform where you can remotely observe Euglena cells swimming in a by streaming video. You can shine light on the small organisms using a virtual joystick control, and when the light hits the cells, you can see how they swim away, in real time. We use two cameras: one for the internal view into microscope where you can see the cells, and the other is the external “macroscopic” view where the student can see the light source. At the same time, we have a modeling environment that enables students to program a model to mimic what they just saw in the real world. By trying to “match” the real world, and realizing the differences between real and ideal systems, students dive deeper into the Euglena’s behaviors. This is all fully automated, almost care-free on our end. For a couple of days to weeks, the system just works on its own. The physical lab is 10 meters from where we are sitting, and anyone can join the lab online.

Who has used your interactive labs, and how have they used it?

We did tests with undergrad and graduate students initially, and a mini online course for 1-2 hours where students could do some simple experiments. We recently completed our first testing with about 100 middle school students across 8 groups in San Francisco. We’re also talking with schools in Oakland.

The primary experiment, as I explained, is that you see cells, you put light stimulus on them, you see a response, and then the system actually collects the data for you. It saves both the stimulus that you did as well as the images of how the cells reacted. Then you can go to another user interface where you can replay your data, and start analyzing your experiments—count how many cells responded, how fast they moved, and so on. We also have made a computer modeling environment where you can try to replicate the behavior of the real organism and change a few parameters—like how fast does the cell move, how strongly does it respond to light. You can do your experiment and then do your modeling, and compare the two side by side.

So our interactive biotechnology is enabling students and teachers to do some very convenient free-play experimentation that can eventually include all parts of science because you can explore, do guided experiments, make models, generate hypotheses (like “does the cell move faster when the light is on or off”), and make measurements to test your hypotheses. By having this all online, it takes a lot of the load off of the teacher because students can do experiments anytime, even in the evening. We see students logging in at crazy hours to see what is going on. They are really hooked! In the beginning, they are very playful, doing fun experiments. Over time, this playfulness evolved into more principled testing. They transitioned into behaving more like scientists. The technology enables it. Scientists also play and find things by chance; they don’t know, they have crazy ideas, and there’s a lot of creativity and exploration, especially in the early phases. Then they move into more rigorous testing. So one important aspect of the system is that is allows student to explore scientific discovery differently than what’s mandated in the “traditional” version of the scientific method. They can start playing around and overtime become more methodical—and the fact that they can interact with the experiments for several hours, anywhere and anytime, has a lot to do with it.

We’re also incorporating learning analytics to track what the students are doing and to learn about what they are learning, and have done interviews and recorded video of students engaging with the system so we can see how they behave. We also have other systems with different types of organisms and experiments that occur over longer timescales, and a maker project, which we demonstrated at Cyberlearning 2015, where children build a little microscope, attach a phone to the microscope to observe similar organisms, and the phone does the data processing and analysis.

Where do you see your work going in the future?

We see this as new technology that should really enable millions of kids in the future to do biology experiments in formal and informal settings, and a new window into learning research.

More generally, the distance between what kids do in science labs in schools and what is done in real science labs is greater than it has ever been. There are a lot of new things that scientists now have at their disposal and are using in their research, like computational models, automated data collection, image processing that can interpret results, and so on. A lot of new things that everyone is using. But kids still do the same stuff in school. They float bacteria in a petri dish and look at them for a couple of days. There are a lot of classic experiments that are like legacy there. But they are less and less interesting because there are lots of more interesting problems the world is trying to deal with. Even with the Euglena, there are a lot of real-world applications around contamination and pollution. There are a lot of scientific problems closer to real life, but kids don't have access to them because they are still stuck in 19th century style experiments.

The problem is that to bring more interesting experiments to schools is hard because you need a big infrastructure and the technical knowledge about how to maintain it, if that's even possible. Labs are very expensive. And we don't want to take 200 year-old experiments and put them online in a model. We don't believe that simply taking the outdated stuff we do in schools and packaging it in colorful simulations will do it. Our approach is to put today's experiments online—not just to cut costs, but because they are more interesting and would be hard to do in real schools because they are technically very complicated. Cutting costs is good, but sometimes it's not the main point. Let's bring the most interesting and complex stuff and make it feasible in schools. Let's stop thinking of "online" as a way to simply make education massive and cheap, but to make it more interesting, more complex, and enable children to learn things that were unimaginable before.

Also, there is a reason scientists do experiments: it's not just because they already know the stuff and they need to just run experiments. They are useful to brainstorm new ideas to find out new things. So we also try to keep what is rich about the experiment in this system, not sanitize it too much so that it doesn't look real. In real life, you never get a perfect result.

NSF Project Information

Title: DIP: Collaborative Research: Taking Hands-on Experimentation to the Cloud: Comparing Physical

When you move the joystick to move the light, not all of the Euglena go away from the light. Some just stay there and go in circles, some even go towards the light. We talk to students and ask, “Why is this happening?” Instead of avoiding that confusion, we engage students in conversation about that. They understand that maybe some of them are very old, they aren’t reactive anymore, maybe their sensor is broken, their eye doesn’t work any more, maybe they are starving; there is some natural variability, just like with people. Some people run faster, some are blind, and so on. The cells aren’t all exactly the same, and that is very generative. The notion that experiments have noise and are inexact is not something you should hide from students. You should actually make kids talk about it. They have very rich discussions, and that is really the spirit of the idea of Bifocal Modeling.

and Virtual Models in Biology on a Massive Scale
Award Details

Investigators: Ingmar (Hans) Riedel-Kruse, Paulo Blikstein

How do you work with teachers?

In the local schools, we tested a 1 hour 50 minute curriculum with sequence of student activities, questions, and pre- and post- test. We did a lot of co-design of the curriculum with teachers, and are refining them so teachers can easily enact them in a normal classroom. For this unit, we worked with teachers for about 5-8 weeks, showing them what we’ve created, and asking them what’s feasible.

In Paulo’s CAREER grant on Bifocal Modeling, we have also been codesigning units with teachers. We went to the school and talked with teachers about what topics they were covering, and a graduate student met with a teacher every week. They went through the topics she covered, picked a topic, and together codesigned a unit on polar and apolar molecules. The teacher picked an oil spill as a theme for the unit, around cleaning with detergents. The teacher was very much an author of the unit, and we learned a lot. We are also working toward making it easier for teachers to create and adapt content on their own in our system. Sometimes teachers will try things because they are a novelty, but if you don’t have them codesign and feel ownership, they’re not going to use it once you leave.

We try to take a layered approach where we start by working with one teacher, then bring in others and have them work together; the teacher who did the codesign can coach the new teacher. So in a school you create a small community of teachers who are well-versed. We try to get them to document what they do in a language that other teachers would understand. Eventually you try to run a professional development program where you bring in other teachers over a weekend. Hopefully at some point have a critical mass of people and materials that become part of professional development programs.

Are there things that CIRCL could be doing to help your work with teachers?

At our FabLearn conference, the participants are roughly half teachers and half researchers. Some teachers haven’t seen a researcher in their life! We have researchers and teachers presenting, and I think that helps teachers internalize the research language, and also helps the researchers. I think ideally it's great to have events where researchers and teachers co-mingle and both present to each other.

Can you say more about the cyberinfrastructure for this work?

Generally, bioengineering technologies are getting better and cheaper in terms of how much biology they can manipulate and measure, how they scale, and how they become higher throughput, so will become easier and easier to build systems and connect them to schools—similar to what happened with the electronics revolution and transistors and electronic circuits. The devices we have are most often used for diagnostics, and many things are being automated, so a student could use them to program and run their own experiments. One experiment might take a minute. And we have an asynchronous mode where you can program something and submit it to a queue to execute. So you could in principle do a thousand experiments a day on one machine. You can see how 10-20 subsystems, managed well, could service a substantial population across the world.

We have a very interdisciplinary group of graduate students in computer science, bioengineering, physics, and education working together to design and build these things. We make our code and building plans available in GitHub so that others can recreate them. The initial technology is just a good microscope; the basic unit should be cheap, between $100-$500. Then you hook it up to the web. We have 2 webcams, and external one and internal one, and an Arduino is actuating LEDs. If you just take the microscope away and put something else in there, controlled, say, by an Arduino, this could be a physics experiment. For example, you could put in a LEGO robot. We have a teacher coming to work with us over the summer on LEGO robots, so that kids in robotics classes could make robots like the ones we use to run our experiments but in a kind of mini-cloud, not even necessarily online. So this whole platform could be used in different ways for doing online experiments. All the hardware is off the shelf and the software is open source. We also have a mini server in the grant that can run in the school. But then the students can't use it at night or as easily run week-long experiments. For some things it might make sense to run the experiment at a university or company. But schools could run their own lab. There should be multiple infrastructure models.

In the end, it's not just about putting labs online. It's about labs with persistence, so you can go back to them, experiments that can be a week long, you can track what is happening. It's a different type of hands-on science that keeps the richness and authenticity of real science labs.

For more information

Biotic Games-Playing with Living Cells (YouTube Video of a talk)

Interactive Cloud Experimentation for Biology: An Online Education Case Study. Describes a cloud architecture for sharing and executing biology experiments in parallel, remotely and interactively, to lower the access barrier for non-biologists, enable discovery, and facilitate learning analytics.

Transforming Learning Technologies Lab

Paper on Bifocal Modeling

Riedel-Kruse Lab page

← Learning Trajectories for Grades 6-8 Rational Number Reasoning

Enabling Collaborative Science Learning Experiences on Mobile Devices →

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Enabling Collaborative Science Learning Experiences on Mobile Devices

An interview with Cathie Norris and Elliot Soloway about their NSF-funded project to enable collaborative science learning experiences on mobile devices.

Watch a 3-minute video about this work from the 2016 Video Showcase

What is the big idea of your project work?

The big idea is this transition from Web 2.0 to what we've been calling Social 3.0. Web 2.0 is support for asynchronous collaboration–whether it's twitter, or SMS, or facebook–where there's a post and a response to the post. What Social 3.0 is saying is that we need to support synchronous collaboration where people are working together in real time. For the classroom, synchronous collaboration really means supporting social learning – learning with and from each other. Coming up with a software environment that support kids in doing that is what we've been all about.

The Google Docs editor is the grandmama of this idea. It provides support when individuals write together. But if you're a 3rd or 4th grade student, Google Docs may be a little too much for you. We try to develop our tools for a K-6 grade audience. We've "collabrified" a range of productivity tools for this younger age group, including a concept mapping tool (WeMap), a " Know, What Do I Wonder About, What Do I Learn" (KWL) charting t (WeKWL), and a drawing and animation tool (WeSketch) and a very vanilla writing tool, WeCompose all collabrified in the sense that the Google Docs editor has been collabrified. We have several videos on YouTube of these tools in action.

During the 2014-2015 school year we offered the collabrified apps written in "native" code – one for iOS (e.g., iPads) and one for Android devices. Using some Google infrastructural tools — protocol buffers — were able to make the different, native apps work with each other, e.g., one child could be using an iPad in WeMap and another could be using a Nexus Android tablet and they both could work together. Pretty nifty.

But, for 2015-2016 we have re-coded everything from the ground up in HTML5 and now the apps are truly device-agnostic! HTML5 is in effect revolutionary; it enables curriculum developers to create computer-based learning activities that will run EVERYWHERE, e.g, in heterogenous BYOD (bring your own device) environments. That's another story.

What schools and other partners are you working with?

We've been working at St. Francis Catholic school for three years, with the same teacher in science. She uses a project-based, inquiry-based curriculum, and uses the tablets and software almost every day. She is an early adopter; she can figure out how to use it. We're also in first grade in Plymouth-Canton, MI, and second grade in Oakland, CA. They've been using it for a year, but not every day. In all of these schools, we've gone in with the software, but not with curriculum. While we talk and think with the teachers about how to use the software with their curriculum, there is still a barrier — nay, a chasm. How do the teachers come to see how they can use the technology as more than just a nice-to-have, as an add-on?

We also wrote a joint paper with the Michigan teachers for a conference. And at the last ISTE conference in June, we had 100 teachers and others at a workshop that we gave on the software. We had a lot of interest, including from the Chromebook people. Although the current project started with a focus on iPads, we are about to release a version of the software that runs on Chromebooks. So we're very excited about that and think we'll have more uptake. The teachers we've talked to also liked the idea of being able to collaborate between schools.

What have you learned about collaboration in the classroom?

There needs to be a good reason to want to collaborate. Talking "collaboration, collaboration, collaboration" is the wrong language. The right language is: What kind of inquiry or writing activities do you want to do in the classroom? Schools don't want technology – schools want curriculum! WE talk techie; TEACHERS talk activities.

It's even more complicated! Educators don't often really understand "synchronous collaboration" means. We know that in general, teachers say

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Title: RAPID: Enabling Collaborative Science Learning Experiences on Mobile Devices

Award Details

they want students working collaboratively – they want to facilitate social learning – but in many cases they don't really mean collaboratively, but rather mean cooperatively. They want the students to work together to cooperate on a project by dividing up the task so one does this part, and one does another part. But the students aren't really coming to a common understanding of what it's all about; each does her or his part. THAT is cooperation – not collaboration – according to Roschelle and Teasley.

Investigators: Elliot Soloway

For example, we saw a teacher asking 1st graders to come up with all the words they could think of that end in "ay". Four of them around a table start with a three-letter word, like "pay", "say", "may". Then one of them thinks of a four-letter word like "play", and others will chime in with "clay" and so on. They tend to feed off each other and are having a good time, but they are just cooperating with each other to do a task. In contrast, we were working with 6th graders who were trying to build a model of what happens with molecules when they get heated up. As you add more heat the molecules move faster, and then they escape as gas. When two or three children are trying to create an animation of this phenomena together, they are really talking intensely to each other – they are collaborating to create the animation that reflects their common understanding. Compare the 6th graders efforts to those of the 1st graders: the latter were almost more competitive than cooperative at times!

Are you helping the teachers define more collaborative tasks?

Yes. And it's really hard to come up with a real task that is collaborative and will force the kids to come to that common, shared understanding, as opposed to simply cooperate while working together to finish something. We've found that collaboration also varies depending on the abilities of the children. When you have very high ability children, your task has to be sufficiently difficult to push them to need someone else's suggestion or input. If the task is too easy, they don't even want to be bothered; they don't want to waste time listening to somebody else.

But we have seen and some recent data support it that lower achieving children really appreciate the help from others and benefit from someone else's ideas. We had some groups that were reading an e-book together, and then were supposed to be writing an essay based on what they had read using our collaborative writing app. One of the girls said that her partners told her to write longer sentences that were more descriptive, with more adjectives; she tried that, and thought that her writing was much better. This was in a 4th grade urban classroom. With the same task in a suburban classroom of real high-end kids, they didn't want to collaborate. They didn't want to use the software together. They could write their outline, get all their images, and write their story without working or talking with others. They thought that having to collaborate on it was more of an inconvenience than an asset.

What these stories suggest is that the nature of the task must truly require students to work together – to engage in social learning, to engage in synchronous collaboration. So, for example, you might change the task so that the students don't already have all of the resources they need. That's what teachers have to be mindful of. The task has to be sufficiently challenging for the students so they really benefit from working with someone else, getting some ideas or opinions from other people.

So how do your collaborative apps help?

In the case of 4th graders, there are typically 4 of them sitting around the table. Instead of all 4 of them trying to crowd around a device, they each have their own device, sitting in their own chair, and whenever anyone writes something, it appears immediately on the screens of the others. All of them see it at once. It gives the kids who don't talk much an equal opportunity to have their input seen. If there were only one device, then, the person who has the keyboard is going to be in control, and the rest tend to sit back and say "let it be". Here, every student has a device and an equal opportunity to have a voice. What the teachers say is that when the children work together, while high-achieving children may almost be experiencing a ceiling effect, the lower achievers are "coming into their own voices."

