

03

CO-INVENTING THE CLIMATE LAB

Partnership with Manomet Center for Conservation Science builds new model for connecting students with long-term field research.



10

FAMILY, FRIENDS, NEIGHBORS, AND MATH: THE NANA Y YO Y LAS MATEMÁTICAS PROJECT

Program with YMCA of Silicon Valley creates early childhood math activities for facilitators, caregivers, and children.



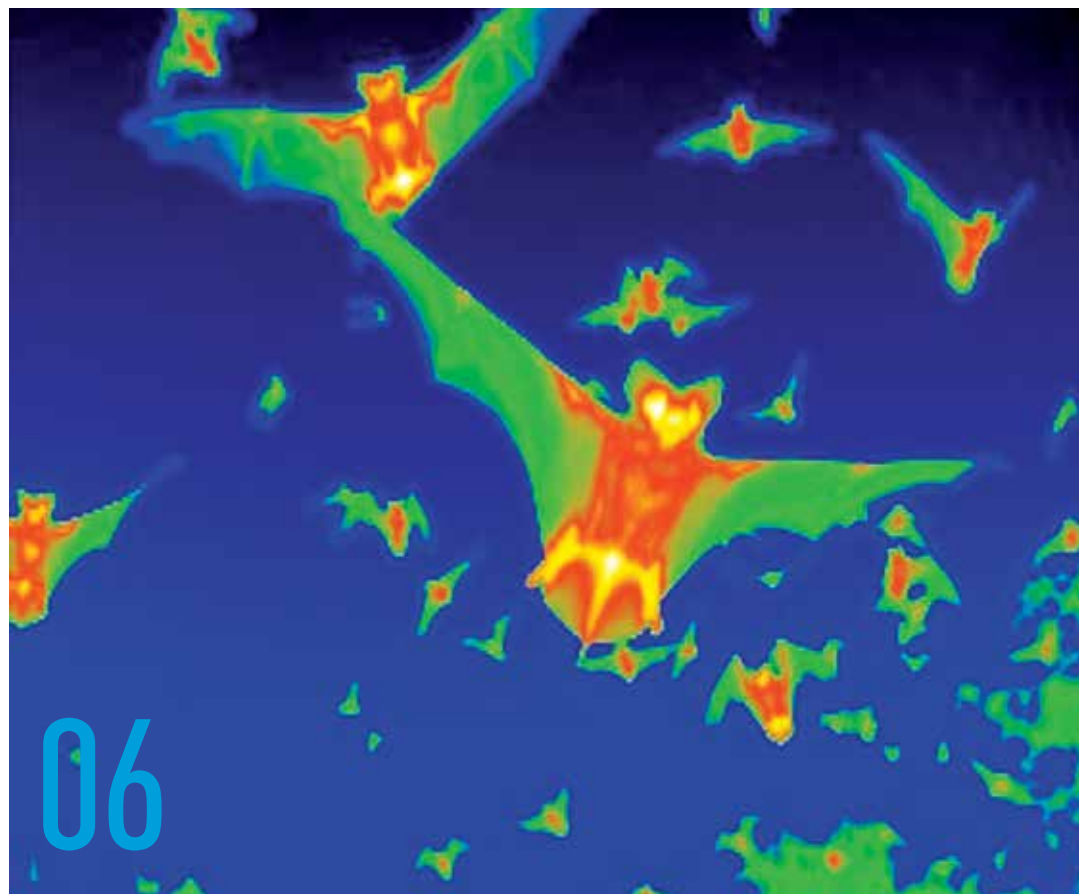
14

DIGITAL GAMES FOR IMPLICIT SCIENCE LEARNING *App built around Newton's laws of motion is part of a research effort to create games where players dwell in science.*

18

TERC AT 50: A LOOK BACK AT

HANDS ON! *Excerpt from first issue highlights emphasis on technology and the power of a hands-on experience.*



06

HOW TO COUNT BATS?

Pilot program at Carlsbad Caverns helps National Park rangers introduce visitors to on-site scientific research.

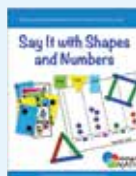


Blend Math and Play Anywhere for Ages 3–12!

Use **Mixing in Math** at home, at school, at child care and after-school programs, in the library—just about anywhere!

We offer games and books full of ways to:

- Combine math with crafts, creative play, gym games, cooking, science, and everyday routines
- Build math skills while boosting confidence and enthusiasm
- Complement any math curriculum
- Meet the Common Core Standards for Math, grades K-5, and the NAEYC/NCTM Joint Position statement on Early Childhood Mathematics



Say It With Shapes and Numbers 300 ways to mix in math for ages 3–6. Includes game boards and materials for projects that combine geometry, patterns, and literacy. Aligned with NAEYC/NCTM Joint Position Statement on Early Childhood Mathematics.



Ladybug Card Deck with Games Card games for matching and sorting by number and color, for counting and comparing, and for basic adding and subtracting. Card deck is especially designed for preschoolers. Card games in English and Spanish.



Food Fights, Puzzles, and Hideouts Book packed with hundreds of games, activities, and projects for K-5. Includes ways to mix math into crafts, cooking, parties, and car rides. Also available in Spanish: *Rompecabezas, escondites y batallas de comida*.



Jump Ship Card Games and Deck Fast-paced card games combining logic and arithmetic. Includes instructions for 22 games and card deck designed especially for young learners. Also available in Spanish: *Escapada y otros juegos*.

TO LEARN MORE ABOUT MIXING IN MATH PLEASE VISIT:

mixinginmath.terc.edu

facebook.com/mixinginmath



TERC at 50

Through the years *Hands On!* has been a major part of TERC's history, highlighting research, new learning materials, and professional development programs designed to improve the teaching and learning of science and mathematics. Even the title of the publication connects back to the beginning of TERC in 1965.

Arthur Nelson founded TERC as a nonprofit research and development organization dedicated to preparing a new generation of technicians to meet the demands of a changing society and economy. The guiding principle behind the design of the early programs is still central to TERC's work today—the educational power of a hands-on experience.

The very first issue of *Hands On!* was published in 1976 and since then TERC has produced 47 issues. We are pleased to offer this issue as part of TERC at 50, a year of reflection, celebration, and anticipation (August 2015–August 2016). In the four featured articles, you will see how TERC's programs continue to connect students to the practices of science and math through a hands-on learning experience.

— *Kenneth Mayer*

Executive Editor

Kenneth Mayer

Contributing Editors

Zoe Keller and Valerie Martin

Designer

Carol Maglitta, One Visual Mind

Co-Inventing the CLIMATE LAB:

First lessons from an innovative partnership

THE CLIMATE LAB

How is a Where's Waldo puzzle like a graph depicting fifty years of average temperatures? In both, the key elements to focus on are disguised by an overwhelming amount of visual noise. Despite the apparent jumble of information, each presents discernable patterns. The trick to finding the "signal" among the "noise" is to assemble a large amount of data.

Getting students in the habit of looking for the signal or trend in a data set is the goal of the first activity in a new climate change unit for the Climate Lab, a prototype education program at the Manomet Center for Conservation Sciences. Students begin the activity by looking at Where's Waldo search and find puzzles and consider the following questions:

- What is the purpose of the game? (*Answer - to find Waldo*)
- What is the purpose of everything in the puzzle that is not Waldo? (*Answer - to make it hard to find Waldo*)
- What help do we have in finding Waldo?
(*We know what he looks like, and we know he's there*)
- Based on this picture, would you be able to predict Waldo's location in other pictures? (?)

The activity then progresses as students continue to explore signal vs. noise in the context of weather vs. climate. They examine graphs showing the average annual temperature in Massachusetts over 50 years, first looking at small subsets of data from short periods. They consider several questions and make predictions and then continue their exploration by looking at larger sets of data and how those data sets impact their predictions of future temperature. These initial activities, along with several others focused on ecology and biology, comprise a one-week unit designed to help the Climate Lab participants get the most out of their field observation and data collection work, which is a primary part of the program.



IMAGE COURTESY OF MANOMET CENTER FOR CONSERVATION SCIENCES

Measuring leaf development: students participating in Climate Lab learn to collect and analyze data on biological climate change indicators.

THE CLIMATE LAB PARTNERSHIP

TERC is designing and field-testing activities in collaboration with the Manomet Center for Conservation Sciences as part of the Climate Lab project funded by the National Science Foundation. The Manomet Center is a research station headquartered in Plymouth, Massachusetts, on a bluff with a wonderful view of Cape Cod Bay. Their scientists, led by Trevor Lloyd-Evans, have been monitoring spring and fall migrant land birds since the late 1960s, and their work has expanded to include other bird research (for example, shore birds), as well as a growing program in climate change and sustainability education around New England. Their research has contributed to an understanding of how climate change is affecting familiar bird species and local ecosystems in New England.

Co-inventing the Climate Lab

First lessons from an innovative partnership



IMAGE COURTESY OF CREATIVE COMMONS - WIKIMEDIA COMMONS

Close up of red maple leaves



IMAGE COURTESY OF ALAMY

*Canada mayflower *Maianthemum canadense* leaves with raindrops in bed of moss*

TERC's participation in Climate Lab grows out of the Biosphere and Climate Initiative at TERC, which helps people learn about climate science by connecting them to the climate changes happening where they live, specifically those related to New England species and landscapes, and helping them find ways to act on their knowledge. The Climate Initiative's collaboration with the Manomet Center offers a great opportunity to design a program that links students and teachers with the long-term work of a research station. Students contribute their own observations and learn from the station's growing data sets. The project provides protocols and a connection to research questions of current interest while helping students and teachers learn science practices that they can use to investigate their own questions.

Students participating in Climate Lab create transects—a line on their outdoor school research sites along which they collect data year after year. Students from the pilot sites on the south shore of Massachusetts took measurements on their transects at specific times in the spring season of leaf size, dates of emergence, and similar information for various

common species such as huckleberry, Canada mayflower, or red maple. These data are added to the growing year-by-year database, contributing to the information that can help build an understanding of how the changing climate is changing a familiar landscape. Our project's aim is to develop a program which can be transferred to other settings, and involve in-school and also out-of-school learners (children and adults), thus supporting the growth of networks of investigation centered on field stations around the country.

CLIMATE LAB RESEARCH AND DESIGN

While TERC and Manomet researchers are designing the educational activities and materials, they are also designing a partnership and learning from the process to improve the project and to share lessons learned with other scientist-educator teams. We have identified potential challenges to the creation of a widely-adaptable model from the Climate Lab prototype, and are testing potential solutions for overcoming those challenges in our three-year research project. The following list includes some of the challenges:

Connections to middle school learning goals. Middle schools are implementing curriculum to meet specific learning goals. The Climate Lab program needs to meet those goals in ways that are fully transparent if teachers are to invest time in the program. Our materials have been tested in approximately 20 middle-school classrooms in the first year. In addition to the unit activities, we are developing teacher supports (both in print and on online) and professional development activities. The diversity of schools in our pilot will help us uncover how to meet the needs of a wide range of schools in different settings and with different resources of time, equipment, and access to field sites. This will be important as we prepare for the second year with a wider range of schools.

Access to scientists. The prototype for Climate Lab assumes a close connection between the researchers at the Manomet Center and the schools. For Climate Lab to grow into a model that can be adopted elsewhere, we need to replace the current need for the scientists to be physically present through the development of websites, guidelines, and other supports. During the second year we will include schools that cannot easily visit the Manomet Center to see the bird-banding work and are too far away for Manomet researchers to pay "house calls." Based on our experiences with the field trial, we are enhancing the web accessible resources which may include "how-to" videos, and possibly webcasts of bird-banding and data collection at the Manomet lab.

Transplantation to new sites. The first two years of the project will prepare us for the biggest step: adapting the innovation to test its transferability to other scientific partners. Our curriculum, teacher supports, and web resources should enable scientist-school partnerships in places as far away as Baltimore and California to adopt the Climate Lab approach, and adapt it to their local settings, including—research projects, species, and climate impacts. The Climate Lab team will advise and provide support from a distance, but this will be our most rigorous challenge to date. We will need to provide guidance and support for the scientists in the new locations, as well as for the teachers and students.

FOUR CREATIVE TENSIONS

The partnership includes overlapping expertise from both teams. The Manomet research scientist team has a long history with school groups, and TERC's Climate Lab staff of curriculum designers and education researchers includes research ecologists and biologists. Nevertheless, there are some “creative tensions” which require the partners to be alert to areas of misunderstanding or opportunities for growth. We at TERC have a lot of experience with school-scientist partnerships and the occasional issues that arise because of the different worlds that the participants inhabit. We have identified four creative tensions:

Local vs. global science. Scientists naturally place their detailed data collection into a “big picture” understanding of how the world works. Students (and often teachers) get focused on the minutiae of the transect, petri-dish, or quadrat. How do you keep the “big” present in the “little” for nonscientists? In our materials, we have sought in several ways to show how “signals” can emerge from “noise.” We’ve created whimsical activities such as the one’s based on “Where’s Waldo?” as well as more serious activities looking at trends emerging from long-term data such as the observations of birds taken at the Manomet Center for the past 40 years.

Science within reach of students vs. cutting edge science. The frontiers of science—even in a local ecosystem—can be some distance ahead of student thinking. Teachers are very aware of what their students are thinking and of how far their knowledge or experience may be from where the new science is being created. How do you connect the “research program” with the “curriculum unit,” so that the curriculum is enriched and enlivened by the collaboration, without too much being demanded of the students or teachers? We have tried to make sure that each aspect of the “fun stuff,” the field work, is related to a program of research about organisms’ responses to climate change—why these measurements relate to the basic biology and ecology of organisms which students are gaining familiarity with through their biology learning career from Kindergarten through 12th grade.

Time warps—it’s the banding season! The plants are leafing out! Oh, wait, it’s time for the annual state-wide student assessment! How to synchronize “scientist time” with “school time”? This one requires lots of communication between teachers and scientists about what their work schedules are like. Maintaining that level of communication is “simple” but hard! TERC can often play a role by noticing that more information is needed and sometimes interpreting one “culture” to the other.

Science research and the learning sciences. How do you design the program, materials, and supports so that students learn authentic science, and project staff can do scientific research about learning? How can TERC help our scientist partners “see” and be engaged by the questions of educational research we are studying? We have addressed this by making clear to the teachers that while they and their students are learning about the world—conducting research—and connecting their learning to Manomet Center’s research program, we at TERC are also engaged in studying how they are learning, teaching, and experiencing the changing world through questions, observations, and measurements. This helps to clarify what “data” means for each of these layers of inquiry, and gives everyone a share in the purposes of all three inquiries.

It is important to identify these “tensions”—not because they cause tension, but because by paying attention to them, we can all gain an understanding about the experiment we are conducting, and tell our story to help others who want to do something similar. Rather than finding that our differing perspectives are points of conflict or confusion, we can make them the subject of joint inquiry and learning.