What are you struggling with now?

Therein lies the rub: We need help in writing this curriculum. It is so hard to write these tasks. You have to take the kids into consideration, the content into consideration, the technology into consideration. And you have to take the time of year into consideration: In September, the kids don't know how to argue, how to resolve conflict – how to engage in social learning! You can see them getting angry and frustrated with each other. But by April, they've learned how to negotiate. As Jeremy Roschelle and Stephanie Teasley write about the collaborative discourse frame in The Construction of Shared Knowledge in Collaborative Problem Solving, the collaborators talk a little, they hit an impasse/a problem, they they resolve the problem, and they start all over and repeat that process. But in September, the kids don't know how to do that yet. So the tasks have to change over the course of the semester. Holy Toledo! Developing good collaborative learning activities is hard stuff!! The teachers start out excited, and then over time we get pushback from them because it's really challenging and not obvious how to do create those activities and scaffold the kids in developing the collaboration – the social learning – skills. Sigh.

We really need curriculum people who will go into the classroom, use the technology, and learn and feel how this technology goes. There need to be materials to help kids understand community and discourse in the classroom. Unless you're one of those higher-level Cyberlearning INDP grants, you may not have the money to develop those kinds of materials for the ranges of classes. We'd really like to see a renewed community effort to create curriculum where learning activities are plentiful, on computing devices, BYOD or otherwise.

Principled Assessment of Computational Thinking

An interview with Marie Bienkowski, computer scientist and deputy director of SRI International's Center for Technology in Learning, about the applying evidence centered design (ECD) to create assessments that support valid inferences about computational thinking practices.

Back to Spotlights

What is the big idea of your project work?

Our work focuses on a principled approach to designing assessment tasks that can generate valid evidence of students' abilities to think computationally. Assessing computational thinking broadly is a long-term goal, but for practical reasons, we've begun by assessing computational thinking instantiated in a particular course, Exploring Computer Science (ECS). What is unique about ECS is that it has a focus on creating equal access to computing for students who are traditionally underrepresented in the computing workforce. ECS is typically a 9th or 10th grade course, and you can imagine a pathway through high school for computer science which is ECS, then Computer Science Principles (CSP), the new advanced placement course that was launched this year, and then the regular AP Computer Science A and B. Alternatively, students could take ESC and CSP to get a general overview and good exposure to computer science concepts along with some practical skills in programming. We do get asked the question a lot, "Where is your assessment of computational thinking?" The answer is: it's hard to assess that independent of a pa[...] curriculum or module or lesson.

The other big idea of our work is that we collaborate with the curriculum developers, who are staunch advocates of equity. Jane Margolis wrote two books on equity: Stuck in the Shallow End: Education, Race, and Computing and Unlocking the Clubhouse: Women in Computing and she influenced the curriculum authors, Joanna Goode and Gail Chapman. They made it very clear in the beginning that they wanted us to build assessments that would push students to do more critical thinking and focus on practices as opposed to rote memorization—in other words, to help drive the values they're trying to teach in the curriculum. They were adamant about no multiple choice; only items that made you think, explain, understand, and do reasoning. We ended up moving toward measuring constructs that the field calls computational thinking practices, which you might think of as a subset of computational thinking. The practices are the "do" part of computational thinking (just as concepts are the "what I know" and "what I do"). The computational thinking practices were what they wanted us to focus on for measurement of learning in ECS.

How did you identify the computational thinking practices?

We ended up adopting the computational thinking practices of CSP, which was developed by a community of K-12 and college instructors in conjunction with the College Board. CSP was developed to address a lowering enrollment in computer science, which was often seen as "just programming." The computational thinking practices in CSP include:

- Connecting computing to other disciplines
- Creating computational artifacts
- Abstracting and modeling
- Analyzing computational problems and artifacts
- Communicating
- Collaborating

How did you develop your assessments of computational thinking practices?

We began with our typical evidence-centered design (ECD) process, where we do domain analysis and domain modeling, and articulate the assessment argument, implementation, and delivery. So it's kind of like a software development process where you have your requirements, identify the constraints you're working with, build out the skeleton, implement it, test, and iterate. By instantiating these computational thinking practices in a particular curriculum, like ECS, you can do measurement.

In our 2015 report, Assessment design patterns for computational thinking practices in secondary computer science: A first look, we walk through our domain analysis and modeling process and describe how these computational thinking practices play out in sample curricula. We describe the sources we used to do the domain analysis, unpack the design patterns, give examples of what's an observation and what's a work product, and so on, so you can understand ECD a little more. Our focal knowledge, skills, and abilities (focal KSAs) are mostly abilities, since we focus on practices. Then we move into how this would play out in other projects, such as the the computational thinking activities in the Computational Thinking in STEM (CT-STEM) project at Northwestern University, and curriculum for Scratch, Alice, and AgentSheets. Do the focal KSAs from our design patterns map to these as well? CT-STEM looks at computational thinking in different courses in high school like math, science, physics, and chemistry; our design pattern on "analyze the effects of developments in computing" is applicable there. We also have a design pattern "analyze computational work and the work of others". When you're reading someone else's code, trying to find a bug, that's what you're doing. In the Scratch environment, they encourage kids to reuse and remix others' code, which involves doing analysis of computational work. We could instantiate our "abstractions and modeling" design pattern to produce assessments for Agentsheets, and our "design and implement creative solutions and artifacts" pattern for making a game in Alice. These are just a few examples of how you can measure things that experts say are important about computational thinking practices in the context of different curriculum.

How do computational practices play out in the ECS Curriculum?

There is a lot of focus in ECS curriculum on problem solving. But a lot of ways to get kids interested in computer science are more about creative expression: We have them build a blog, tell a story, make a character dance on the stage. So what we've tried to do is to walk the line between solving a problem and designing something; creative design and creative problem solving. Sometimes you don't have requirements for an artifact that are based on something the user needs; you just want to design something to have creative expression.

There is also a focus on collaboration and communication. Collaborating with peers on a computing activity involves things like "developing a shared understanding of the problem and requirements" or "understanding and valuing multiple perspectives on a problem and its solution". Those are things specific to a design and problem solving activity. We also have students using collaborative tools like Dropbox, Google Docs, and techniques like peer programming and code reviews. Similarly, with communication: can students explain why they took a particular approach or use different representations (like a narrative or a storyboard) to describe their code? We hope that teachers might look at these and come up with ideas about what productive collaboration and communication might look like.

How has your work evolved and what is unique about it?

We started by planning for the assessment development with the ECS authors, then built and tested (multiple times!) paper and pencil assessments. Now we are putting the assessments online as part of our work with the CS10K Community of Practice to make them more available to more students. Teachers increasingly want their students to practice taking things online because of high-stakes tests. The CS10K Community provides a rich array of resources for teachers, including our assessments. And we are using the assessments to study implementation: how do different implementations of ECS affect student outcomes?. Generally when people do studies of computing education they look at things like whether the students are more interested in computing or see themselves as a computer scientist. We are really interested in using these assessment measures to look at things like the impact of teacher training and experience on student learning.

How do you work with teachers and students?

We did codesign of the items with the authors of the ECS curriculum to begin with. With our items, we try to be very careful about the equity issue, for example, not writing about things (like an iPhone) that only a special class of people would have access to. The curriculum authors had a lot of experience with that, working with LA Unified. So they were very sensitive to those things, and gave us feedback along the way.

In piloting, we started with cognitive think alouds with students as they took the assessment. Then we had students in a class take it, and asked teachers to tell us how they thought their students would do for each item. We wanted to see what teachers expected students to do after they had taught the content. And then we scored the tests and modified the items based on what saw in the scores. Scoring isn't easy, because the assessments are scenario based—just reading their handwriting can be tough to do! We also had some IISME teachers work with us over the summer.

Now we've had thousands of students use the assessments – mostly students in California (Santa Clara and LA), and piloting in Chicago and Boston. It's really exciting. We had a moment of debate where we didn't want to release the assessments widely—we just wanted to use it for our research purposes–but then we decided we'd license them for use by any teacher using ECS.

The other thing is that you don't just write the assessment. You also have to write the rubric for it. That's another thing where looking at the student data helps you understand what you should actually count as evidence of a correct answer to the question. That went through refinement as well. The package that teachers get now are the assessments and the rubrics.

NSF Project Information

Title: Principled Assessment of Computational Thinking (Award Details)
Investigators: Eric Snow, Marie Bienkowski

Title: Computer Science in Secondary Schools (CS3): Studying Context, Enactment, and Impact (Award Details)
Investigators: Eric Snow, Marie Bienkowski

Title: CS10K Community of Practice (Award Details)
Investigators: Melissa Rasberry, Eric Snow, Marie Bienkowski, Kathleen Perez-Lopez

More broadly, we're looking at how teachers who are new to teaching computer science find evidence of student learning throughout the course. Do they develop their own rubrics? Give assignments that are more challenging? Look at what kids are doing when they are pair programming? There are all kinds of ways of looking for evidence of learning in a course.

Any closing thoughts on what you've learned?

I think that the biggest thing is that the field still hasn't cracked the nut of what is coding vs. what is computational thinking. I think we could still devolve into that we're "just teaching coding." So Florida, in March 2016, voted to approve a proposal that would allow coding classes to count for foreign language credit for high school graduation. We still don't have a good sense of what does it really mean to think like a scientist or think like an engineer. How do you approach a problem computationally so it can be solved, and then understand what are the big ideas in computer science? What are the contributions that it's made? I think a great book on the key ideas is one written by computer scientist's themselves: Computer Science: Reflections on the Field, Reflections From the Field.

There are all these different ways that computer science has impacted us, and we're not communicating that well to kids. Somebody said that it's easier to understand what an engineer does vs. a computer scientist because everyone has gone to IKEA and put together a piece of furniture!. Well, maybe. So people have been trying to make definitions of what computer science is and what computer scientists do, but he point that we make is that when you have to measure it, you have to be really clear about what it is.

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The Invention Coach

An interview with Catherine Chase, Assistant Professor of Human Development at Teachers College, Columbia University. Dr. Chase studies how exploratory learning activities impact student learning, transfer, and motivation, largely in the context of STEM education.

Back to Spotlights

What is the big idea of your project?

How do we we help students transfer, in a flexible, adaptive way, what they are learning in school to novel contexts and situations? Our project focuses on transfer of concepts at the intersection of math and science, and one thing that we've found to be very successful at promoting this type of transfer is a method we call "invention" (Schwartz et al., 2011).

Invention is an exploratory task where students engage in inventing conceptual ideas through an exploration of data, often contrasting cases. Contrasting cases are examples that have many similarities but a few key differences that relate to deep principles and conceptual ideas. By contrasting the cases, students come to notice features that are important to understanding, but may not be obvious to novice learners.

As students explore the cases, they are asked to "invent" fundamental equations such as those for density or speed. The process of inventing or even attempting to invent equations on their own (even if they fail) prepares students for additional learning. After the invention process, we follow up with expository instruction (i.e., lecture) on a topic important to the concept, such as ratio.

We are currently building the Invention Coach — a system that guides and scaffolds students throu messy and iterative process of Invention. The picture below shows the Invention Coach's main inter this screenshot, a student is working to invent an index of “clown crowdedness,” which is a proxy for density (mass/volume).

Invention Coach Main Interface. The goal of the task is to invent an index of "clown crowdedness" for each of the buses in the contrasting cases (A). Students receive support from the Coach (B) in the dialogue box (C), and input their ideas into index generation spaces (D). Additional student-led actions (E) include accessing the calculator (F), taking notes in the notepad (G), reviewing the rules (H), or soliciting help from the coach by clicking "Help!" or "Submit Idea."

How do you use cyberlearning in your work?

Prior classroom studies with paper-based invention activities show that the process of invention is really successful in promoting transfer. The cyberlearning part comes in with the technology we are developing to support the learning. Invention works well for promoting understanding, but students often need one-on-one time with a teacher or facilitator to engage in productive invention. Unfortunately, it’s not possible to give a teacher to each student in a classroom to support the process. Our project is working to create a technology that can reduce the demands on the teacher by providing individualized and timely feedback to students throughout the invention process.

Before building our technology, we wanted to know what a human would naturally do to promote transfer. We started by observing the guidance a human invention coach (a teacher) naturally gives in one-on-one invention tasks with students as the students invent formulas for density and speed. Our initial research showed human invention coaches did help students learn (Chase et al., 2015) and that much of the work the coach did during the task involved asking questions and not giving answers. In fact, the more explanations a coach gave, the lower the transfer test score for the

NSF Project Information

Title: EXP: Developing a tutor to guide students as they invent deep principles with contrasting cases (Award Details) student. One might think that a human coach gave explanations because a student was struggling, and perhaps it was a poorer student to begin with and thus the lower scores aren't surprising. However, our analysis showed that frequent explanations were not related to how a student was doing on the task, and that those explanations hurt the student's transfer. It may be that the explanations "cut short" the time the student spends exploring and generating ideas, so the student doesn't do as well on the transfer task.

Investigator: Catherine Chase, Vincent Aleven

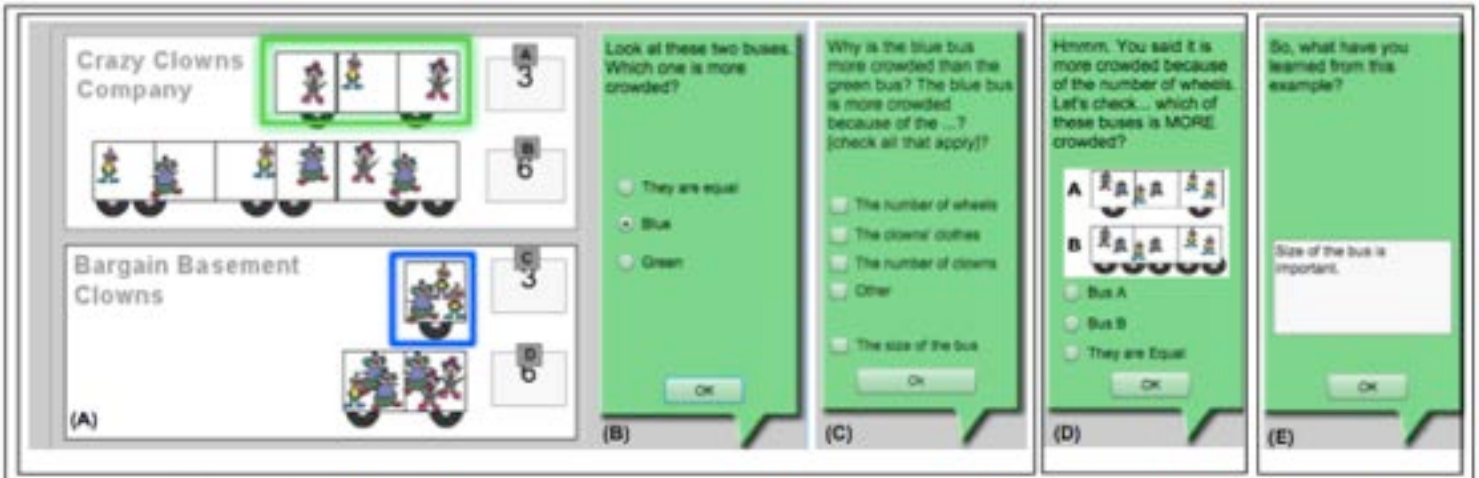
Our initial work helped us understand the human expertise we needed to include in the technological Invention Coach. Now we are working to develop that Invention Coach to support all students in the classroom so they can engage in a productive exploration and invention experience.