The Climate Lab program will continue to develop so that it can be transferable to other partnerships between schools and research stations. It is our hope that the curriculum, teacher supports, and online resources will enable scientist-school partnerships in faraway states to adopt the Climate Lab model and adapt it for their location so that students can become researchers about climate change on their own landscapes and share in the important work of education about the science and implications of climate change. ■

Brian Drayton and Gillian Puttick are the TERC principal investigators for Climate Lab. Abe Drayton is the project lead curriculum developer. Trevor Lloyd-Evans is the Manomet Center principal investigator for Climate Lab.

Climate Lab is funded by the National Science Foundation (DRL-1417202, DRL-1417332.) Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

TO LEARN MORE:

manomet.org/climatelab
biosphereandclimate.terc.edu

HOW TO Count Bats

In summer in New Mexico, the natural entrance to Carlsbad Cavern beckons, offering shade from the sizzling desert sun. The path is steep and dimly lit. Visitors to the national park pause to take pictures of the glowing cave formations. Rangers do a last pass before the natural entrance closes at 5:00 p.m., walking down the main corridor past Witches' Fingers and Devil's Hump and shepherding visitors toward the elevators.



VIDEO MADE COURTESY OF NICKOLAY HRISTOV

The fascinating but challenging study of bats—small, fast-moving animals that live in darkness and travel in enormous numbers—is made possible by new technologies such as high-speed video photography.

While waiting for the evening bat flight, a dozen visitors of all ages take their seats in the theater of the visitor center. Ranger Eric begins his presentation with footage of bats circling through the air in front of the cave. His talk is illustrated with images gathered by researchers Dr. Nickolay Hristov and Dr. Louise Allen, biologists from Winston-Salem State University studying the Brazilian free-tailed bats, the main type that roost at Carlsbad Caverns.

Ranger Eric begins: "I'm an education ranger. I've been here four years, and I'm still figuring things out. Researchers are helping us understand our world and the world of bats."

During his welcome, Ranger Eric begins by asking what questions are swirling in visitors' minds based on their observations in the cave.

This is a departure from the typical ranger talk, which focuses on bats' importance in the eco-system. Instead, in this research-based talk, Ranger Eric emphasizes how we know what we know, rather than bat facts alone. He is changing his talks based on his experiences in the pilot *iSWOOP* program (Interpreters and Scientists Working on Our Parks). Rangers learn from *iSWOOP* to hold back and guide visitors to answer their own or each others' questions in order to build scientific literacy.



To better understand colony dynamics, researchers used a laser scanner to create a 3D representation of the bat cave.

The National Science Foundation-funded *iSWOOP* program aligns with the evolving mission of the National Park Service (NPS) in its second century. Once focused on maintaining land and building scenic roads, NPS will now play a strong role in informal science learning. “There’s a lot of research going on in every national park in the country, but that’s pretty much invisible to the visitor,” according to Dr. Allen. Our nation’s parks are the site of a great deal of research because they are protected places. In turn, research in NPS’s more than 400 sites informs decisions about wildlife protection, visitor access, preservation for geologic formations, the microbial world, and plants adapted to harsh conditions—decisions made more complex by recent changes in both weather patterns and land use.

The dilemmas NPS faces in achieving its mission of protecting and preserving public lands call for public engagement, and *iSWOOP* opens a window into the park-based research underway. Dr. Allen sees *iSWOOP* as a way “to bring scientists, educators, and interpreters together to foster a better understanding of science that’s going on in national parks, to really enhance STEM learning for visitors.”

The National Parks Service’s 3,400 interpretive rangers are an essential part of the process. “When visitors come to the national parks, the people they are going to be interacting with are interpreters,” explains Ellen Rohn, a Carlsbad Caverns park interpreter. “We’re the front line staff in many ways. We’re supposed to hold the answers to their questions.”

In *iSWOOP*, TERC is designing a professional development process to help park rangers bridge the gap between the public and the researchers. Project staff seek to build expertise within the interpreter and ranger community. Staff engage with the researchers on site, and they host sessions to help the rangers interpret complex data and ask informed questions of the researchers. When the rangers come to a deeper understanding of the research, their interactions with visitors are also transformed. Dr. Hristov refers to *iSWOOP* as “a sandbox where researchers, park interpreters, and educators come together to hone their storytelling skills and celebrate learning.”

While many Americans have visited a national park within the past two years, most won’t have the opportunity to hear about the scientific research occurring on site. Interpreters like Ranger Eric are working to change this reality by giving

visitors a view into the questions and technologies at work. Presenting to the audience in the park’s theater, Eric first invites questions:

VISITOR: “How far do bats fly?”

VISITOR: “Do bats poop upside down?”

VISITOR: “Does the number of bats correlate with the insect population?”

RANGER ERIC: “Thinking like scientists! I love it.”

VISITOR: “Could we find out more if we attached a camera to the back of a bat so we could see what it’s doing?”

RANGER ERIC: “You’re funded!”

VISITOR: “Is there an alpha or queen bat?”

RANGER ERIC: “There might be if my sister were a bat.”

Bringing research to the visitor experience

Current research is particularly compelling for visitors, especially if they get a glimpse of real, ongoing investigations. We live in a world where we expect to find instant answers to any question, and curious park visitors are no exception. Every night, visitors ask how many bats there are, which is also an essential question for NPS’s conservation mission. Anyone who has witnessed bat flight can see firsthand that there are too many to count—bats are small and fast, and they come out when it’s dark. Thanks to *iSWOOP*, the Carlsbad Caverns rangers are able to tell the full story.

Questioning the data

Ranger Eric begins the story by recounting the research a naturalist named V.C. Allison conducted in the 1930s. Allison published his method and his claim that nine million bats exited the cave in 20 minutes, equaling a rate of 500,000 per minute (Allison, 1937). Two decades later, other observers estimated one million bats in the colony, which was a much smaller figure than Allison’s. This discrepancy sent researchers scrambling to determine causes of the sharp drop in the size of the colony. Did nearly eight million bats die off in twenty years? What could have caused this catastrophic decline?