One of the design challenges we face is that we are essentially developing an intelligent tutoring system to scaffold the solving of ill-defined problems whereas most intelligent tutoring systems focus on well-defined problems (often in algebra) with clear steps to get to the answer. In our ill-defined problems it's not clear what the goal is nor is it clear exactly what the path is to the goal. Thinking about how technology can scaffold students through that process without overly guiding is one of the critical challenges of our work.

Tell me more about the Invention Coach and what it looks like

The Invention Coach is an exploratory learning environment that follows a student's trajectory through an invention task and provides adaptive feedback and scaffolding to help them engage in productive exploration to prepare them to learn from later expository instruction (Marks, Bernett, & Chase, 2016). We have designed the initial prototype (see figure above). The software gives students an invention activity and the students can ask for help, submit their solutions, and get feedback along the way. We've created a few different kinds of interactive modules that focus learners on diagnosing their own errors and thinking deeply about these concepts. Some modules focus learners on comparing specially designed contrasting cases. In the literature, there is a lot of research showing the benefits of compare and contrast activities for helping learners focus on the deeper features that novices often overlook.

The image below shows the "feature contrast module" where students are asked to compare the highlighted green "Crazy Clowns Company" bus with the highlighted blue "Bargain Basement Clowns" bus, to help learners realize that space (the bus size) is an important feature of density (e.g. "clown crowdedness").



Feature Contrast Module. This module first highlights a key contrast of two buses (A), asks the student which bus is more crowded (B), invites the student to identify which feature causes one bus to be more crowded than another (C), problematizes misconceptions through additional contrasts (D), and elicits open-ended reflection on what the student has learned (E).

Other modules focus learners on explaining their solution as, through the process of self-explaining how they arrived at the solution, kids often identify their own errors or notice gaps in their understanding and seek to fill them. The guidance provided walks a fine line between guiding but not "spoon feeding" them as this cuts off the exploration process. In general, the feedback the system provides attempts to problematize students' solutions, contradicting what they've done or pointing out errors in their reasoning, rather than giving direct feedback.

If we walked into a classroom, what would it look like to have students using the Invention Coach?

We're gearing up to do our first classroom study with the Invention Coach in the Fall, but right now, students work individually with the computer. As discussed above, there is a mentor character on screen that guides them through the process and provides hints and feedback (see first figure).

Invention can be pretty frustrating, because it is a very novel task for kids and it's also an iterative task, where students frequently fail to come up with the right solution. However, in our studies, we often see kids having "Aha!" moments when they come to discover critical pieces of a sensible solution. Or more often, this happens during later expository instruction when they realize the sophistication of the canonical solution. For example, after attempting to invent a ratio-based equation (Density = mass/volume), one student said during the post-lecture on ratio "Oh! Now I finally understand division!"

In the future, we are open to the possibility of students working in collaborative pairs and are currently toying around with ideas for how to do that. David Sears has done some work with Invention and found that it's much more productive when students work in pairs. In our work, they are paired with a computer-based coach. Supporting students working together may lead to more discussions, argumentation, explanation with a live partner and could be future work.

I'm also interested in developing more teacher-focused technologies that would engender classroom-based discussion around the kinds of mathematical models that kids are inventing and building. I want to understand when those models are effective or ineffective.

Is there more about the project you would like people to know?

People can visit our website to learn more or see our publications.

Further Reading and References

Chase Lab Web Site

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This material is based upon work supported by the National Science Foundation under grants 1837463 and 1233722. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Curriculum + Community Enterprise for Restoration Science

Back to Spotlights

An interview with Lauren Birney, Assistant Professor of STEM Education at PACE University and Director of The STEM Collaboratory NYC™. Dr. Birney leads the NSF-funded CCERS project, which connects teaching and learning to the restoration of New York Harbor to create enhanced learning and life outcomes for students historically underrepresented in STEM fields. The $5M, 3 year project connects teachers, curricula, technologists, developers, and scientists, with the restoration of New York Harbor as its platform, to create enhanced learning and life outcomes for students historically underrepresented in STEM fields.

What's the big idea of your project?

The big ideas are the model, the curriculum, and the platform. The project is creating a collaborative model of 10 independent institutions working together to create a curriculum and digital platform to give students the opportunity learn about STEM as they participate in a real research project to restore over 11 million oysters to the New York Harbor. We have a brochure that gives a nice snapshot of the partners and what each partner is doing.

The curriculum, which being co-designed by teachers, scientists, and curriculum developers, is bei implemented in the New York City public schools, the largest school district in the U.S. To me, the n important component is the lasting impact, the sustainability of that impact, and integration within t community. It's a wonderful opportunity and has become a signature grant for New York City. If it can be done here in this large city, it can be replicated at different scales and different locales – like in Australia with koalas, or with fish in Finland. It's kind of like the song New York, New York – If you can make it there, you can make it anywhere. That should be our theme song!

What is the biggest success you've had in getting people to work together?

As scientists and researchers we're often so involved in our own realm. That is definitely one of the challenges we face: How do we bring people – who have full time jobs already – together on a project and have them work at capacity. You have such a short time from when the grant is given to achieve what you want to achieve. I was talking with some NSF program officers last week and they asked a similar question: How do you give your partners the training to work together well?

The integral component is communication and collaboration. Without strong communication, people can feel left out, and there can be a lack of understanding about the trajectory we want to move in. I have a natural affinity for collaboration and bringing people together; I'm a connector. I try to make each person feeling very important and extremely valuable. I love to read books about how CEOs run companies, and what works and doesn't work. A cadence that seems to work is where you do push people beyond their capacity but still understand and appreciate the context they work in. Everybody in this project was chosen because they were extremely dedicated to their individual craft and invested in the project outcomes. You just have to be aware of where people's capacity is, and push in the right direction.

So my biggest daily challenge is to make sure that the oars are rowing toward the same goal and we're all rowing in unison. It's not always easy with all the entities in different locations: Columbia is all the way up on the Upper West Side; Governor's Island in one location, the New York Aquarium is over on Coney Island, then we have the University of Maryland, and some researchers on the west coast. Since we're not physically in the same place, it's really important that we connect. We do that through weekly and monthly meetings by phone or video conference with all the partners, and visiting sites. We have two design weeks together each year so that all the team comes together. We do some team building activities, like bowling or rock climbing, so people get to know each other. You have to make sure that everyone buys into the ideas and concepts as you row forward. I also have a project manager who reports to me on what's happening, and helps with the day-to-day management. You have to have a project manager for something this large.

Can you say more about the digital platform for teachers that you're building?

The digital platform was initially being designed by a team at the University of Maryland, and then we brought in private company called Fearless Solutions to move it forward faster. The project was originally proposed to be 5 years and they gave us 3 years instead, so we had to ramp up quickly. The platform supports the core communication piece: All the lesson plans, data for teachers and students, data that is uploaded from the field through an app, and data uploaded in the classroom through a web interface. Because this is an ITEST project, the communication piece is paramount. The digital platform was just completed and is usable. To me it's key to the project: once you design the platform and it's functional, you can learn how it works best with different settings – even outside of the current project. The other day, I spoke with a physics professor at Berkeley who was interested in working with the platform. The hope is that it can be used in other content areas and projects eventually.

A lot of detail and work has gone into this piece. As with the curriculum, in designing anything within the project, we have scientists, educators, and academicians involved. We approach design by listening to what makes sense and what actually works from each perspective. One you field test it, before you know it, the app is obsolete. So we backed up and said let's do the digital platform first, and the app will function off the digital platform. But having students be able to enter the data — like pH, acidity of the water, growth of the oysters, and video from different locations – all of those things will be usable by all the schools throughout New York City. If you can't get to the water's edge, you'll still be able to have access.

How many teachers are involved?

Right now we have 52 teachers. We accept 30 middle school teachers per cohort, and each has 30 students. The first cohort of teachers started in February 2015, and we start a new cohort every February. It's a 1-2 year program, so the first cohort is in its second year.

The teachers usually visit the restoration station, which is placed into the harbor, 3-4 times/year. We do Saturday teacher training for those teachers, to show them how to take measurements and how to build the restoration station themselves. The field science component involves scientists coming out to help explain concepts. Sometimes science is scary, so that's a barrier to overcome. We have trainings with scientists from all over who over come and talk to the teachers about the content so they feel comfort with the environmental restoration piece.

NSF Project Information

Title: Curriculum and Community Enterprise for New York Harbor Restoration in New York City Public Schools (Award Details)

Investigators: Lauren Birney, Meghan Groome, Denise McNamara, Jonathan Hill, Robert Newton

We didn't limit the people applying to the program to just science and math teachers; we allowed English language arts (ELA) and social studies teachers to apply as well. If you want to study the geography of New York harbor, there should be a way to integrate the curriculum into your classroom. We also wanted to connect people at school sites so there is a sense of local support. If you have a solo teacher working at a site, the project will more likely fail. So we ask for 2 people at each site, and the administrator has to buy into that. The teachers get a stipend, and the school gets one to purchase equipment that supports the type of curriculum they're implementing. In June, we do a big event on Governors Island where the teachers and students presents their research. We have oysters they can eat, but they aren't from the harbor; you actually can't eat the oysters from New York Harbor – until maybe 2030!

Are you thinking this as a Design Based Research (DBR) project in action?

The original design was to have a 1-year ramp up phase with more time for design, but we really had 5 months. So we designed everything at the same time as creating the implementation and finding the challenges. It was almost developmental evaluation; conducting research at the same time doing the development. We had 3 goals: for students to become more interested in STEM, for teachers to integrate STEM in their classroom, and to develop the actual collaborative model about what makes it work and function right. And one of my long term goals is to create a San Francisco Bay project, so maybe we'll have an opportunity to collaborate with SRI and CIRCL there!

Can you tell us more about the curriculum piece?

We have a design team that includes field scientists, curriculum specialists, and teachers who help with both the design and testing in the classroom. As curriculum becomes apparent, they implement various lessons plans and tell us what works and what doesn't. So the curriculum gets vetted on the front end early on, and works in unison with the field science piece. I was a biology and chemistry teacher for 20 years, and the idea of kids being able to go out in the field, actually produce things and try things out, and bring them back to the classroom to share with their classmates is super important. They learn what research looks like. As we design curriculum, that's paramount: What works, what's the research component, what does data look like, creating tools and skills for kids in the field and in the classroom, and having them actually do things. It's near and dear to my heart.

The curriculum is designed around science, but there are ways that non-science teachers can support the science component—for example, by doing a report on the geography of New York Harbor and how it relates to the measurements and the surrounding community.. The global science, integrative science pieces are being integrated in the ELA and social studies areas. What kids are doing in science shouldn't be totally foreign from what they're doing in these other areas. If it's' being done across the board, it makes more sense to the kids. So that's what we try to do with the curriculum.

Is there a citizen science or a smart and connected learning piece?

Yes. The central idea behind the Billion Oyster Project was put the oysters into the New York Harbor to make the water clean and support the Clean Water Act. We want to get the community and parents involved in ways that feel meaningful, so we opened up a citizen science piece of having them go out into the harbor and participate in restoration. In a summer camp, the kids also designed apps that were integrated into the oyster project. The kids love the coding piece. We're bringing in environmental policy, too – PACE Law School is going to be a part of this. The project has gone in the trajectory of Smart and Connected Communities for Learning, bringing these various entities together to make this a smart community that's not just solely education based or solely science based. We can make change happen by changing people's views, making curriculum and technology interesting for kids, and through environmental law and policy.

We had the devastating superstorm Sandy that wiped out Staten Island. So there's a big push from the EPA –a 60 million dollar grant to design a coastline which will use oyster shells as a substrate so that the tidal flow coming in like that won't happen again. A component of that grant is an educational center offering opportunities for community members to participate in the citizen science piece. We collaborate with the company that is funded under that grant on this citizen science piece.

How do you see this work being sustained?

We're getting our data now, and would like to extend the project for two years. We're also looking at the venture capital world or an angel investor to help sustain this after the grant ends. This seems like a clear direction that smart and connected communities will need to take. We need to create a business model that works. There are deliverables that will come out of this – a digital platform, apps, a model – but will those be marketable? But it may make sense to some VCs to incorporate this into other projects they're doing in other urban cities that live on the water's edge. The Clean Water Act applies across the U.S., and people want accessibility to clean water. We have all this water here, but nobody can go in it! Environmental efforts for smart and connected communities may draw funding from other institutions. Urban communities need citizen science.

Learn More

2016 Showcase Video on CCERS – Curriculum and Community Enterprise for the Restoration of New York Harbor through New York City Public Schools

Environmental restoration and citizen science: Curriculum and Community Enterprises for Restoration Science (Brochure)

CIRCL Primer: Smart and Connected Communities for Learning

STELAR Center: Blog post on Smart and Connected Communities in Practice: The Billion Oyster Project

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Scaffolding Learners' Self-Regulation Skills to Optimize Science Learning

An interview with Roger Azevedo, a professor in the Department of Psychology at North Carolina State University about his work to study the effectiveness of intelligent virtual humans (IVHs) on learners' self-regulatory processes and other learning outcomes in undergraduate biology.

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What is the big idea of your project?

Generally, we're focusing on a triad of ideas. First, let's look at learners; what are the cognitive, metacognitive, and affective, motivational processes when they are working individually or collaboratively, when they are using some advanced learning technologies? Some of that is around tangible computing that we're doing with geospatial colleagues, so it's no longer even screen based — it's embodied cognition. If we have students who are instrumented, and the technology is instrumented, we can study the learning phenomena and how it is related to scientific reasoning through the multimodal data we are collecting, which includes eye tracking, physiology, log file, screen recording, and hand movement data.

Second, we want to train data scientists. Now, imagine having all the data I mention above fed to a data scientist who is also instrumented. That data scientist could be an undergraduate student in psychology, could be a graduate student in engineering, someone working at SAS, or any of us as scientists. The learning phenomena is so complex, so what I also want to study is: How do data scientists make inferences with this multimodal, multichannel data? What inferences are they making? What are these inferences based on, are they accurate? So we can think about training future scientists in different sectors, including acader

And third, because we know that human scientists are biologically limited, we could have a virtual human connected to the data scientists? Imagine a partnership where the virtual human is watching both the learners interacting with the technology, but also the data scientist as he or she observes and makes inferences about the multimodal, multichannel data in real-time. So now we're bringing in AI, deep learning, and computer vision so we can get to the point where the virtual human can meta reason about what it's learning, how it's learning, what it knows, what it doesn't know, and what the scientists know and don't know. You can learn more about this idea in the following video (from Cyberlearning 2017 Shark Tank session).

Cyberlearning 2017 Shark Tank - Roger Azevedo

How might the human and virtual human interact?

Discourse through natural language processing would be great, so we get to a point where there is artificial and real human collaboration to make inferences about this data. The virtual human could be embodied and living in your lab, in your computer, or ubiquitous, like Siri is.

We are also working with a colleague in electrical engineering on a visual analytics cluster. How do we get the human to query the virtual human's mind; what would that look like? Is it graphic? If I'm the virtual human watching the data scientist, imagine being able to project a visible 3D neural net so that the human scientist can turn around and see how the virtual human is making inferences about what I'm observing.

We've been talking to design colleagues about what is the best way to represent the neural network of the virtual being, and to be able to interrogate it. What's happening now with a lot of the deep learning is that it's a black box, and nobody really knows how decisions are made. We need to open that up so the humans can understand, and query it. So data visualizations come in, and what would those visualizations look like — not only the representation of the human data, but also the representations of understanding how the virtual human is understanding what the learner and data scientist are doing. There are a lot of meta-level things going on.

How do you work with teachers and students?