HOW TO Count Bats

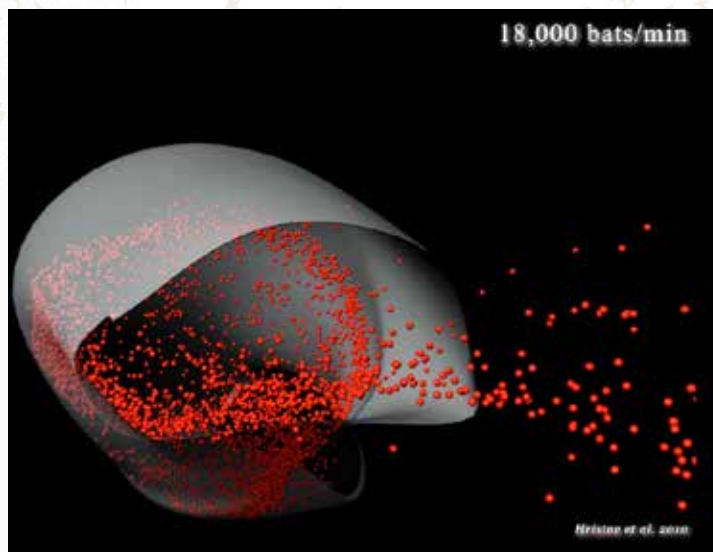
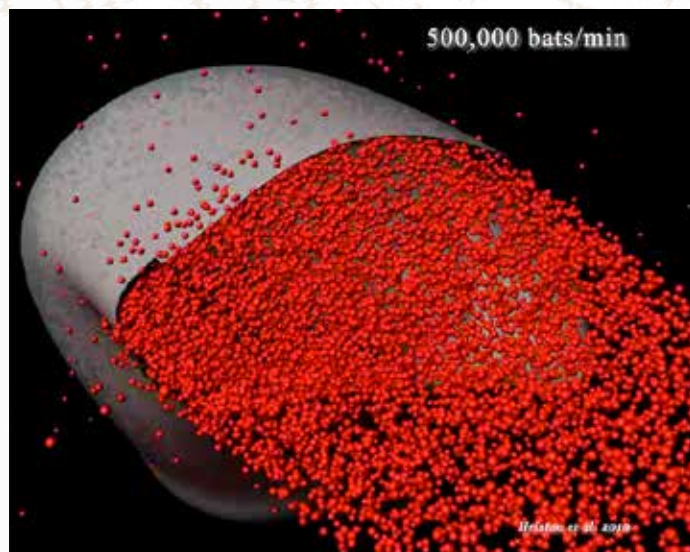
While early naturalists like Darwin recorded their observations in notebooks (still an important part of modern scientific research), Dr. Hristov and Dr. Allen study bats using new technologies originally developed for military purposes. Starting in 2004, a team from Boston University under the leadership of Tom Kunz began using high-speed and thermal video cameras to reveal details of bat flight, including the patterns in movements in and out of the cave. Like traffic study consultants, Drs. Hristov and Allen set up their video equipment in a spot where bats pass. The thermal cameras could sense and record warm bodies silhouetted against the cooler sky. They used a laser scanner to create a 3D exploration of the cavern's interior, or as Dr. Hristov calls it, "a cathedral of nature." And they used high-speed video to observe the flight patterns of individual bats within the undulating river of bats pouring out of the caves for their sunset feedings.

With the help of computers, Drs. Hristov and Allen tallied the numbers of bats over many seasons. Like the naturalists before them, they observed large numbers: up to 18,000 bats emerging in one minute, crowding the mouth of the cave. Dr. Hristov reevaluated Allison's estimate of 500,000 bats per minute and found these early findings to be unrealistic. If 500,000 bats had exited in a minute, spectators would have witnessed thousands of collisions. But how could he prove it?

“The experience for these visitors goes far beyond answering the question “How many bats are there?” They have encountered a moment of real scientific inquiry and leave wanting to learn more at other national parks.”

Based on the dimensions of the cave opening and the amount of space each bat occupies in flight, Dr. Hristov created a 3D animation of the bat emergence.

The resulting 3D animation is now part of the *iSWOOP* image library, making it possible for Ranger Eric to play it for the park visitors, who observe for themselves that Allison's estimate is likely inaccurate. They are quick to share their impressions of the cave model and the red dots emerging from it: “Looks like a bat meat grinder.” “Looks like ants.” As they view the numbers of bats spewing out of the cave, visitors laugh and express their disbelief as they come to an understanding that Allison's estimate cannot be right. Eric concludes the *iSWOOP* program by encouraging visitors to observe all they can, to walk with their eyes open, and to be curious.



To test the 1937 estimate of nine million bats, Drs. Allen and Hristov created computer models of bats flying out of the cave at a rate of 500,000 per minute, demonstrating the improbability of that estimation. Modern tracking software has recorded a much lower rate of 18,000 bats per minute.

VIDEO IMAGE COURTESY OF NIKOLAY HRISTOV

Wanting to learn more

The visitors are not ready to leave the theater just yet. They continue to call out questions about the cave, the bats, threats to this fragile population like disease, fire, and drought, and about the life of a park ranger. The experience for these visitors goes far beyond answering the question “How many bats are there?” They have encountered a moment of real scientific inquiry and leave wanting to learn more at other national parks.

Dr. Hristov feels that everyone has benefited from the collaboration between the researchers and interpreters. “It is very clear how invested, interested, and excited the interpreters are.” As for the researchers, Dr. Hristov reflects “we realized we lack significantly in the ability to communicate in an accessible way with the public so that we don’t rely on the traditional scientific jargon.”

“It could pave the way for a lot more interaction between other researchers here and the interpreters,” comments Ranger Rohn. “We have lots of people who come—microbiologists, cave climatologists, biologists on the surface—and yet we never have interaction with them, so I hope that *iSWOOP* could be a foundation to build on.”

When visitors to Carlsbad Caverns now ask how many bats there are, rangers have a number, a story, and a visual. They can show a video of the bats’ flight with the tally running at nearly 1,700 bats passing in a 10-second interval. They can tell the story of how Drs. Hristov and Allen and their colleagues figured out that on most summer nights, about 350,000 bats fly out of the cave. They can show graphs to illustrate fluctuations by season and precipitation. Through its focus on active research, *iSWOOP* builds public awareness of scientific processes and research, and reveals aspects of parks and their species that are complex, beautiful, and fragile.

REFERENCES

Allison, V. C., (1937). Evening bat flight from Carlsbad Caverns. *Journal of Mammalogy*, 18:80–82

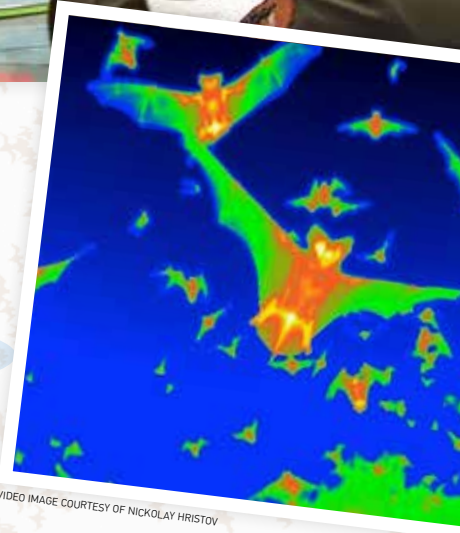
Martha Merson (TERC) is principal investigator and Nickolay Hristov (Winston Salem State University) is co-principal investigator for *iSWOOP*. Louise Allen (Winston Salem State University) is senior staff for *iSWOOP*.

iSWOOP is funded by the National Science Foundation (DRL-1323030). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.



VIDEO IMAGE COURTESY OF NICKOLAY HRISTOV

Park rangers, biologists, and informal education experts have come together to learn from one another. As a result, park visitors are drawn into the process of scientific inquiry, examining data like this thermal image.



VIDEO IMAGE COURTESY OF NICKOLAY HRISTOV

LEARN MORE ABOUT *iSWOOP* AT:

 iswoopcave.com

See images and video from Hristov and Allen’s research, read about high-tech research methods, Select Locations > Carlsbad for images and an interview with Dr. Hristov.

SEND COMMENTS TO:

 [@myswoop](https://twitter.com/myswoop)



Family, Friends, Neighbors, and Math: The Nana y Yo y las Matemáticas Project



Imagine a community center common room dotted with a dozen activity stations, each offering a lively way for caregivers to engage with their infant to five year old charges. At every station, children and caregivers—parents, grandparents, babysitters

and neighbors—explore the theme of the month, nature in our neighborhood, through a different lens, including math. For instance, at the science station, they make patterns with acorns and leaves gathered outside; at the healthy eating station, they use stickers to “vote” for their favorite locally grown fruit; and at the math station, they solve geometric puzzles based on images of local animals.

As adult-child pairs visit different stations, a facilitator circulates to model asking questions that spark children’s mathematical thinking to highlight the math inherent in the activities and to encourage caregivers to consider how and why they might do similar activities at home. With math critical to children’s futures—early math scores are the most important predictor of overall academic success (Claessens and Engel, 2013)—the caregivers are eager for children to approach math with enthusiasm, skill, and confidence.

Welcome to a typical morning at one of several Nana y Yo y las Matemáticas sites around San Jose, California. Funded by the Heising-Simons Foundation, Nana y Yo y las Matemáticas is a partnership between the YMCA of Silicon Valley and the MIXING IN MATH group at TERC. The project builds upon the Y’s Nana y Yo early childhood program, which simultaneously engages children and their caregivers in an informal preschool setting. As children experience a range of enriching activities, caregivers, many of whom have little formal education, gain skills promoting and sustaining children’s enthusiasm about learning.

Establishing an environment comfortable for local caregivers is fundamental to the Nana y Yo model. Program sessions, always free of charge, take place at neighborhood venues such as community meeting spaces, cultural centers, and library branches. Program facilitators come from the same demographic as caregivers. And, in order to ensure cultural resonance, facilitators design activities appropriate for the particular participants in each neighborhood they serve.

Prior YMCA evaluation has shown that the Nana y Yo model is highly successful in many areas but less so in math. Like many informal educators, the facilitators have had scant experience designing activities that engage children in exploring math content. Although Nana y Yo has tremendous potential for bringing many and varied mathematical experiences to caregivers and children, until recently, this potential went untapped.

“Although Nana y Yo has tremendous potential for bringing many and varied mathematical experiences to caregivers and children, until recently, this potential went untapped.”

More math meets Nana y Yo

Nana y Yo y las Matemáticas is bolstering the mathematical component of the program for all three audiences: facilitators, caregivers, and children. The aims are to expand the quantity, nature, and contexts of mathematical experiences for caregivers and children, and to broaden facilitators’ and caregivers’ understanding of young children’s mathematical development.

To accomplish these goals, the project in its first year is creating and piloting a sequence of math activities for Nana y Yo and weaving in elements of math professional development. The program is conducting ongoing evaluation to illuminate evolving math-related opportunities and challenges as they evolve and looking for signs of an impact on the facilitators, caregivers, and children.

TERC's MIXING IN MATH group is leading the mathematical components of the project, drawing upon a history of collaboration with informal educators to craft mathematically rich programs that resonate with local interests and projects, draw in the mathematically reluctant, and serve as a catalyst for change when in-depth math professional development is not feasible.

Designing for the realities of Nana y Yo

Through ongoing evaluations in the first months of the project, we identified several challenges and opportunities, and shaped project processes accordingly:

Activities must be self-guided and accessible to those with low literacy. Caregivers encounter the math station activities without a formal introduction as they move around the room, just as they would encounter exhibits in a museum. While nearly all caregivers speak Spanish or English (the languages in which we provide materials) some can barely read in either.

To offer guidance for those with low literacy in English and Spanish, we convey activity instructions graphically, with minimal accompanying text (Figure 1). To encourage sharing of mathematical thinking, we include sample conversation starters at a low reading level (labeled “Talk About” or “Para Conversar”). As needed, facilitators model these as they circulate by the math station.

Most math professional development needs to take place “on the job.” Although facilitators have some opportunities for reflecting on children’s mathematical development at monthly staff meetings, available time for this is minimal, given the many goals of the Nana y Yo program.

Activities are designed both as a way to do math and a way for facilitators to learn about mathematical thinking. As children and caregivers engage in math activities, facilitators and caregivers have an opportunity to observe children’s blossoming math abilities. As facilitators model conversation starters or listen in as caregivers do so, they gain first-hand experience with math talk that goes beyond reciting a correct answer.

Despite the desire for children to gain math skills, caregivers have historically been reluctant to congregate at the math station. Although facilitators encourage visits to all the stations, caregivers are free to focus their attentions as they wish, and math has never been a popular station.

To ensure that caregivers not only visit the math station but stay to thoroughly explore the activity and return next time, we asked facilitators which stations typically draw the largest crowds and why. We then incorporated features of those

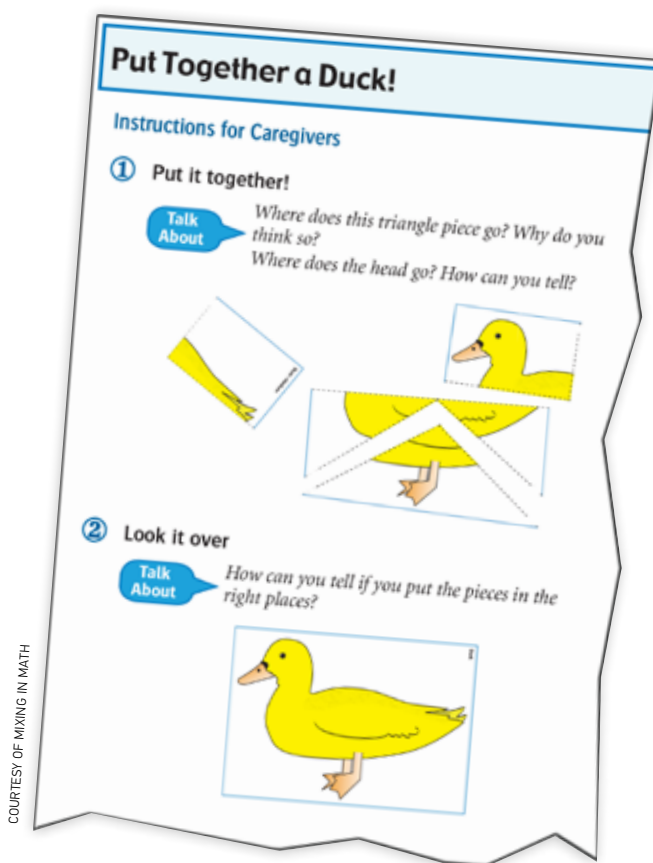


Figure 1. Sample math station activity, geometric puzzles. Instructions rely largely on images. “Talk About” conversation starters model ways to engage children in math talk.

stations into our math activities. For instance, we learned that crafts are very popular, so we incorporated a craft element into many of our math activities.

Facilitators are accustomed to creating their own curriculum. Community resonance is critical to Nana y Yo, so facilitators consider the particular families in the neighborhood when designing activities for each station. Nana y Yo y las Matemáticas is different because facilitators are given math activities to use. However, we design activities to be readily adapted to the specific community, while retaining a solid mathematical scaffolding. For example, the activity in Figure 1 can be adapted by using a different image with the geometric puzzle grid we provide.



FEATURE // BY MARLENE KLIMAN // CONTINUED

Family, Friends, Neighbors, and Math:

The Nana y Yo y las Matemáticas Project



Nana y Yo y las Matemáticas activities: Making counting books with fruits and vegetables, and sorting foods into categories.

Math experiences and understandings: What changes?

Although the final impact evaluation for the year is still months away, we compare pre- and mid-year data to offer initial glimpses of its impact.

IMPACT ON FACILITATORS

At baseline, the facilitators and the Y staff involved have expressed confidence in their ability to engage children in activities involving numbers. When asked to describe a favorite preschool math activity, they invariably mentioned one that culminated in counting a quantity or reciting a counting sequence. Facilitators acknowledged that they had less familiarity with geometry, patterns, measurement, and logic. They also noted that they would like to build their skills for engaging caregivers and children in math conversation.