We just finished and IES grant working with 8th grade students, studying 100 kids a day for 3 weeks where we took a hydrosphere unit and turned it into software. That was in collaboration with Gautam Biswas and Vanderbilt. Collaborating with colleagues in computer science and STEM education, our new EHR CORE grant, MetaDash, brings MetaTutor into the high school biology classroom. We're collecting learning data and presenting the teacher with a dashboard that has information about students' cognitive, affective, and motivational processes.The question is: Given all the multimodal data that we're collecting from instrumented students, how can we repackage it to give teachers a dashboard that presents useful information about the students? We ask teachers what data they would want to see, how they would want to see it, and when they would want to see, and pilot test that. We can also instrument the teachers with portable eye trackers and physiological bracelets, and collect verbalizations. Now suppose that at some point during class, data presented on the dashboard says that 70% of the students are confused. Does the teacher pay attention to that data? What inferences does he or she make? How does that change instructional decision making?

IES Project Information

Title SimSelf: A Simulation Environment Designed to Model and Scaffold Learners' Self-Regulation Skills to Optimize Complex Science Learning (IES Award Details)

Investigator: Gautam Biswas, Roger Azevedo

Can you tell us more about MetaTutor and Hydrosphere?

Metatutor has been funded close to 9 years now, all the way back to an NSF REESE grant. It's an intelligent tutoring system that has 4 pedagogical agents to train college students to use cognitive and metacognitive

NSF Project Information

Title: The Effectiveness of Intelligent Virtual Humans in Facilitating Self-Regulated Learning in STEM with MetaTutor (NSF Award Details)

Investigator: Roger Azevedo, James Lester strategies. During learning, if a student does something overtly like spend too much time on a particular diagram that we know is not relevant to their current goal, Mary the Monitor, an agent, will pop up and prompt a metacognitive judgement by saying something like: “Hey, do you think this diagram is relevant to your current learning goal?” Depending on how the student responds, she’ll agree or ask you to explain why if you say that the diagram actually it is relevant. We have a Strategizer agent who models strategies for the students, like summarization and taking notes. It’s really trying to provide adaptive scaffolding of self-regulated learning, focused specifically on cognitive and metacognitive processes.

The Hydrosphere IES grant with Gautam involved taking Betty’s Brain and MetaTutor and kind of mashing them together. The idea was that we had two agents: Rachael, who was in charge of science content, and Brad, who was in charge of regulatory processes. The kids thought that having more than 2 agents was going to be confusing, so we just had two. It was a 3-week curriculum in a hypermedia environment, with a skills diary. Gautam collected data in Nashville and we collected data in Raleigh. At the beginning of each class, students were given an assignment by their teacher. They then looked at several multimedia resources, including videos created by the teacher and others, and indicated what their cognitive strategies were going to be. So for today, or for this particular learning goal, they might say: “I’m going to read a lot.” The skills diary had sliders, and they could set them, begin their work, and then go back to their diary and change the sliders if they changed their mind. They could also indicate affective states with the sliders, like “Today, I’m probably going to be very confused” or “very frustrated”. The idea was to make them aware of the self-regulatory strategies that they were about to use in the next 50-minute period, access them at any time, and recalibrate their perceptions of their self-regulatory skills.

Title: MetaDash: A Teacher Dashboard Informed by Real-Time Multichannel Self-Regulated Learning Data (NSF Award Details)
Investigator: Roger Azevedo, Min Chi, Soonhye Park

Title: Improving Science Problem Solving with Adaptive Game-Based Reflection Tools (NSF Award Details)
Investigator: James Lester, Roger Azevedo

The kids were not instrumented; Wake County doesn’t allow the instrumentation of children with physiological sensors. We did capture some facial expressions, but in the classroom, that’s messy; we end up losing most of the facial expression data when you are talking about 100 kids a day over 3 weeks, That’s another big issue: collecting real data in a messy classroom. A major implication is the need to find, test, and implement valid and reliable methods to collect emotions data in the classroom and other authentic contexts outside the lab.

Where do you see your work going in the future?

What was interesting is that the students didn’t do much in terms of metacognition; they didn’t understand that very well. Most of what they used were the cognitive strategies. These were 8th graders, and they were not keenly aware of fluctuations in their motivation and emotions. We did a pretest and posttest, and all kinds of embedded quizzes, but we never got to point where the system was intelligent enough to provide kids with individualized instruction around these self-regulatory processes. That's where we would like to go next.

And at a high level, as researchers, we're all experiencing an issue of a lack of theories that are comprehensive enough. For example, cognitive theories typically don't address emotions or motivation. We have theoretical issues, conceptual issues, measurement issues, and of course the applied issues for education and training. I talked about some of this in my CIRCL perspective. Lastly, our collaborative work with researchers from several disciplines focuses on the collection of multimodal data from students of all ages, across different contexts and with different types of advanced learning technologies,promises to advance interdisciplinary models, theories, frameworks, methods, and analytical techniques.

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How K-8 Teachers Are Using Virtual and Augmented Reality in Classrooms Today

Back to Spotlights

Kiley Sobel and Catherine Jhee at the Joan Ganz Cooney Center summarize the results of their interviews and surveys of 15 pre-K to grade 8 teachers to learn more about how they use virtual reality (VR) and augmented reality (AR) in their classrooms, and general lessons learned from this work. For more information, see What Will it Take for Virtual Reality to Become Education's Next Big Reality? blog post by Catherine Jhee and Virtual, Augmented, and Mixed Reality and Kids: Planning Ahead for a Positive Future blog post by by Kiley Sobel.

What is the big idea of your work?

Despite the challenges associated with using VR and AR in the classroom and the dearth of research in this area, teachers have been able to integrate these technologies into their curricula in successful and innovative ways. The Joan Ganz Cooney Center queried 15 pre-K to grade 8 teachers through questionnaires and interviews to learn more about how they use VR and AR in their classrooms.

Following are snapshots of how three teachers are using virtual and augmented reality in their classrooms. All teacher names in the snapshots are pseudonyms. The snapshots include some of the challenges these teachers have had to overcome as they implemented these technologies in their curricula too.

Drawn from our research with teachers, as well as research conducted by foundry10, a philanthropic educational research organization that has studied VR with thousands of middle and high school st[...] also offer advice for educators interested in AR and VR.

We hope these profiles and advice will inspire more educators to use AR and VR technologies productively, creatively, and meaningfully with their students as well.

Snapshot 1: Augmented and Virtual Reality for Digital Storytelling and Family Engagement

Ms. Dopker is a science and technology teacher at a religious day school that serves preschool to eighth grade students. This year she has incorporated AR and VR into her technology class for eighth graders, which focuses on digital storytelling. The course is integrated with other subjects students are learning about, including history, reading, writing, and Jewish studies. Following a unit on video production, including how to create a storyline and storyboard, students learn how to use Unity and Vuforia in order to produce their own stories using AR and VR. In this way, as noted in the Key Lessons of the CIRCL Primer: Virtual Reality in Educational Settings, students engage in constructivist activities and are able to apply their knowledge from other subjects in new, authentic problem contexts.

During the course, students produced their own graphic novels about the Holocaust and the Warsaw Uprising during World War II, which they were learning about in history class. They added augmented reality components to their graphic novels and supplemental virtual reality experiences, drawing on a scene or theme from their novel, to give users a chance to immerse themselves in that experience or landscape.
Ms. Dopker has eight Oculus Go headsets for students to use. During a 45-minute class session, half of the students are able to use the headsets for 15 minutes at a time, while the other half build environments in Unity or work on other activities related to the immersive experience. Students are required to stay seated during VR engagement, and are advised to remove their headset if they feel ill. Students also must put away and charge the headsets when they're done.

At the end of the unit, students shared their graphic novels with AR and VR components at a school “book club event” for parents. Families talked about the novels and other books students were reading, while the Oculus Go headsets were available to parents so they could experience the environments their children had created.

In terms of assessments in her digital storytelling class, Ms. Dopker noted that students were evaluated not only on the technical skills that they applied to their class projects, but also on the quality of the AR and VR content they produced as well. She explained that students who engage in coding and digital media tend to gain confidence in their production and communication skills because they must find ways to tackle problems by breaking them down into smaller parts.

> “We are giving students different ways to tell stories, allowing them to develop tech skills, and helping them become better communicators. The main objective is for students to become content creators, for them to make their own AR and VR projects.”

Ms. Dopker said she had extensive support from her school’s administration and IT department. Yet, she still ran into some technical difficulties: the school’s firewall blocked software her students needed for their work, and the software required wasn’t always installed correctly on classroom computers. Luckily, IT was able to resolve these issues. Ms. Dopker also had to learn how to use the AR and VR hardware and software she integrated into her curriculum on her own time, by using CoSpacesEDU and getting help from an expert outside partner who’s also her co-teacher. As a staff member at a local university that has partnered with Ms. Dopker’s school to collaborate on multiple projects, this co-teacher is an expert on digital visualization and science education.

Ms. Dopker said her greatest challenge—more than ensuring that the technology worked during class—was ensuring that all types of learners could access the content she was teaching and participate in her lessons, especially since it was easy for students to get frustrated and give up. She said, like all good teaching, overcoming this challenge required not only lots of preparation but also trial and error in attempting different pedagogical approaches to teaching AR and VR production skills (e.g., some students learned better from demonstrations, others from video tutorials, while still others found written instructions to be more helpful, etc.). She admitted that at first she wasn’t sure that everything was going to work. In the end though, while it took some students longer than others, all were able to participate and finish their projects.

Snapshot 2: Integrating Virtual Reality into Current Curricula to Deepen Learning for Younger Students

Mr. Huang is a third grade teacher at a public elementary school, where he integrates virtual reality into his social studies curricula, particularly around geography, ocean life, and history. He has hands-on support from one of the school's technology teachers who works with faculty members who want to use new technologies in their lessons. The school has access to 26 iPod touches and smartphone-based viewers like Google Cardboard that teachers can check out for their classes.

Before introducing students to VR, Mr. Huang makes it a point to discuss physical space and safety. He explains that other children may be around you even if you can't see them in VR. This was important because, early on, his students tried to reach for things that they saw in VR and sometimes bumped into each other. Therefore, while exploring Google Expeditions, the third graders stay seated on rotatable stools, so they can turn around more easily. In other cases, they sit on a carpet spot with clearly marked squares for them to stay in. Mr. Huang explained that he finds it easier to guide students through an "expedition" when students use the viewers individually as he follows a script to tell the students what specific things they should look for.

> "[The biggest benefit of using immersive media in my classroom is] being able to immerse yourself in an environment that you normally wouldn't be able to go to. And I think that that is the next best thing. [For example,] when you travel you really get to know the culture, you really get to know the geography. And when you can't do that, I think VR provides a very suitable alternative to that."

During a unit about geography and ocean life, students used VR to explore archipelagos and coral reefs in order to see and grasp the environmental consequences of coral bleaching. As students studied Chinese history, Mr. Huang collaborated with another teacher to have students explore different parts of China, like the Forbidden City in Beijing. Mr. Huang found that when students explored these faraway places in VR, these places seemed to come alive, unlocking an intrinsic, "emotional piece" to learning and, therefore, motivating and deepening their understanding of this content.

Mr. Huang assesses student learning (i.e., understandings of science concepts and terms; connections between history and place) through a set of questions about the content they have observed. Because students feel that they are more engaged in what they are learning, they ask questions that reflect a deeper level of interest in the material too.

Mr. Huang explained that his greatest challenge in using VR in his classroom was with figuring out the best way to manage the logistics of using VR with almost 30 young students who had never used the technology before. It took practice and patience to overcome this challenge; he started by teaching students the basic mechanics at first—turning on the mobile device and putting it into the viewer. Then, through discussions, he encouraged students to try to handle troubleshooting any issues they were having on their own, because it would be difficult for just one or two teachers to help all students simultaneously. Over time, the students became more independent with managing the equipment. Still, similar to Ms. Dopker, Mr. Huang said using VR in the classroom took a lot of trial and error—being okay with things not going the way he planned initially and then trying again.

Snapshot 3: Virtual Reality for Collaborative Mathematics Learning

Mr. Colusso, the Director of Digital Learning and Media for a county-wide school district, is a strong advocate for the use of learning games in the classroom. He described his most successful use of VR as a collaboration with a middle school math teacher and librarian to design a mathematics lesson. For this unit, students needed to design and construct a water park according to specific parameters, using the original version of Minecraft (Java Edition) on a shared multiplayer server. Mr. Colusso helped to connect the multiplayer server to Vivecraft, a modification to Minecraft, which allowed students to enter and explore their shared world and theme park at scale using HTC Vive VR headsets.

The main learning objectives for this lesson were for students to master mathematical concepts of area, perimeter, and volume and to develop their spatial reasoning and a sense of scale. Mr. Colusso explained that the creative parts of building a world in Minecraft in conjunction with the immersive elements of virtual reality gave students “a powerful experience with these math concepts.” Here, as described in the Key Lessons of the CIRCL Primer: Virtual Reality in Educational Settings, students used VR for STEM learning through constructivist activities and collaboration.

> “This technology can let you do things that simply aren’t feasible or even possible with your students, giving them powerful experiences that can help them build connections to the concepts they’re learning.”

To overcome the challenge of having all students engage meaningfully in the VR-based lesson when only one student could use a headset at a time, the teachers had to come up with creative implementation strategies. For example, they connected a large television to the system running the VR experiences, which allowed others to watch what a student in VR was experiencing in real-time. Additionally, the teachers implemented rotating activity stations, where VR was only one station among others, including designing the water park and working in Minecraft on the computer. As Mr. Colusso explained, using these strategies ended up being “a really powerful catalyst in breaking cycles of teaching [involved in] more traditional, lecture-driven classrooms.”

Advice for using virtual and augmented reality with students

Getting Started

Reach out to and join forces with others. Working with experts can help you find ways to use VR effectively and meaningfully with students. They may also be able to provide technical support. Plus, if you don’t already have administrative approval or support, banding with other teachers and technical experts may help you in advocating for why these technologies will be beneficial for your students.

Try connecting with other teachers in your area who are comfortable with technology or use VR/AR already, and join online VR+learning communities (like the Facebook groups Oculus Education, VR in Education, and Virtual & Augmented Reality for Education). If you're comfortable, reach out to faculty/students at local universities in computer science, education, design, and other related departments to see if they can help too.

> "Find a partner who's very comfortable with technology already. I couldn't have done this by myself…" — Ms. Dopker

Ensure your computers meet recommended system specifications for tethered VR systems. Teachers in one of foundry10's studies had issues with school computers being incapable of the processing speeds and graphics necessary to run tethered VR headsets (i.e., those requiring wired computer connections to run, such as Oculus Rift and HTC Vive) (Castaneda & Pacampara, 2016). To run VR equipment, it is necessary to ensure that your computer meets system specifications or can otherwise be updated or replaced. If not, it may not be powerful enough to handle running such VR experiences for your students. Luckily, not all VR and AR systems need to be wired to computers to work; for instance, Oculus Quest and Google Cardboard are completely untethered systems.

Planning the curriculum

Explore content and try it out before your students. If you don't know where to start in terms of looking for content, look over the Resources in the CIRCL Primer: Virtual Reality in Educational Settings and see how these applications may fit into your curriculum. Common Sense Education has curated their own top picks for AR/VR apps for students as well.

> "Explore everything you can get your hands on and look for ways to connect to your standards…. Explore every experience you want to use with students, fully, prior to use with students. Some experiences are so powerful, there are ethical considerations to be mindful of." — Mr. Colusso

Wondering how to integrate content into lessons? Common Sense Education provides examples of apps and lesson plans teachers use (Major, 2017). Their article links to, for example, Nearpod's VR lessons and a blog post about how a teacher used the NYT VR app (unfortunately no longer available) on Google Cardboard (50 of which were donated by Donors Choose) with his middle school students. (Note, however, that Elements 4D by DAQRI is also no longer available.)