At midyear interviews, several themes emerged:

Facilitators are altering their views of what constitutes a successful preschool math activity. After six months, facilitators said that some of their favorite math activities were projects and experiences that typically involved content other than numbers. One facilitator described an activity of measuring with paper chain links, explaining that it “showed me that something so simple could have so much math in it. And they can do it at home. We measured height, we made links to measure things in the room, and we made patterns out of links.”

Facilitators are learning, and learning to explain, that preschool math is more than counting and right answers. As the math portion of Nana y Yo has expanded to embrace content beyond numbers, facilitators report having had to justify to themselves and to caregivers that children are engaged in mathematical thinking and learning. One facilitator noted that when observing children doing a sorting activity, she realized—and later explained to a caregiver—that, “it’s logic, it increases visual skills, and you learn even if you get it wrong, because you see that things don’t go together.”

Facilitators are starting to model and listen for math conversation. They report a growing awareness of the role of communication in teaching and learning math. As one explained, “I’m learning that when helping caregivers do math with children, [I] model an example question.” Another described learning to listen for caregivers’ and children’s appropriate use of relevant math vocabulary like “circle” and “pattern.”

Facilitators are learning to modify the contexts of an activity while retaining the underlying mathematics. For instance, one facilitator described adapting a pattern-making activity so that it would align with a thematic focus on feelings. Instead of colored squares, she offered children three types of stickers—happy face, sad face, and neutral face—with which to make patterns.

IMPACT ON CAREGIVERS AND CHILDREN

At the beginning, all of our sample of caregivers reported wanting to learn how to help children build math skills, but few expressed confidence in their own ability to do so. Only 30% believed they knew how to support children’s learning in number and arithmetic, and only 10% in other topics such as

“Caregivers and their charges have come to enjoy math and to seek it out at the math station, throughout Nana y Yo, and in their daily lives.”

geometry, patterns, and measurement. Very few reported doing any kind of math at home with children, although nearly all said that they'd like to learn how.

Halfway through the year, we asked facilitators for their views on impacts on caregivers and children, and they reported changes that parallel their own—perhaps in part as a reflection of what facilitators are coming to observe and encourage in others.

Caregivers and children flock to the math station!

Facilitators noted the popularity of the math station, reporting “Their favorite part is the math. They go right to the math,” and, “Children and caregivers seem to enjoy math like it is one of the art centers. I believe it was something they used to be afraid of.” When asked why math is so compelling this year, facilitators talked about different types of activities, like crafts or movement, as well as the opportunities for communication. They also reported that the activities foster caregiver-child interaction, which is a fundamental goal of the Nana y Yo program.

Caregivers are initiating more math conversations, and not just about numbers. Facilitators report that caregivers are following their lead in using the conversation starters. Some caregivers use them as a springboard for their own math prompts. For example, while making patterns from colored squares, a caregiver followed the conversation starters to engage a child in describing the pattern. The caregiver then introduced her own open-ended questions, such as, “If I move this [colored square] here, how does the pattern change?”

Caregivers and children are increasingly adopting a mathematical lens. Facilitators report observing caregivers and children initiating math throughout Nana y Yo. One facilitator noted that after a caregiver and child explored patterns at the math station, they went on to an art station, and spontaneously began to make patterns of circles, squares, and triangles with play dough.

Caregivers and children are doing more math outside of Nana y Yo. Caregivers have shared with facilitators that children are eagerly showing family, friends, and neighbors the math activities they did at Nana y Yo. Several caregivers spoke of an impact extending to home life, like the mother who said Nana y Yo inspired her to engage her son in math through his daily chores. Now he also looks for those opportunities himself, such as pairing socks in the laundry, or giving out one of something to each person to share it fairly.

Communities are the key

Nana y Yo y las Matemáticas offers all three audiences a new vision of what it means to do math. Math is no longer focused on numbers, with activities structured around arriving at a single answer. It's now a rich arena for making, doing, and discussing, it's relevant to everyday experiences, and it's something to share with others.

The activities provide opportunities for caregivers and children to experience math together, they enable caregivers and facilitators to observe children's mathematical thinking, and they form the basis for facilitator professional development. Caregivers and their charges have come to enjoy math and to seek it out at the math station, throughout Nana y Yo, and in their daily lives.

While the desire to help young children achieve in math may be near-universal, it is essential that the strategies for engaging adults in that success be local—relying on factors ranging from locally prevalent forms of childcare, to caregiver demographics, to the status of math in the spectrum of priorities for the caregiver. As we look to the future with other YMCA programs and beyond, we know that our strategies and outcomes may vary, but our commitment to crafting approaches to math learning in partnership with community agencies will remain steadfast.

REFERENCES

Claessens, A. & Engel, M. (2013). How important is where you start? Early mathematics knowledge and later school success. *Teachers College Record*. 13(6). <http://www.tcrecord.org> ID: 16980

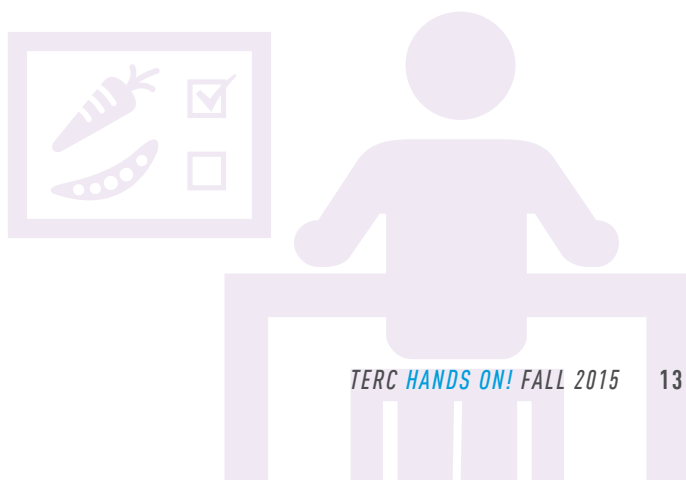
Marlene Kliman is the director of the MIXING IN MATH group at TERC.

The Nana y Yo y las Matemáticas Project is funded by Heising-Simons Foundation.

The author thanks: Mary Hoshiko Haughey, Morgan King, Lupe Rupalcava, the Nana y Yo facilitators at YMCA of Silicon Valley for making this project come alive; TERC colleagues, Valerie Martin, for finding ways to explicate math activities and ideas with images, and Nuria Jaumot-Pascual for research and translations; and the many caregivers and children who participate in the program.

TO LEARN MORE:

 mixinginmath.terc.edu
 facebook.com/mixinginmath



Digital Games

for Implicit Science Learning



The tablet screen displays a swirling blue circle in the upper left corner. A green ball is to the right. An arrow next to the ball and pointing in the direction of the swirling blue goal calls out for a tap to the screen. You tap near the green ball and it slowly moves toward the goal and enters it. The goal disappears to reappear in a new location along with some red balls now floating around the space. Another tap moves the green ball toward the new goal but this time some of the red balls are in the way. How do you avoid them? What happens if they collide with the green ball? Can you tap the screen to move the red balls too?

Creating Fun Games with a Purpose

The swirling blue goal and single green ball are the simple start of *Impulse*, a digital game developed by the Educational Gaming Environments (EdGE) group at TERC. It is one of several games being designed and tested by EdGE as part of a research effort to investigate implicit science learning in game-based learning environments.



In the free-choice game Impulse, players try to get their green ball to the goal without crashing into the other balls as they build a tacit understanding of Newton's laws of motion.

In EdGE we view games, like most forms of play, as a way to build implicit knowledge—knowledge that is not yet formalized in learners' minds (Polanyi, 1966). We seek to design games that kids do not view as educational. Instead we aim to create free-choice games—public games that people choose to play in their own time.

Players build foundational tacit knowledge from repeated, and increasingly complex, experiences in a game. They grapple with the game mechanics—the rules and challenges of the game—and in doing so they learn. In some games this learning can take place in meaningless or perhaps even socially unproductive contexts, but the EdGE games are designed to allow players to dwell in science. Players generalize solutions that help them become intuitively familiar with scientific phenomena that ground each game through the ongoing gameplay.

Impulse is built around Newton's laws of motion. It immerses players in a particle simulator where they must predict

In Quantum Spectre, a puzzle-style EdGE game, players use flat and curved mirrors, lenses, and other optical instruments to get lasers to hit targets.



“EdGE games are designed to allow players to dwell in science.”

Newtonian motion in order to successfully avoid collisions and reach the goal. The particles—balls of different colors—obey Newton’s laws of motion and gravitation. Players use an impulse, triggered by their touch or click, to apply a force to the balls. If the green ball collides with any ambient ball (red balls in the earlier example), the level is over and the player must start again. Each level of the game gets more complex, requiring players to contend with the gravitational forces of an increasing number of balls and also balls of different mass (and thus inertia). Within each level, players may impart up to 20 impulses. Each impulse depletes the energy available (measured by a green bar in the right corner). Once the 20-impulse quota is reached, the player no longer has energy left to apply additional forces to the balls.

Studying Game Play

Digital games generate a stream of player-activity data, which can be captured through digital logs. This data exhaust (Owen, Halverson, and Willis, 2012) can be used along with educational data mining (EDM) methods to detect learners’ patterns of play and reveal how those patterns change as players advance toward more successful and sophisticated gameplay (Baker and Yacef, 2009; Martin, et al, 2013). EdGE has built data mining detectors to “watch” implicit learning in our games. By analyzing the data logs generated during digital gameplay, we can detect the patterns in gameplay that are consistent with an understanding of the scientific phenomena underlying the game design.

In order to identify starting points for what to look for in the data logs, we reviewed video of more than 70 high school students playing *Impulse*. We began to identify strategic moves that seemed related to the physics of the game (Asbell-Clarke, Rowe, and Sylvan, 2013). Players were observed to develop gameplay tactics such as “let it float”—letting a ball stay in constant motion without exerting an external force (Newton’s first law of motion). Players also talked about wanting to stay away from the “heavy ones” because they take so many clicks to move, a strategy consistent with an implicit understanding that you would need to apply more force to redirect the heavier balls than you would to change the motion of the lighter ones (Newton’s second law of motion).

Through data mining, we have detected patterns of gameplay in *Impulse* that appear to show evidence of the same strategic moves identified in the video observations. The “let it float” strategy seen in the videos was also evident in the data logs. This strategy demonstrates an intuitive understanding that the ball will remain moving at the same speed and in the same direction if no external force is applied. While seemingly simple, this concept is elusive for many learners (McCloskey, 1983; diSessa, 1993), likely because we don’t live in a frictionless, gravity-free world. There are nearly always external forces upon us but not in the ideal world of a digital game. In the logs, we also saw evidence that players use more force to push the heavier balls than the lighter ones, which is consistent with an intuitive understanding of Newton’s Second Law: $\text{Force} = \text{mass} \times \text{acceleration}$.

Digital Games *for Implicit Science Learning*



With the return of Zoombinis, an award-winning game by TERC from the '90s, EdGE is researching players' computational thinking skills.



In the higher levels of the game, there are gray balls that have a heavier mass but a smaller diameter than the other balls. This was to differentiate if players were reacting to size or mass when deciding to use more force. Indeed, they used more force for the gray balls than any of the others, indicating that they were correctly reacting to the mass (Rowe, Asbell-Clarke, and Baker, 2015). Although the game does not explicitly explain, or even mention, Newton's laws, players are demonstrating through their gameplay that they understand the physics—at least at an implicit level.

Bridging Game-Based Learning to the Classroom

One long-term goal of our work is to use the data we collect from the gameplay to create a personalized, adaptive gaming experience for learners and to help teachers use the data to inform classroom instruction and discussion. We hypothesize that if teachers use examples from games, drawing on implicit game-based learning to “bridge” to explicit curriculum outcomes, students will be better prepared to learn new concepts in the classroom. Our early research suggests that when high school students play *Impulse* and their teacher uses and discusses examples from the game when teaching

Newton's laws, the students show greater learning gains on related test questions compared to students who didn't play the game or didn't have the teacher-led game-to-curriculum scaffolding. This is particularly true for students in non-honors and non-AP science classes, suggesting that games may be a powerful vehicle for supporting students who have been placed in lower level tracts for science learning (Rowe, Asbell-Clarke, Bardou, Kasman, and MacEachern, 2014; Rowe, Bardar, Asbell-Clarke, Shane-Simpson, and Roberts, in press).

Next Steps for EdGE

We are further exploring and building upon our model of game-based implicit learning through several research and design initiatives. This includes studying new constructs, such as computational thinking, the use of digital games to get people outdoors, the enhancement of available tools for bridging games and schools, and the inclusion of physiological, psychological, social, and neurological data sources in our research to build a more complete picture of implicit game-based learning. (See About EdGE page 17.)

In the SportsLab gaming environment, students develop 21st Century skills while competing in a parkour shoe design competition.

ABOUT EdGE

The Educational Gaming Environments (EdGE) group at TERC is a team of designers, educators, and researchers working together to study how game-based learning can be measured and then used for teaching and learning in and out of classrooms. Over the past six years, EdGE has been building games in online and wireless environments for the public so that they can grapple with intriguing mystery, puzzle, and action games grounded in science. Players learn how to survive in the wild as a bird, use mirrors to direct lasers through complex puzzles, or apply Newtonian mechanics to guide their ball to a goal without collisions. Players persist because they are having fun, and EdGE research—which involves looking at the “click” data generated through digital gameplay—shows that players are learning at the same time.

Selected EdGE Initiatives: Zoombinis and Computational Thinking—*The Logical Journey of the Zoombinis* was the first in a series of three computational thinking games developed by TERC in the 1990s. TERC and partners are re-launching *Zoombinis* for wireless devices (e.g., tablets) and new operating systems to reach a large commercial audience ranging from ages eight through adult. Building on prior research, EdGE is studying the cognitive strategies that emerge through *Zoombinis* game play. Researchers are looking at the data logs and employing other digital methods to study collaboration and social interaction in middle school classes that support the learning of computational thinking—the set of skills and understandings that learners need as they learn to program and build algorithms in computer science.

STEMLandia and Getting Folks Outdoors—When EdGE was founded in 2009, the aim was not to make more gamers, but rather to make all the time kids spend

in games more productive. This evolved into a mission to also use digital games as a vehicle to get kids back outside. Through the STEMLandia project (STEMLandia.com), EdGE is using location-based games, like Geocaching, to build STEM puzzles discoverable by exploring the local environment. EdGE is also looking at ways to add augmented reality tools to these outdoor games to allow learners to see the past, present, future, and imaginary changes of the world around them.

Taking Games to School and Bridging Games and Curricula—EdGE is building tools to help teachers use their students’ game-based implicit learning to help teach explicit science learning in the classroom. By providing teachers access to the same types of data that EdGE researchers use to study learning—and doing so in ways geared toward the needs of those teachers and the realities of classrooms—teachers will be better prepared and informed about what to do next in their teaching. Knowing where their students are in a game, what strategies they are developing, and where they are getting stuck, teachers can customize their lessons to get at the material kids need to work on.