But remember, just because a virtual experience is available doesn't necessarily mean that it's high-quality content or right for your classroom. It's important to continually review games and applications for both connections to learning goals and developmental appropriateness.

In fact, if you're working with older students, you can also try involving them in the review process before they actually try out content. By doing so, you will not only get help in picking appropriate apps that students are enthusiastic about; but your students will also have a chance to develop critical digital literacy skills by finding and evaluating VR content.

Be purposeful; capitalize on the unique affordances of VR.

> "…there needs to be a purpose for using [AR/VR] other than just because we can." — Middle school teacher

> "VR opens so many possibilities that simply aren't possible outside the technology. For example, while teaching about coral reef ecosystems and even showing a well-made documentary can help connect students to the underlying concepts, being able to take them scuba diving with an app like theBlu connects on a more visceral/emotional level. [When we did this at our school], this was especially true in the case of a wheelchair-bound, quadriplegic student for whom the experience of scuba diving is practically an impossibility. With this technology, we were able to offer her an experience that was otherwise impossible. It was truly powerful." — Mr. Colusso

To echo these teachers, rather than using VR in the classroom just because it's an exciting new technology, we encourage teachers to think about VR as a medium that can expand learners' reach. Could students already do what they are doing in VR in other ways? Or are they doing things in VR that wouldn't necessarily be safe, possible, productive, or cost-effective in the physical world? Bailenson (2018) points out that VR should only be used when the latter case is true.

Recognize the complexity of empathy-focused VR content. While Bailenson and colleagues have found that VR can be effective for empathy-building and behavior change, it is imperative to recognize that not all VR content is created equally for building empathy in adolescents and children. Castaneda et al. (2018) explain how, compared to adults, students in their research had different reactions to VR experiences specifically meant to elicit empathetic responses. They describe how these immersive experiences can sometimes backfire by being overwhelming, even decreasing empathy, and/or providing limited perceptions of what it is like to be in someone else's shoes. Therefore, the researchers suggest teachers "balance the benefits and risks of emotional connection" in VR content; utilize this type of VR content "only within a larger context/curriculum to help students connect to larger ideas;" and have discussions with students about the strengths and limitations of these types of VR experiences (Castaneda et al., 2018, p. 460).

Managing the classroom experience

Establish clear guidelines for use and then introduce students to VR gradually. Castaneda and Pacampara (2016) discuss how it was crucial for teachers in their study to initiate clear guidelines for students' VR use right away. These guidelines included creating explicit systems for how to use, store, and retrieve VR controllers and how to transition into and out of hardware. They also involved creating routines for sharing headsets to make sure there was never a line of waiting students. At one middle school, students created their own "commandments" for hardware usage. Creating similar guidelines that work for your classroom should help students learn how to use these new technologies more seamlessly.

> "Establish solid expectations for your students ahead of implementation (…how we behave while using VR, what we do if we are uncomfortable, how we treat the equipment, etc.)." — Mr. Colusso

After establishing expectations for students, the next step is not to jump right into VR. Rather, to mitigate potential adverse responses, Castaneda et al. (2018) suggest that educators provide a class introduction to headsets; preview VR experiences through trailers and discussions; take into consideration students' past experiences or fears that might intensify engagement; allow students to opt out of or leave VR experiences ; and debrief with students afterward. Castaneda (2016) also recommends beginning students in "innocuous, relatable, controlled experiences, such as Tiltbrush" so that students can "figure out movement, sense of space, controls, and input while allowing them to largely control the environment at first so they feel comfortable and capable in VR."

Consistently clean shared headsets between uses. It is entirely possible to spread conjunctivitis through VR headsets, and, in fact, this did occur in one school after students and teachers were not diligent about disinfecting the headsets after each student's use (Castaneda, 2016). In classrooms, make sure to consistently clean anything that touches students' eyes with alcohol wipes to prevent the spread of infections.

Discuss fantasy vs. reality. Developmentally, children have more difficulty distinguishing between what is real and what is not real compared to adults (e.g., Bruck & Ceci, 1999; Lindsay, 2002). Thus, students, especially younger children, may have trouble recognizing that what happens in VR may not be truthful nor a real experience. Castaneda et al. (2018) emphasize the importance of discussing how VR is a secondary source and may reflect developers' points of view, just like other media produced as secondary sources.

Support students in setting expectations and contextualizing engagement beforehand, and later, reflecting on what they experienced. Like with any new curricular experience, scaffolding student engagement will help them gain deeper understandings of the content and move them toward more independence in the learning process.

> "Before putting the VR glasses on the children or toddlers, we had some predictive dialogue. [For example,] [o]ne superpower is the ability to fly—would they like to fly using the glasses? Where would they go? Then we let them put the glasses on and experience the simulation… the experience-rich simulation pulls many children into themselves more and requires intentional prompting by an adult to help them verbalize what is happening. Asking them what they see and giving specific motion directions like, 'Look below and tell me what you see,' or, 'What happens when you look to the side?' helps them gain more from the experience." — Director of early childhood and family engagement outreach group

Be aware that VR content can be overwhelming for students to process. While there are benefits to engaging with an app like theBlu, Castaneda et al. (2018) recount how, during their research, many students became frightened while engaging in the same VR simulation. This was due to how a giant whale approaches the user and looks directly at them during the virtual experience. While this and other similar encounters may not be intentionally designed to be scary, the fact that viewers don't have control of approaching objects/characters may be uncomfortable, alarming, or otherwise difficult for students, even those 13 and older, to process. Therefore, being aware of varying proximity, scale, and movement in VR experiences is essential. Castaneda et al. (2018, p. 461) suggest telling students about objects and characters that may come close to them in VR and providing specific procedures for students to stop VR engagement if they become overwhelmed.

Pay attention to time and how students are feeling physically. Due to a lack of research on the physical and cognitive effects of children being in VR for extended amounts of time, it's safest to have students use these systems, especially high-tech headsets, in moderation. Common Sense Education recommends limiting engagement to 20-minute chunks (Higgin, 2018). We recommend keeping a tab on students and making sure they are aware they should alert an adult if they begin to feel sick, dizzy or nauseous, and, if so, have them exit the experience immediately.

And finally, be resilient because, more likely than not, something will not go as planned. Rather, learn from your struggles and keep experimenting!

> "Don't be afraid to fail." — Ms. Dopker

Related work

Cheng, B. & D'Angelo, C. (2018). CIRCL Primer: Virtual Reality in Educational Settings. In CIRCL Primer Series. Retrieved from http://circlcenter.org/virtual-reality-in-education.

What Will it Take for Virtual Reality to Become Education's Next Big Reality? blog post by Catherine Jhee, August 13, 2019

Virtual, Augmented, and Mixed Reality and Kids: Planning Ahead for a Positive Future blog post by by Kiley Sobel, May 6, 2019

Citation

Sobel, K., & Jhee, C. (2020). CIRCL Spotlight: How K-8 Teachers Are Using Virtual and Augmented Reality in Classrooms Todayl. In CIRCL Project Spotlight Series. Retrieved from how-k-8-teachers-are-using-vr-and-ar-in-classrooms-today

← FUSE for STEM Learning and Interest Development

This material is based upon work supported by the National Science Foundation under grants 1837463 and 1233722. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Computational Thinking & The Game Zoombinis

An interview with Jodi Asbell-Clarke about her NSF-funded project to study the development of computational thinking for upper elementary and middle grades students.

Back to Spotlights

What is the big idea of your project?

The Logical Journey of the Zoombinis was the first in a series of three award-winning computational thinking games developed in the mid-1990s. In August 2015, TERC and partners re-launched Zoombinis for tablets and desktops for the commercial market. The Educational Gaming Environments (EdGE) group at TERC is studying how playing Zoombinis can help upper elementary and middle school learners build implicit computational thinking skills that teachers can leverage in formal instruction. Building on prior work creating implicit STEM game-based learning assessments, we are combining video analysis and educational data mining to identify implicit computational thinking that emerges through gameplay (Rowe, Asbell-Clarke & Baker 2015).

EdGE researchers are currently analyzing synchronized screen activity video and log data from elementary learners, middle school learners, and computer scientists. Building from the ground-truth of human-coded videos, we identify systematic, automated ways of predicting implicit computational thinking skills from gameplay behaviors. The videos of players' gameplay is human-coded for evidence of specific computational thinking skills (e.g., problem decomposition, pattern recognition, algorithmic thinking, abstraction), with a sample double-coded to establish inter-rater reliability. We then distill features from log data from players' gameplay and build detectors (e.g., classification algorithms) to identify each computational thinking within the gameplay data.

What are you struggling with?

As I mentioned in my CIRCL perspective, we've found in previous work that what students do in game play matters and teachers need to bridge what they are doing to make the implicit knowledge explicit. We're using similar methods to look at computational thinking Zoombinis, which is all about computational and logical thinking.

But it's very early days in computational thinking. We're 2 years into this grant, starting up an implementation study, and still people don't agree on what computational thinking is! It was so much easier with physics, which has been around for hundreds of years. CIRCL has a primer on computational thinking, we know now to talk about it, CSTA knows how to talk about it, Google knows how to talk about it. That's not the problem. It's that students and teachers don't know what we are talking about when we talk about problem decomposition. They might be doing it, but they don't recognize it. So there is a communication problem.

There are threads of computational thinking in Common Core, but grades 3-8 don't have really it. We have been in discussion with Shuchi Grover and other computational thinking researchers, and think they are finding the same thing. Some teachers want to jump to coding without building a conceptual foundation for computational thinking. It's the analog of wanting to teach science by throwing kids into a lab with equipment and they'll learn. No teachers really do that with physics; they talk about the theory and there is preparation.

NSF Project Information

Title: The Full Development Implementation Research Study of a Computational Thinking Game for Upper Elementary and Middle School Learners (Award Details)

Investigator: Jodi Asbell-

It's very early days in computational thinking. All of this is totally understandable. As I said earlier, with game-based learning, teachers need to bridge what they are doing to make the implicit knowledge explicit. We're trying to apply this with computational thinking, but we don't have as much to bridge with. It's becoming more and more of a design-based implementation research study by the day.

Clarke, Elizabeth Rowe, Teon Edwards

Some data science education researchers express similar struggles. Do you see them as similar?

Yes, data science education has similar issues. My understanding from my colleague Andee Rubin is that things we could have tapped into were in the old math standards, but many have been taken out. They were in curriculum that were evolving in the 1990s and 2000s. But those have all either stayed on the shelf or because of the evolution of the Common Core, teachers have stopped using them because it doesn't fit into their curriculum anymore. That's my impression. It's disappointing.

Our own experience is that when we run workshops at CSTA, NSTA, ISTE, and a couple other, and we get rooms of 75 teacher who want Zoombinis, but when we talk about concepts like computational thinking and problem decomposition, we're not connecting. It's not to mean they are not teaching good stuff, it's just that we're not connecting. It's a researcher-practitioner gap. Add it's because it's the early days: It's like talking about scientific inquiry in the 70s. It's a way of thinking that's different from a curriculum standard. But now scientific inquiry is an inherent part of the Science Standards. Computational thinking will get there too.

← The Invention Coach

Scaffolding Learners' Self-Regulation Skills to Optimize Science Learning →

This material is based upon work supported by the National Science Foundation under grants 1837463 and 1233722. Any opinions, findings, and conclusions or recommendations

Learning Analytics Goes to School

CIRCL Spotlights illuminate a diverse set of projects funded by NSF. Want us to spotlight your project? Contact CIRCL to contribute your story.

Back to Spotlights

This spotlight is based on a blog post and interview with Andy Krumm, Director of Learning Analytics Research at Digital Promise, and Barbara Means, Executive Director of Learning Sciences Research at Digital Promise.

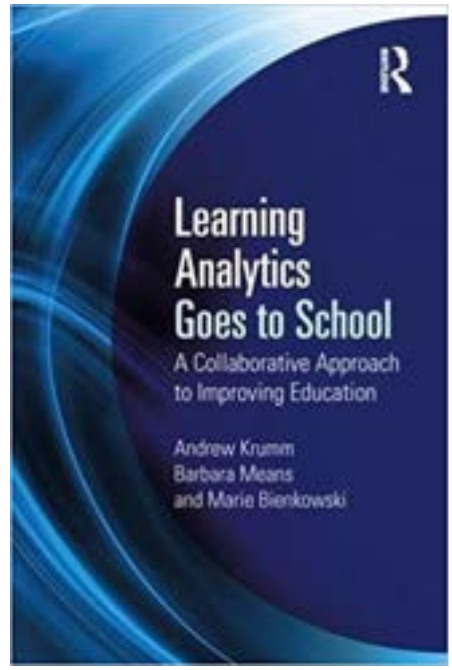
Portions reprinted from Learning Analytics Goes to School Blog Post with permission.

What is the big idea of your work?

Collaborations among researchers and practitioners have long been framed as an ideal, but the elements of what makes for an effective collaboration are often not well understood, and the funding for such work has been scarce. Recently, however, both government and private research funders have become interested in collaborations under the label of research-practice partnerships. As partnerships have proliferated, collective knowledge and wisdom about how to implement successful partnerships has grown.

Over our years of work with educational organizations, we've identified several factors that contribute to successful partnerships — such as the importance of forming trusting relationships between researchers and practitioners, using an explicit improvement method to guide research activities, and intentionally d[illegible] learning opportunities that build the capacity of both researchers and practitioners.

Our new book, Learning Analytics Goes to School, co-authored with Marie Bienkowski at SRI Education, describes a particular kind of partnership that is focused on **leveraging complex data** from various technologies to improve teaching and learning.



How can researchers, practitioners, and technology developers best use the wealth of data generated by the increasing use of technology in schools?

We've been among the many people wrestling with this question over the last five years, and our efforts have led us to a surprisingly simple answer: The best way to use data from digital learning environments for the purposes of educational improvement is in collaboration with the practitioners who will take action based on the data.

The book distills insights gathered over the course of dozens of cycles of inquiry involving work with K-12 schools, community colleges, and youth-serving organizations, and offers an account of the supporting conditions and key phases involved in what we refer to as **collaborative data-intensive improvement**.

Related DOE OET Project

Title: Enhancing Teaching and Learning Through Educational Data Mining and Learning Analytics (Issue Brief)

Investigator: Marie Bienkowski, Mingyu Feng, Barbara Means

Tell us more about your book?

We begin the book with an introduction to the developing fields of learning analytics and educational data mining and end it with calls to action for new as well as experienced researchers, practitioners, and technology developers. In between, we provide accessible descriptions of the new sources of data fueling data-intensive research in education, the application of new analytical techniques, and the importance of students' privacy in using data for research and improvement. We've worked to avoid pat exhortations to be "data driven" and instead to provide a historical account of data use in schools to ground our approach for working directly

Related NSF Projects

Title: EAGER: Elaborating Data Intensive Research Methods through Researcher-Practitioner Partnerships (NSF Award Details)

Investigator: Andrev

with practitioners to analyze, make sense of, and take action on data spread across various learning technologies and databases.

Along with useful background information and historical framings, we offer advice for launching data-intensive research-practice partnerships. Based on first-hand experiences leading multiple partnerships, we describe the importance of cultivating trust between researchers and practitioners, using explicit improvement methods, creating learning events for partnership members, and developing common workflows for sharing and analyzing data.

Krumm, Mingyu Feng, Alex Bowers

Title: A Data-Intensive Exploration of the Links between SES and STEM Learning (NSF Award Details)
Investigator: Andrew Krumm

The core lesson is that data is a necessary but not sufficient condition for creating more equitable and effective learning environments. We hope researchers and practitioners alike can use the book as an on-ramp to the exciting possibilities of data-intensive research in education.

Where do you see your work going in the future?

Data-driven improvement requires more than just data and partnerships. In order to effectively work with data, researchers and practitioners need a technical infrastructure that supports secure partnership-driven, data-intensive research.

Many of the most powerful data analysis approaches require a workflow and technical infrastructure that many schools do not yet have. In general, this necessary infrastructure includes data analysis tools and storage that allow researchers and practitioners to jointly explore and model data originating from multiple sources. Currently, this work is either not occurring (i.e., data from multiple systems are not being merged and analyzed with state-of-the art statistical and machine learning approaches) or is carried out in labor intensive ways. Key to engaging in partnership-driven, data-intensive research involves reducing the movement of "big" datasets, supporting collaborative and distributed data analyses, and expediting the process by which practitioners access the products of analyses. We're currently designing and pilot testing a cloud-based infrastructure that we can "spin up" for new partners or projects to offer partnerships a secure set of tools to engage in collaborative data-intensive research.

Resources

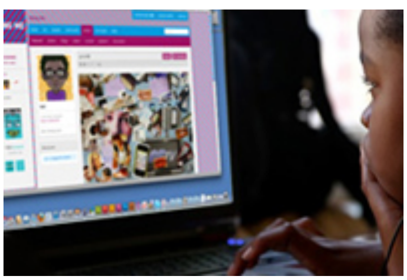
Krumm, A., Means, B., & Bienkowski, M. (2018). Learning Analytics Goes to School: A Collaborative Approach to Improving Education. Routledge.

Designing and Supporting Blended Learning Environments

An interview with Nichole Pinkard, Denise Nacu, and Caitlin Martin about their NSF-funded project to understand and design for contexts that use a blended approach to organize learning.

Back to Spotlights

What is the big idea of your project work?



The world is excited about blended learning as a solution for the educational system, but we haven't really opened the black box of what it means to be an effective instructor in a blended learning context. How do we make sense of the learning that's taking place in an online context and have it connect fluidly to in-school, face-to-face learning opportunities? Our big idea is that the same way that teachers have command over the different type of spaces in the classroom and know how to use them effectively, we want to understand how to help teachers have command over the different type of spaces that are part of online learning environments. How can teachers be more strategic about it? What are the challenges and barriers? How can we design social practices, tools, and widgets to help them? For example, the bulletin board in your classroom has only a certain amount of space, and you know you there are only certain types of things that you can put up there. How can we create useful intuitive features like that in the online space so teachers know how to use them? How can we make the online space more familiar so they can more easily map it to their practices, and help them be strategic about when to organize learning activities online vs. face to face?

There are also very few data sets that allow researchers to understand what is going on in blended l
environments. If anyone wants to work in this area, they often have to go to Facebook or some big c

So, we hope that one of our contributions is to also create a data set and contextual information around the data set that can allow for more shared conversations and collaborative work around what learning and teaching look like in these type of blended spaces.

What is the age target and topic area for learners in your project?

NSF Project Information

Title: DIP: Developing Frameworks, Tools and Social Practices to Support Effective Instructor use of Online Social Learning Networks in Blended Learning Models

Award Details

Investigators: Nichole Pinkard, Denise Nacu

We think of both educators and students as learners. The students we are working with are middle school to high school age. Our work is situated in the context of the Digital Youth Network, a mix of school, after school, and online spaces designed to provide youth with opportunities to develop traditional and digital literacy within a supportive and interactive community in formal and informal spaces and opportunities. In this case, the face-to-face environment includes both afterschool programming and in-school classes on the south and far west sides of Chicago, in predominantly African American and Hispanic communities. We're working closely with teachers and students in English language arts and social studies middle school and high school classrooms, and with educators and youth from the Digital Divas, an afterschool program for girls focused on engineering and computational thinking. In each context, a focus on digital literacies is combined with specific topic areas. We're working to understand how mentors and teachers navigate blended learning spaces, and we're fortunate to have multiple spaces to study here in Chicago. Since we wrote our grant, a larger citywide initiative called Chicago City of Learning was launched, combining online and face-to-face opportunities available to youth throughout the city, which we're also going to explore in this work.

Are you creating any products?

Yes. One product we are working on is to develop a framework for understanding online educator – learner interactions, and how we can look at these interactions in terms of youth learning and development. To help teachers be effective online, we're trying to define the types of roles that educators play in networked environments, how those roles might differ for different students and teachers, and how to create tools that can enable generative roles and interactions for learning. For example, one role that teachers play both off and online is to encourage students about their work and learning. That looks different online than it would face to face, but we know that encouraging is an important part of helping students persevere through challenges and are working with teachers to understand what this looks like online and how to make options for encouraging more visible in the online environment. Another important role we have seen teachers enacting online is that of prompting students to question, revise, and further their work. There are ways you can support that by allowing teachers to write comments when students post their artifacts, but are there other ways that we can do that? We think that if we can articulate this framework of online learning support roles, it will help teachers understand how they can interact, and also help us as designers create tools that can enable and enhance teachers' ability to play those learning support roles.

Along with the framework, we will also be putting these ideas into practice by creating various online features to promote and make visible the different learning support roles. In collaboration with teachers, will be working to develop the new features and experiment with using them in blended learning contexts. As we develop ways of operationalizing the framework of support roles in the design of online learning environments, we expect to share design principles that we hope will be useful to others.

> **Quick Facts**
>
> **Age**: Middle school and high school
>
> **Subject area**: Digital literacy, computational literacy
>
> **Setting**: Afterschool programs, schools, and blended learning environments
>
> **Geographic location**: Chicago

Another product is visualizations. One concern that teachers have when using the online spaces is: How am I going to know what is going on in there? Are students learning? How are they interacting with each other and with the learning resources? We're taking advantage of the dataset from the online space and working with teachers to create dashboards that provide snapshots of what they care about in a way that is easily visible, customizable, and that they can act upon both in and out of the online system. The trick is figuring out what types of information to provide and when to provide it. That's the hard part. We can figure out lots of data to display, but the data needs to be specific, actionable, and changing over time to reflect the ongoing activity. You have to provide layers of visualizations and consider where the teachers and students are in a project cycle to know what to show them. And over different cycles of a project, different visualizations may be more or less relevant to the teacher. Our work is designed to be highly collaborative with participating teachers as they help us to figure out answers to these and other questions.

Can you say more about the youth experience? What do they see?

All of the youth are all using the same online platform, but are involved in different face-to-face learning contexts. In the afterschool program, Digital Divas, youth focus on computational design and programming through interest-based projects such as designing wearable computing. They work with an adult mentor after school, and for the most part, their work is driven by what we're calling online learning "pathways". When they begin the online pathway, they are shown the multiple steps that make up the path for that subject area. They typically start with smaller, scaffolded activities that have embedded resources like videos or how-to guides. The activities are often hands-on, so the work transfers back and forth from digital screens and resources to physical sewing and circuitry. It's a blend of mentorship and kids working at their own pace on a variety of scaffolded activities.

Another part of the student experience is connecting them to each other. In the face-to-face environment, they are sitting next to their friends who are working on their own pathways. They collaborate, encourage, and help each other. They also post their work online and see similar work posted by other youth. So they are building a shared community and shared understanding and experiences. We are working to help build up even more communication around shared ideas both face-to-face and online, but they are definitely looking at each others' work.

We also want to understand how these learning experiences are connecting youth to other spaces, resources, and programs beyond the Digital Youth Network. Often, those connections arise because an adult helps to make a connection as a result of the mentoring relationships that are formed.

How about the teacher experience?

In this learning environment, youth records of actions and portfolios of work span over time and have the possibility of extending from one program to another, from middle school into high school, from school-program to summer program. This is a new type of intentionally designed learning environment for youth and for teachers. We're working with teachers to understand how to take this structure in order to build and achieve their learning goals. Depending on what their content area is or the particular unit, we work with them to create learning pathways: What are the different activities that are incorporated? How do they scaffold activities? What resources can be provided? How can we combine work in the face-to-face environment with what is possible online? How can we support collaboration and generative learning interactions, like teaching others? As part of our ongoing overarching vision and project work, we're working closely with teachers as design partners through collaborative design workshops to help us design online features, professional development sessions to build learning pathways and review use data, and classroom implementation.

And finally, can you say more about your research approach?

Our research is very much design-based. We're working in real classrooms and real afterschool programs, and working with a real tool that is being implemented in classrooms beyond our Cyberlearning project work. Over the three years of the project, we are focusing on big questions such as, What does learning even look like in these online environments, and how can we show that learning is happening? What online interactions seem to be generative for and around learning, and how does this relate to the face-to-face world? How can we design for the learning outcomes and interactions that we think are important? How can we create visualizations that will help teachers and youth improve learning, design, and practice?

In year one, we followed our educator partners closely, developing case studies through interviews, observation, workshops, and professional development sessions. We also collected more quantitative data including surveys and extensive, detailed logs of student and teacher actions online that tracks things like what they looked at, whose work the teacher commented on, and what kind of assignments and feedback the teacher gave. We are analyzing this data currently using our online learning support roles framework to identify the roles educators played for students online in this first year of study. Social network analysis offers another lens for analysis, helping us understand what relationships the students and teachers have, and how their relationships and viewing habits impact their creation habits and how this pattern changed over the course of the year by viewing snapshots at different time periods.

We are entering year two, where we are working with our same educator partners and their students, but diving into student cases using similar methodologies. In year three, we will focus on the school, classroom, and online community as a unit of study.

One challenge with this kind of data and the learning analytics involved in this kind of work is difficulty around IRB processes. For example, when kids are in the same online system but in different projects that may have different IRB approval chains, it's hard to manage the complexity. There probably needs to be more voice for bringing together researchers to understand the difficulties of this work from the ground up, to understand how we can share the articulation of this work, and share data sets that are both usable for understanding learning and that also maintain safety and privacy.

← Giving Students Feedback on Complex Tasks in Virtual Biology Labs

Activity monitor game increases youth fitness →

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Giving Students Feedback on Complex Tasks in Virtual Biology Labs

An interview with Eli Meir about his NSF-funded project to use dynamic formative assessment models to enhance learning of the experimental process in biology.

What is the big idea of your project? What is the problem you're trying to solve?

We make virtual labs that have some very open-ended components that let students explore and discover concepts on their own. These components are trying to address higher order thinking skills and big ideas. It is hard to assess whether students are understanding those skills with standard auto-gradable assessments like multiple choice. While you can assess higher-order thinking skills with more open-ended assessments like asking students to write an essay, or draw pictures, or make graphs, and so on, those are not easily auto-gradable. So if you want to do those kinds of things in a large class, grading is hard for many professors. Furthermore, you can't give students immediate feedback on those types of assessments – the feedback only comes a week later after the professor has had time to do the grading, which is too late for most of the learning that comes from more immediate feedback.

In our grant, we are focusing on giving students immediate feedback on open-ended, higher-order thinking skill tasks, by trying to take the kind of assessments we'd like to do— more open ended assessments—and putting enough constraints on those to be able to have a computer

NSF Project Information

Title: DIP: Using dyn
formative assessmen
models to enhance le

algorithm recognize what the students is thinking and give them appropriate feedback. We've specifically been focusing on what we are calling intermediate constraint questions that where students can still construct their own answers, but within certain boundaries that make analysis easier. For example we've created two different interfaces that can replace a short-answer essay question, which we call LabLibs (modeled after the madlibs game) and WordBytes (modeled after fridge poetry sets). We've also created constrained graphing exercises and a constrained simulation-based experimental design exercise. In the latter, when students design experiments we can recognize, for instance, when they haven't included a control or when they're varying more than one variable at a time.

of the experimental process in biology
Award Details

Investigators: Eli Meir, Joel Abraham, Eric Klopfer, Zhushan Li

Web site: Simbiotic Software

My impressions is that the field hasn't thought very much about constraints; they've been enchanted by algorithms and data, and the idea that if you get enough data and get enough computers and have smart enough machine learning, you'll be able to figure everything out. Instead, we're focusing on constraints to make the machine's job easier; it's kind of low-hanging fruit in a way. And in this process, we're improving our SimBio Virtual Labs to include feedback in places where we weren't previously able to.

Can you say more about the research you are doing?

We're doing a lot of validation around questions such as: How much does putting constraints on what the student is doing affect what they do? Are we actually capturing what the student is thinking? There is design research as well, about how to make our interfaces so that they are constrained and still allow the students to do interesting things.

The last year of the project will be devoted to more summative assessment which addresses whether giving student feedback actually helps students learn these concepts. The software will be used in several classes, and we'll do pre- and post testing to assess learning gains, compare pre- and post tests across classes with and without feedback, and then culminate with split class studies—where half of the students are working with the constrained interfaces and the other half are doing something else—and look for a difference in learning gains.

Quick Facts

Age: Primarily undergraduate; some high school

Subject area: Biology

Setting: Face to face, in person; remotely, online, at a distance

Geographic location: Colleges and universities across North America

Can you give an example of a constraint, and how you'd compare across classes?

One interface that we're building, called WordBytes, is modeled after fridge poetry sets. We give students sets of words and phrases which they have to use them to construct sentences to answer a question. We've come up with algorithms that allow us to give students quite fine-grained feedback depending on the answer they compose, and the feedback comes right away. This has advantages over both multiple choice and short-answer essay questions. In multiple choice, the student also gets feedback right away, but the thought process in coming to the answer is much lower-order. In essay questions, they construct their own answer, but usually get no feedback (or if there is feedback, it's not as fine-grained).

A big advantage when they get immediate feedback is they can then go through a learning process with their answer. Students will often that will start off with a wrong answer, and then get the feedback, and then after 2 or 3 tries, end up with the correct answer. So that's indirect evidence of learning — given that you could make millions of combinations out of the words and phrases we're giving them, the fact that they can come to a correct answeris evidence that they are actually figuring out what their mistake was. It's not just picking the next answer out of 4 multiple-choice answers.

What is the learner experience like? If I were a student participating in this project, what would I experience?

Our labs are used on about a fifth of campuses in North America. Students get a virtual lab that includes one or more fairly sophisticated simulations of some biological system. They play with those simulations by changing parameters or by doing an experiment like a researcher would. Unlike many virtual biology labs, we make our tools quite flexible so that you get the same conceptual experience as in a wet lab. For instance, we might let students add or remove critters in an ecosystem, and they decide how many to add, where to add them, how long to run the simulation, and which critters to measure afterwards to get their results.

Students in this study are doing these virtual labs very similarly to how other students would be doing SimBio labs, but embedded in the labs are the intermediate-constraint interfaces that we're developing. For the most part, the students don't know they are doing anything different or nonstandard. They are just going along and encounter questions they have to answer, in a slightly different interface, or they encounter a simulation they have to play with, but they don't realize they're only getting certain tools and not as many as they might have got a year before. Then they get feedback and can change what they do based on the feedback.

What is the teacher's role and what is their experience?

Some of the teachers have used the software in the past, and some are brand new to it. In the study condition, the biggest thing that will change for them is that they have to do less grading if there are no short answer questions, so it saves them time. They also get a little more information about their students because the system reports out what their students have been doing in these interfaces. In general, it is not a lot of extra work for the professors although there is some coordination involved when we ask them to do pre and post tests.

You have partners at universities; what is their role on the project?

It's been a really productive partnership. Our MIT partners are contributing a lot to the design ideas, and to assessing the innovation—how to built the pre- and post tests and analyze that data. Our partners at Cal State are contributing to the design ideas, and will be contributing to the summative assessments at the end. Our partners at Boston College are focused on statistical analysis of the data. We (SimBio) are a company rather than an academic lab, and within the company we also have multidisciplinarity in that we have an education person, biologists, people who teach, programmers, etc. So in that sense, we built our company to try to do what cyberlearning is trying to encourage. But that said, partnering has been great, and the project is a lot stronger because of the contributions of the partners.