Revealing the Invisible and Additional Measures—With MIT and Landmark College, an institute for higher learning for students with dyslexia, ASD, and ADHD, EdGE is examining how to infuse eye-tracking and other sensor data into game-based learning logs to inform the development of adaptive games that provide customized experiences to accommodate different learning styles.

SportsLab—EdGE is developing and testing SportsLab, a collaborative game-based interactive environment where students, ages 12-18, participate in a sport-product design challenge, such as designing a parkour shoe. Each team creates and submits a



concept model and pitch for a product design. Participants, sport researchers, and product experts determine the best pitches with awards for top designs. SportsLab brings pedagogical frameworks from game- and project-based learning together with a design challenge that fosters learning and understanding of 21st Century skills and STEM concepts. The ultimate goal is to test the effectiveness of a game-based STEM and ICT-infused design challenge in collaboration with industry partners as a way to motivate disengaged youth in ways that lead to potential STEM career paths.

The EdGE team is led by Jodi Asbell-Clarke and co-founders, Teon Edwards and Jamie Larsen. Elizabeth Rowe is the director of research, Erin Bardar is in charge of educational materials, Barbara MacEachern leads outreach and communication, and Katie Stokinger manages day-to-day operations. EdGE collaborates with research partners such as Columbia University's Teachers' College, North Carolina State University, and New Knowledge Organization.

EdGE Research is conducted through several initiatives including projects funded by the National Science Foundation under grants DRL-1119144, DRL-1415284, DRL-1502882, and DRL-1417967. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

- Asbell-Clarke, J., Rowe, E., & Sylvan, E. (2013, April). *Assessment design for emergent game-based learning*. Work-in-progress presented at the ACM SIGCHI Conference on Human Factors in Computing Systems (CHa'13). Paris, France.
- Baker, R.S.J.d., & Yacef, K. (2009). The state for educational data mining in 2009: A review and future visions. *Journal of Educational Data Mining* 1(1), 3-17
- diSessa, Andrea A. (1993). Toward an epistemology of physics. *Cognition and Instruction*, 10(2/3), 105-225. doi: 10.2307/3233725
- Owen, V.E., Halverson, R., & Willis, N. (2012). *CyberSTEM: Game-based learning telemetry model for assessment*. Presentation at 8th Annual Games+Learning+Society, Madison, WI.
- Martin, T., Aghababayan, A., Smith C., Olsen, D., Pfaffman, J., Phillips, R., Baker, S., & Janisiewicz, P. (2013). *Nanogenetic learning analytics: Illuminating student learning pathways in an online fraction game*. Paper presented at the Proceedings of the Third Conference on Learning Analytics and Knowledge. Leuven, Belgium.
- McCloskey, M. (1983). Intuitive physics. *Scientific American*, 248(4), 122-130.
- Polanyi, M. (1966). *The tacit dimension*. Chicago, IL: University of Chicago Press.
- Rowe, E., Bardar, E., Asbell-Clarke, J., Shane-Simpson, C., & Roberts, S. (in press). Building bridges: Teachers leveraging game-based implicit science learning in physics classrooms. To appear in D. Russell & J. Laffey (Eds). *Handbook of Research on Gaming Trends in P-12 Education*. Hershey, PA: IGI-Global.
- Rowe, E., Asbell-Clarke, J. & Baker, R. (2015). Serious game analytics to measure implicit science learning. In C.S. Loh, Y. Sheng, & D. Ifenthaler (Eds.), *Serious Game Analytics: Methodologies for Performance Measurement, Assessment, and Improvement*. New York, NY: Springer Science+Business.
- Rowe, E., Asbell-Clarke, J., Bardar, E., Kasman, E., & MacEachern, B. (2014). *Crossing the bridge: Connecting game-based implicit science learning to the classroom*. Paper presented at the 10th annual Games +Learning+Society conference in Madison, WI.

TO LEARN MORE:

 @EdGE_at_TERC  edge.terc.edu
 facebook.com/EdGEatTERC



Looking Back at *Hands On!*

The first issue of Hands On! was published by TERC in 1976 when the United States was celebrating its bicentennial. Perhaps the celebrations had an influence on the original editors, since there are repeated calls for a revolution in education in the inaugural issue.

The first editorial by Robert Tinker, then Principal Investigator of the Modular Course in Electronic Instrumentation at TERC, called for a revolution in education that would reflect the revolution in electronics and technology development. Bob, who later became TERC's chief science officer, was the initial force behind *Hands On!* He viewed the publication as a "grassroots cooperative venture among

educators who have ideas to share on ways to bring reality and practicality into teaching."

The excerpt below is from Bob's first of many editorials for the publication. We take this look back in time as part of **TERC at 50, a year of reflection, celebration, and anticipation (August 2015-2016).**

Hands On Electronics

(excerpts from the first *Hands On!* editorial by Bob Tinker, 1976)

There are two broad ways in which modern electronics needs to be brought into education. The most obvious problem is, of course, that the revolution in electronics needs to be reflected in a revolution in education; our instruction must be up-to-date. In many cases this means that adding to existing curricula or shifting its emphasis slightly is unsatisfactory. Entire courses and curricula need to be restructured in the light of the opportunities and special problems raised by the powerful new devices currently available.

A more visionary opportunity for education involves the application of modern electronics to teaching. In keeping with the "underground nature" of this newsletter, we will be particularly interested in low cost applications you have developed. In this category we envision powerful instrumentation opportunities for laboratories in all the sciences, inexpensive computer terminals, and a variety of simulators and demonstration devices. In this mode, modern electronics offers the opportunity to students for getting direct hands on experience with physical phenomena. — **Bob Tinker, Editor**

Hands On! issues from the late 1970s

One of TERC's early homes was Technology Square in Cambridge, Massachusetts, the infamous site of so many early computing research laboratories in the 60s and 70s.





Investigations Workshops
for Transforming Mathematics

Mathematics Professional Development for the Elementary Grades

Developed with the authors of the *Investigations in Number, Data, and Space* K-5 mathematics curriculum.

Some current offerings include:

- Computational Fluency
- Algebraic Reasoning
- Making Sense of Fractions
- Counting and Computation
- Implementing Investigations
- Principals' Institute

**Face-to-Face
Workshops**

Online Courses

**Blended Learning
and Customized
Programs**



TO LEARN MORE visit investigations-workshops.terc.edu

To stay current with new offerings sign up for the Investigations e-newsletter.



2067 Massachusetts Avenue • Cambridge, Massachusetts 02140

@TERCtweets terc.edu facebook.com/TERCed

Nonprofit Org.
U.S. Postage
PAID
Permit No. 375
Nashua, NH



For iOS and Android Tablets



Zoombinis – the classic research-based logical puzzle game from the '90's returns!

Build math & logic skills as you guide the Zoombinis through increasingly difficult challenges. Twelve perilous puzzles, 4 levels of difficulty, an appealing story, and memorable characters make for a fun, engaging experience for everyone (ages 8+).

***Zoombinis* was created to help players develop skills in:**

- Algebraic thinking
- Data analysis
- Graphing and mapping
- Logical reasoning
- Pattern finding
- Problem solving
- Statistical thinking
- Theory formulation and testing

I'm Arno the pizza troll!

Can you figure out the combinations of toppings to pass my challenge?