How do you see your project advancing the broader cyberlearning field?

I think the things we'll contribute for the larger field are some demonstrations of interfaces that fit this idea of using constraints at scale. We'll show interfaces that work at scale. We'll also have some information to contribute on algorithms to analyze those kind of constrained but still fairly open-ended data. And probably one of our biggest contributions will be rules of thumb for how to use these interfaces and make them work. We're trying them in different places and have failures as well as successes. So by the end we should have something along the lines of "if you want to use this type of constrained presentation, here are the top 10 things to pay attention to in order to maximize the chance of success."

← Learn About our Complex World through Map-Based Games!

Designing and Supporting Blended Learning Environments →

New to Cyberlearning?
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Head-Mounted Displays in Deaf Education

Based on a submission by Michael Jones about his NSF-funded project to use augmented reality to improve learning by deaf children.

With a head-mounted display, deaf children can see sign language even when their head is turned away from the signer, allowing them to "hear" explanations and see scientific phenomena at the same time. Head-mounted displays (HMDs) are small computer screens attached to a glasses frame and worn next to the eye. Researchers at Brigham Young University and Gallaudet University have worked with deaf children to learn how to make HMDs comfortable and useful for deaf children. Researchers studied the fit and balance of the display and also the size and position of the signer within the display. The signer shown in the display should be sized to match the relative real-world size relationship of the signer and the phenomena and the signer should be placed near the center of the student's field of view.

A person watching sign language can either watch the signer and see what is being said or watch some phenomenon and see what is being talked about—but not both. This makes it difficult for deaf learners to focus their attention on both an explanation and a phenomenon at the same time. Watching sign language in an HMD moves the signer with the person's head and allows a person to switch between signer and phenomenon with

NSF Award Information

Title: EXP: Exploring augmented reality to improve learning by deaf chil[dren in] planetariums.

Award Details

less effort. This work was done in the context of planataria, and deaf learners were part of the research team. Results are expected to be applicable in other formal and informal learning settings.

PIs: Michael Jones, Fred Mangrubang, Eric Hintz, Ron Proctor

We know that people can pay close attention to only one thing at a time. Understanding how people switch attention effectively among multiple inputs helped us understand ways that HMDs could be used by deaf children to more easily switch their attention between a signer and some phenomenon of interest or importance. For full transfer to other aspects of deaf education it is important now to direct our attention to other learning scenarios such as reading a book at home, dissecting an owl pellet in class, or taking a field trip outside.

Image credit: Michael Jones, Brigham Young University

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Learn About our Complex World through Map-Based Games!

Based on a submission by Karl Ola Ahlqvist about his NSF-funded project to use map games for teaching and learning.

Back to Spotlights

The GeoGame framework turns online maps, like those in Google and Bing maps, into a game board. Any place in the world can be experienced through a game that gives a micro-experience of what life is like in other places of the world. In the first game "GeoGame – Green Revolution – India" users have learned what goes into farming in emerging economies and why farming in these economies is often a matter of survival rather than a means of becoming wealthy.

In the first two years of this project, researchers at The Ohio State University developed GeoGame – Green Revolution – India, and over 600 students have test-played the game as part of an undergraduate geography course. In a playful way, these students have learned facts about farming in India and, in particular, have learned to appreciate how complex farming can be!

NSF Project Information

Title: EXP: GeoGames – Online Map Games for Teaching and Learning through a Real-World Spatial Perspective

Award Details

PIs: Karl Ola Ahlqvis

The data collected from our user studies help us understand:

- What are key components and needed functionality in this learning technology

- How educators can naturally integrate an online, social game activity into the classroom.
- How a virtual micro-experience can generate critical thinking and impact learning about a far-away place when the students can relate to what they experienced rather than what they have read.

Andrew Heckler, Rajiv Ramnath

Our first results demonstrate that many students who play the game increase their understanding from simple explanations, to an awareness of the complexity of agriculture in the developing world. Our continued research will seek to determine how that awareness is developed and how the technology can be used to take the students one step further to formulate explanations of what happens in the game.

"The mapping of the fields on a satellite image gridded out gave the farming a more realistic feel."

The innovation allows almost any type of board game to be played on top of a current or historic real world map. This also means that the game can directly access and allow any known real-world information to affect the game play. Just imagine playing the popular game RISK with your friends, but in Google Earth, on a current or historic map, allowing real-world information on economy, population, and other conditions affect the game in real time. Or, playing Farmville in a village close to you, or in a faraway Indian village, planting, buying supplies, fertilize, irrigate, trade goods, and so on. You would have a lot of fun, while learning a lot about real-world facts and complex, human-environment interactions.

"…I started to consider success in the context of the Green Revolution in India. Before I was thinking about success in the American context, […] That is not the reality in India. The definition of success changed from earning money to simply surviving".

Learn more at the GeoGame project web site.

← Head-Mounted Displays in Deaf Education

Giving Students Feedback on Complex Tasks in Virtual Biology Labs →

Revolutionizing Education in Haiti

Based on a submission by Michel DeGraff about his NSF-funded project to help Haitian faculty deepen their expertise in the innovative use of digital resources for STEM learning.

Back to Spotlights

For the first time ever, Haitian faculty are using their national language of Haitian Creole (aka "Kreyòl") for high school and university-level education in Science, Technology, Engineering and Mathematics (STEM). Open digital resources created at MIT and elsewhere, translated into Kreyol, are providing portable virtual laboratories to Haitian universities and high schools, most of which do not have access to traditional physical laboratories. Teachers are becoming passionate about active learning and facilitating it in their classrooms for the first time. The Initiative has garnered the support of key stakeholders, including educators at public and private universities throughout the country, alongside the highest echelons of the Haitian government.

NSF Project Information

Title: INSPIRE: Kreyol-based Cyberlearning for a New Perspective on the T
of STEM in local Lan
Award Details

The use of Kreyòl, coupled with state-of-the-art educational technology and online open-education resources, holds the promise of making quality education available to all in Haiti. This initiative has potential to help Haitian faculty and students leapfrog into universities of the future. The initiative presents a significant step in developing readiness and capacity to address the needs of the innovation-driven economy that Haiti needs, as STEM education has proven to be a major factor in economic development. The initiative also has potential to become a model for other countries in the Global South.

PIs: Michel DeGraff, Vijay Kumar

This project started as a response to the destruction of Haitian universities by the earthquake of January 12, 2010. One silver lining was the unique opportunity for Haitians to create a high-quality education system accessible to all. Currently only 10% of those who enter primary school graduate from high school. About 1% have some college-level study. In addition, most education is taught in French, and only 3 to 5% of the Haitian populations speaks French, whereas everyone speaks "Kreyòl." The technology-enhanced STEM tools and Open Education Resources for active learning in Haitian Creole ("Kreyòl") are building a solid basis for faculty and curriculum development in Haiti.

We've been conducting a series of faculty- and curriculum-development workshops in Haiti, working with Haitian faculty to deepen their collective expertise in the innovative use of digital resources for active learning in STEM, specifically in physics, biology, biochemistry and math, with other STEM disciplines being considered for the future. The workshops are used to teach teachers to incorporate effective Kreyòl-based pedagogical techniques and resources into Haiti's educational strategies and academic curricula and to get feedback from teachers that is used to refine curriculum units and the deveopment of scientific Kreyol vocabulary (called Language Engineering). The Initiative is looking at three factors at the core of modern STEM education: 1) online educational technology coupled with open education resources, 2) active-learning pedagogy, and 3) native language (i.e., Kreyòl) as medium of instruction. Each factor has been shown to independently enhance learning gains. Haitian faculty who participate in the INSPIRE workshops are disseminating these Kreyòl-based active-learning educational materials throughout Haiti.

"(When I teach in Kreyòl) **children ask more questions**. Sometimes you even feel that they are speaking too much; then you switch over to French so that there will be less interactions in the class."

Image credit: MIT EdTech Times Blog

← Understanding Sustainability Through Discovery and Play

Head-Mounted Displays in Deaf Education →

Understanding Sustainability Through Discovery and Play

Based on a submission by Stephen Uzzo about NYSCI's NSF-funded project to explore issues of sustainability within the context of imaginative, playful, immersive worlds.

Back to Spotlights

By interfacing gesture and location tracking technologies to computer animation and environmental models, "Connected Worlds" helps visitors to the New York Hall of Science notice connections and build understandings of complex systems. Groups of museum visitors are able to formulate common goals, take on different roles and responsibilities and solve problems while exploring issues of sustainability within the context of imaginative, immersive worlds. This experience serves as a cyberlearning platform to elicit systems thinking, elucidate complex sustainability ideas, and allow learning scientists to study how people interact and cooperate in live, technology-mediated spaces.

The Connected Worlds exhibition, opening in October 2014 in the New York Hall of Science's Great Hall, invites visitors to explore issues of sustainability within the context of imaginative, playful, immersive worlds. Through state-of-the-art sensing technologies visitors engage with any one of the six diverse ecosystems created through projected, dynamic, real-time animated imagery. Visitors interact with the imagery through gestures

NSF Project Information

Title: DIP: Interaction Research in Complex Informal Learning Environments

Award Details

and manipulation of computer-tracked objects (such as logs and rocks). The effects they produce model complex systems of interdependent relationships among and within human-nature coupled systems. Each habitat connects with the others through water – their shared resource – that the visitors must manage to maintain healthy environments. Visitors have the opportunity to notice and explore complex issues of resilience and sustainability. The exhibition will be experienced by approximately 450,000 visitors each year, and will result in a body of research examining the ways in which young people interact in the environment to understand systems concepts.

PIs: Stephen Uzzo, Marc Levy, Jan Plass, Eric Siegel, Margaret Honey

The tracking and sensing system built into Connected Worlds allows analytics to be built around human dynamics and can be applied to a variety of social learning contexts, from classroom interactions, to large-scale embodied games, to visitor interactions in museums and other informal learning spaces. In addition to creating a unique, playful experience for museum visitors to embody systems thinking in sustainability ideas, Connected Worlds can serve as a research platform for studying group and social learning to advance the understanding of the kinds of dynamic interactions that lead to cooperation, division of labor, and socially-mediated response in complex environments.

Image Credit: New York Hall of Science

← Linking Superheroes and Technology to STEM Aspirations

Revolutionizing Education in Haiti →

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Linking Superheroes and Technology to STEM Aspirations

Based on a submission by June Ahn about his NSF-funded project to develop STEM identities.

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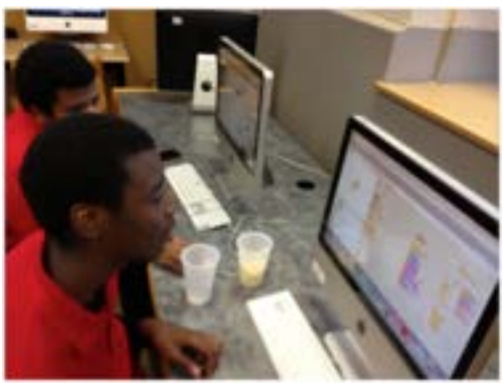

If you could be a super hero, who would you be? How would you get your powers? What sorts of gadgets would you possess, and how would they work? Youth who are asked to imagine alternative worlds and futures, and express these ideas through storytelling, have rich opportunities to connect science, technology, engineering, and math (STEM) to their personal interests and future goals.

This project demonstrates how making these connections during early adolescence helps to spark aspirations to pursue STEM-related interests and academic pursuits. Laying this foundation is important for adolescents as they begin to a) Recognize the relevance of STEM in their everyday life; (b) Understand how personal interests relate to formal academic endeavors, such as the importance of computing, art and design in becoming a game designer; and (c) Formulate growing aspirations and plans to pursue these interests in future academic and career pathways.

The "Sci-Dentity" project is a weekly afterschool program that served 61 urban, middle school students and was implemented in school libraries.

NSF Project Information

Title: Developing STEM Identities through Participation in Science-Infused Media and Virtual Peer Networks

Award Details

PIs: June Ahn, Mega Subramaniam, Alliso
Kenneth Fleischman

Our youth participants engaged in science storytelling, discussed the science behind popular science fiction stories, created superheroes, designed video games, programmed “monsters” in Scratch, and helped a production company design a sci-fi transmedia game. Our research team followed a cohort of middle school learners, longitudinally from 6th-8th grade, to track how youth developed interests, literacy skills, and aspirations toward STEM over this time period.

Learn more at the Sci-Dentity project web site.

Image Credit: Research Team, University of Maryland, College Park

← Synergistic Teaching of Computational Thinking and Scientific Modeling

Understanding Sustainability Through Discovery and Play →

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Mixed Reality Brings Science Concepts to Life

Based on a submission by Charles Xie and Jennifer Chiu about their NSF-funded project to integrate sensors and simulations to improve learning.

Back to Spotlights

More than 1,000 middle and high school students in Massachusetts and Virginia have used a novel class of mixed-reality technologies to learn complex science concepts. Leveraging existing software and probeware widely used in schools, these technologies blend virtual and real experiences into a single activity and create a genre of applications with unprecedented learning opportunities.

One of the reasons that science is difficult for students is because many scientific phenomena are invisible to the naked eye. To help students see science concepts in action in the real world, researchers at the Concord Consortium and the University of Virginia have developed mixed-reality technologies that augment hands-on laboratory activities with sensor-driven computer simulations. These technologies are widely applicable in science education.

For example, the mixed-reality gas laws activity supports deep inquiry into the Kinetic Molecular Theory, a cornerstone of chemistry taught in every school. In this activity, students interact with a visual molecular dynamics

NSF Project Information

Title: DIP: Collaborative Research: Mixed-Reality Labs: Integrating Sensors and Simulations to Improve Learning

PIs: Charles Xie, Concord Consortium (Award)
Jennifer Chiu, Univer
Virginia (Award)

simulation of a gas through tactile inputs spatially aligned with objects in the simulation.

Students can warm an edge of a tablet computer to “transfer” heat into the virtual gas. Or they can push a real spring visually attached to a virtual piston to “compress” the gas. Or they can use a plunger to “inject” molecules into a virtual chamber. In this way, the technology creates a unique experience as if students could directly manipulate molecules—an experience that is only possible in research labs with advanced nanotechnology instruments.

“I liked the interactive materials such as the spring and the touch pad to change the temperature. These provided us with tangible objects that changed what was happening on the screen, and it made it more engaging, and thus easier to learn from.”

Anonymous surveys of more than 100 early participants indicated that 80% of students found mixed reality helpful. Interviews with 60 additional students randomly selected from 14 high school classes showed that about 75% of students preferred mixed-reality activities over purely virtual ones. Pre/post-tests demonstrated learning gains for all students. A quasi-experimental study suggested that the mixed-reality gas laws activity was significantly better than traditional lab activities in helping students understand the molecular basis of gas laws.

Learn more on the Mixed-Reality Labs web site.

← When is a classroom not a room?

Synergistic Teaching of Computational Thinking and Scientific Modeling →

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Digital Promise

SRI Education

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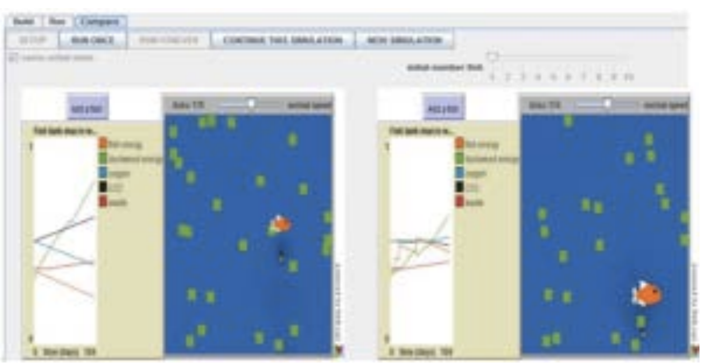
Synergistic Teaching of Computational Thinking and Scientific Modeling

Based on a submission by Gautam Biswas about his NSF-funded project to foster computational thinking through scientific modeling and simulation.

Back to Spotlights



CTSim Envisionment World Interface

Computational Thinking (CT) is now considered a core competency in problem formulation and problem solving. In spite of the known synergies between CT and science education, integrating CT in K-12 science classrooms is challenging. CTSiM, a visual programming environment that supports development and practice of curricular units specifically for middle school classrooms, has successfully demonstrated that these challenges can be overcome and lead to demonstrable learning gains in middle school classrooms. When adopted on a wider scale, this project will result in strengthening a STEM-oriented computation-ready workforce.

Using the CTSiM (Computational Thinking for Simulation and Modeling) system, a 6th grade science teacher has successfully demonstrated that computational thinking and learning of science by building, verifying, and analyzing scientific models can become a regular component of classroom instruction. Through these model building and verification experiences, learners work on a sequence of science units that increase in complexity,

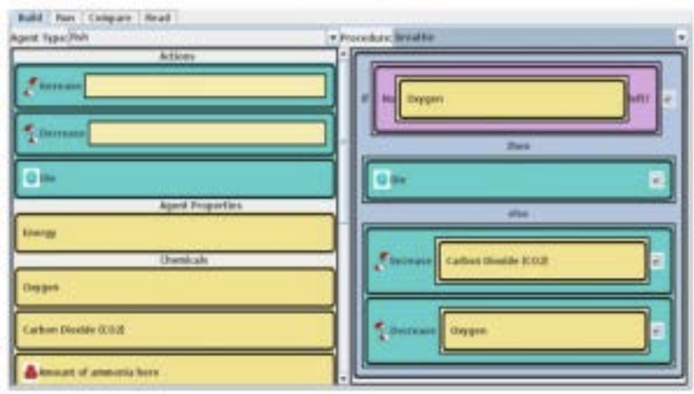
NSF Project Information

Title: EXP: CTSiM: Fostering Computational Thinking in Middle Schools throu[...] Scientific Modeling a[...] Simulation with the increases in complexity informed by the challenges of becoming a computational thinker. In this recent, teacher-led, classroom study, pre-post comparisons showed that students made significant gains, both in terms of computational thinking and conceptual understanding of the relevant science concepts.

Award Details

PIs: Gautam Biswas, Douglas Clark, Pratim Sengupta

CTSiM adopts a learning by design paradigm, where students iteratively design, deploy and revise conceptual and computational (i.e., simulation) models of scientific phenomena. Student model building and learning is scaffolded by an agent-based modeling paradigm, where the term “agent” indicates an individual computational object or actor (e.g., a roller coaster car or a fish in a fish tank), which carries out actions based on simple rules that can be assigned or modified by the user (e.g., moving forward, changing directions, etc.).



CTSiM Construction World Interface

The system implements a visual mode of programming to enable students to represent phenomena computationally without having to learn the syntax of a programming language. This makes understanding computational structures and programming more intuitive, and, therefore, accessible to novices. Another key aspect of the system is that it integrates domain-specific science primitives and domain-general computational abstractions that exploit the synergy between science concepts and computational thinking constructs. The current version of CTSiM includes learning modules in (1) kinematics for learning about Newton’s laws of motion and the relations between distance, speed and acceleration, and (2) ecology, where students learn about ecological processes for sustaining fish in a fish tank ecosystem.

Learn more at the CTSiM project web site.

← Mixed Reality Brings Science Concepts to Life

Linking Superheroes and Technology to STEM Aspirations →

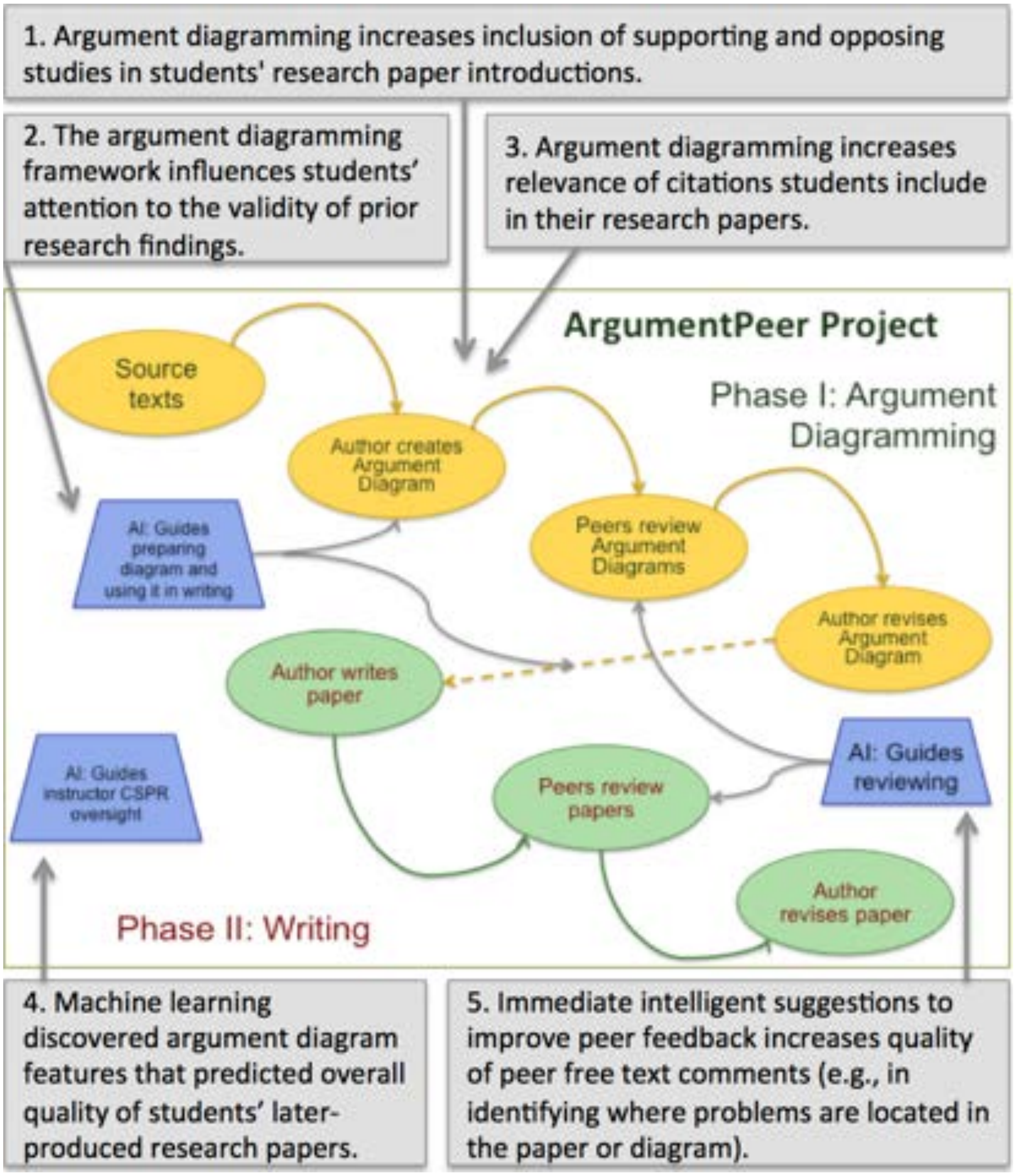
Technology Helps Students Do a Better Job of Writing and Reviewing Arguments

Based on a submission by Kevin Ashley about his NSF-funded project to teach writing and argumentation with AI-supported diagramming and peer review.

Back to Spotlights

Argumentation is central to reasoning in many domains: law, natural science, policy. Students normally have unjustified positions, or include irrelevant information as evidence. ArgumentPeer helps students learn how to build strong arguments; it has been deployed in professional, graduate settings (law), and undergraduate settings (research methods).

In the ArgumentPeer project, students plan written arguments by diagramming them with automated feedback. They review each other's argument diagrams based on key criteria; machine learning helps reviewers make critiques more localized and actionable. The system transforms diagrams into copy-friendly texts, students write their arguments, and the peer-review cycle begins anew.



ArgumentPeer Flow

The ArgumentPeer process includes two main phases: I. Argument Planning, and II. Argument Writing. Fig. 1 shows an overview of the process and its underlying components and steps. In Phase I, students examine background readings and then diagram an argument for a research study they will conduct (or legal brief in a law class). An intelligent help system in the diagramming tool guides them. Then students submit their argument diagrams to a web-based system for peer-review and revision (SWoRD). Students use a detailed rubric to evaluate their peers' diagrams. After receiving the reviews, authors revise their argument diagrams, and then can export their diagram content into an automatically created paper outline.

NSF Project Information

In phase II, students write their paper first drafts using these outlines and submit the drafts to SWoRD for peer review. Finally, the author submits the second draft to SWoRD and the final drafts can either be graded by peers or by the instructor. Across both phases, three key features of SWoRD are: 1) Instructors can easily define rubrics to guide peer reviewers in rating and commenting upon authors' work. 2) SWoRD provides pressure for high quality reviews such as automatically determining the accuracy of each reviewer's numerical ratings using a measure of consistency against the mean judgment of other peers for the same papers. 3) A natural language processing component automatically evaluates the peer review comments to make sure the comments are useful (e.g., specify problem locations and possible solutions).

Title: DIP: Teaching Writing and Argumentation with AI-Supported Diagramming and Peer Review
Award Details

PIs: Kevin Ashley, Diane Litman, Christian Schunn

← Cyberlearning technologies help teachers prepare the next generation of data scientists

When is a classroom not a room? →

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CIRCL
Center for Innovative Research in Cyberlearning

When is a classroom not a room?

Based on a submission by Thomas Moher about his NSF-funded project to use embedded phenomena to engage learners in scientific practices.

Student monitoring populations of bugs in the WallCology embedded phenomenon

Researchers from the University of Illinois at Chicago have designed a method for turning elementary school classrooms into imaginary places—subduction zones, planetary systems, small towns sitting atop aquifers, or ecological habitats—that become the object of collective scientific investigation. Dynamic phenomena are imagined to be "embedded" in the physical space of the classroom, made accessible through stationary or mobile "portals" (tablet and laptop computers, large displays, etc.) that provide continuous location-specific visualization of the phenomenon. Over weeks, students collectively observe, manipulate, and chronicle the embedded phenomenon, and constructing models to reflect their understandings.

Embedded phenomena instructional units engage young learners in the kind of collective, patient science practices that involve careful and collaborative data collection, analysis, and interpretation over an extended period of time. While advocated within modern pedagogies and science education standards, these remain rare experiences in elementary classrooms. By situating learning within social role-play in a responsive,

NSF Project Information

Title: EXP: Using Technologies to Engage Learners in the Scien
Practices of Investiga
Rich Behavioral and

immersive public environment, affording opportunity for physical activity, and engaging whole classes simultaneously, embedded phenomena provide strong motivation for productive engagement in science practices.

In a collaboration with researchers at the University of Toronto, embedded phenomena technologies are complemented with software tools that allow students to create, share, and use one another's contributions to an electronic community knowledge base. In another collaboration, the project is working with National Geographic to make a seismology embedded phenomenon, RoomQuake, available as a public web-based resource.

Ecological Questions

PIs: Thomas Moher, Tanya Berger-Wolf, Leilah Lyons, Joel Brown, Brian Reiser

Award Details

Image Credit: Brenda López Silva, University of Illinois at Chicago

← Technology Helps Students Do a Better Job of Writing and Reviewing Arguments

Mixed Reality Brings Science Concepts to Life →

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Cyberlearning technologies help teachers prepare the next generation of data scientists

Based on a submission by Fred Martin about his NSF-funded project to enhance science and math instruction with a web environment for data sharing and visualization.

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GPS data logged by students running and walking on the school's football field

Usually when a student pulls out a cell phone in science class, the teacher takes objection. But that's changing with the introduction of new mobile apps and web technologies developed by the University of Massachusetts Lowell (UML) and Machine Science Inc. These tools enable middle school and high school students to collect scientific data using smart phones or tablet computers, and then share and visualize the data online using an open web platform called the Internet System for Networked Science Experimentation (iSENSE).

Researchers from UML's Graduate School of Education are studying how iSENSE can enhance science and math instruction and help students understand the changing face of science in the era of big data. Over the past year, science and math educators have incorporated iSENSE into their teaching in a variety of creative ways. A math teacher from Hollis, New

NSF Project Information

Title: DIP: Collaborative Research: Transform Science Learning wit Interactive Web Envi

Hampshire, devised a probability experiment to demonstrate the law of large numbers. Her students repeatedly rolled a pair of sixsided dice and shared the results of each trial on iSENSE, showing how the sums of the rolls become normally distributed as the number of trials increases. A physics teacher from Tyngsborough, Massachusetts, used a mobile app developed by the iSENSE project team to collect and upload data on the accelerations experienced by students during a field trip to a local amusement park. In another project, students in Reading, Massachusetts, studied velocity and acceleration by collecting timeseries global positioning system (GPS) data while running sprints on the school's football field.

for Data Sharing and Visualization

PIs: Fred Martin, Michelle Scribner-MacLean, University of Massachusetts Lowell (Award)
Samuel Christy, Machine Science Inc. (Award)

The iSENSE web site offers a repository of usercontributed datacollection activities, such as engineering projects, environmental studies, classroom science experiments, and surveys, together with the data produced by those activities. The system enables users to contribute their own activities, upload data, and configure and save dynamic data visualizations.

Image credits: Fred Martin, University of Massachusetts Lowell

Technology Helps Students Do a Better Job of Writing and Reviewing Arguments →

New to Cyberlearning?
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Activity monitor game increases youth fitness

Based on a submission by Cynthia Ching about her NSF-funded project to educate teens about personal health.

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Lifestyle-driven disease is responsible for nearly 70% of deaths in the United States, and there is a current epidemic of child and adolescent obesity. Urban minority youth are most at-risk for these health concerns. Videogames are often blamed for youth sedentary behavior and obesity, but games can have a positive impact on health. In this project, some youth players had difficulty increasing their out-of-school fitness due to poor neighborhood safety and limited outdoor activity spaces. These youth were more motivated when they played the game to be active during school-based activities such as lunchtime and PE. The connections between activity tracking and gaming designed for this project, as well as resulting insights into how and why youth are motivated or constrained in their everyday choices, will be vital as tools for not only the current metabolic health crisis, but also for addressing other kinds of social challenges that require behavioral change.

As a result of playing a videogame that syncs with 24/7 wearable monitors, youth ages 11-14 are increasing their fitness awareness and physical activity. Initial results suggest that, contrary to popular belief, game features involving customization are more motivating than competition for increasing physical activity. Active-display wearable devices are also necessary for youth to pay close attention to their real-world beha

Landscape of *Terra* with alien creatures and spaceship base

Finally, youth strategies to become more physically active are sustainable when they involve taking advantage of existing opportunities for exercise, rather than trying to invent new ones.

Based at the University of California Davis, this project is a collaboration among learning scientists, health researchers, game industry and fitness-device industry leaders, and award-winning commercial game designers. Together they have created *Terra*, a futuristic online game about a team of scientists attempting to explore and terraform a distant planet to provide a new home for the citizens of Earth. The game can be played on any web browser and is appropriate for a variety of educational contexts.

NSF Project Information

Title: EXP: Educating Teens to Understand Personal Health (GET-UP)
Award Details

PIs: Cynthia Ching, J. Bruce German

Learn more at the GetUp project web site.

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This material is based upon work supported by the National Science Foundation under grants 1837463 and 1233722. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.