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Perspective:

Is Remote Learning a Panacea for the Pandemic?

By Chad Dorsey

I'm concerned about the times we're in. But perhaps not for the reasons you expect. Yes, I'm concerned about the health and well-being of our globe in the throes of a staggering pandemic, and about its unprecedented toll on the economy. And yes, like so many others, I wish this all had never happened, or at least that it would all just go away. But therein lies the matter I'm most concerned about: I'm worried that we might return to normal.

When the pandemic first arrived, we recognized almost immediately that lockdown meant schools couldn't function as they had previously. In an attempt to get through the closing months of a school year, educators began offering whatever they had at hand. A massive shift occurred to anything-goes learning models, all pegged with the moniker "remote learning." While these ranged widely from multiple hours of synchronous Zoom instruction to periodic check-ins—or none at all—they were all hasty solutions to a problem that had caught everyone utterly by surprise. And they were about as effective as one would expect: zoned out kids, frustrated and harried parents, and millions of students left by the wayside.

This educational breakdown was no one's fault. While we certainly should have acted faster as a nation to contain the pandemic's spread, nobody expected already-strapped schools to have a contingency plan in place for such a dramatic and unprecedented shift in learning scenarios for all students.

However, this tumult disguised an ironic casualty: online learning. Amid the struggle of those first months, we did not take the time to emphasize that the educational experience these raucous times generated should not be interpreted as representing the power and potential of online learning. Because of this, millions of Americans' first experience with technology-mediated learning has brought about some serious misunderstandings of technology's value. And as we know, first impressions can have a lasting impact.

Opening school again across the country has been an immense undertaking, one involving extensive planning, broad anxiety, and significant social tumult. This work gave rise to multi-phase plans, with options and contingencies ranging from fully-at-home to hybrid. In the precious little time that remained, teachers had to jury-rig face shields, sanitize work stations, organize to protest unsafe conditions, or all of the above. Amid this pandemonium, it's not surprising that we missed the opportunity to really think through our approach to learning.

Perhaps for as long as classroom education has existed, a tacitly understood social contract has defined what students and teachers must do to fulfill their roles. Teachers are supposed to teach, and students are supposed to absorb what is taught. This transactional model of education runs deep in our national history and personal experience, significantly influencing our expectations of proper behavior and interaction. Educational reformer Ted Sizer helped showcase the effects of this agreement in his fictional account of a teacher, Horace, who exposed the implicit compromises in the teacher-student relationship: we both know this isn't challenging you, but we've got to get through it, so don't make a fuss and we'll just keep going. As Sizer wrote so clearly, "Very few high schools ever give their students a clear long-term academic goal and an equally clear signal that it's the student's responsibility to get there."

I'm not denigrating the generous and resourceful work of teachers—teachers have been doing ingenious things to help their students adjust to a new normal, especially considering the challenging limitations of this pandemic. But amid the rush to get some kind of meaningful curriculum in place, we repeatedly see unfortunate compromises taking place in high school and elementary school alike. Teachers are expected, even required, to provide information or lectures. Worksheets stand in as substitutes for reasoning and sense-making activities. Students sit restlessly, if at all.

And where does technology fit in this picture? Currently, it's plunked smack in the center, in a mediating role designated largely by circumstance. While video technology has been the hero of the pandemic, seamlessly connecting family and loved

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We stand at a juncture that will prove pivotal for educational technology's role in years to come.

ones across the country and around the globe and bringing everyone from colleagues to congregations "face to face virtually," the same attributes that connect us may have erected silent barriers to learning. First, both the form and the inherent constraints of synchronous video technology provide a too-easy pathway to providing what we know is less-than-ideal learning. In the process, technology becomes tightly associated with people's experience of "remote" (i.e., low-quality) learning, a scapegoat for all the issues and grumbles of our larger predicament. The second effect is more insidious—videoconferencing's present role as core mediator subtly reinforces the view that learning is something delivered from teacher to student. With actual transmissions as the main medium for interaction—in some cases literally beamed from a live classroom to those opting for remote learning at home—the concept of teachers as purveyors of knowledge reigns dangerously supreme.

There is an alternate scenario, one that casts technology in a different light and exposes the irony of the many complaints about remote learning. When properly used, technology can put learners in the driver's seat, revealing unseen worlds for STEM learning, and fostering key skills in collaboration, argumentation, critical thinking, and problem solving. Simulations and online environments can provide worlds that beckon students to explore natural principles. Tools for discovery allow learners to posit and test their own hypotheses, create and run models to investigate their ideas, and make original discoveries. With the proper use of technology—all available now and ready during the pandemic—teachers can actually step back, giving students agency over their own learning and allowing them to take responsibility for developing and communicating their ideas. Technology can serve as an incredibly rich platform for active learning, using tenets of online learning that have been well established for decades.

But wait, some might say—if our current situation is temporary, why worry so much about all this? Therein lies the problem. Rather than highlighting its amazing strengths, we're too often placing shallow uses of technology center stage. When the dust settles, what will we have learned? My biggest fear is that we may come away having acquired the view that remote learning means second-rate learning, and having learned to associate technology with compromised educational experiences in the process. In that scenario, a natural reaction would be to breathe a sigh of relief that we can return to normal, relaxing back into the now-even-more-familiar groove of teacher-to-student delivery that Sizer's Horace would recognize all too well.

We stand at a juncture that will prove pivotal for educational technology's role in years to come. If we take the right path, we have the opportunity to transform education itself for millions of students. But we must think carefully and broadly about how we use this moment, because the alternative could squander this opportunity or even set us back years in the process. The pathway to powerful learning is well understood. The freedom to make use of game-changing tools and resources lies before us, offering a much more promising future than a simple return to "normal."

Let's commit now to taking that second path. If we do, we can create a new, better future, one in which we see technology as an ally to high-quality, life-changing education, and in which we empower students to take control of their learning in new ways. Join us, and help pave the way to a *better* normal once the crisis has finally passed.

Learning Everywhere
During a Pandemic

By Sarah Haavind

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> *"I believe working with my students and actually having a job to go back to has helped to get my mind off the devastation that is all around me. My students and this class have really helped me through one of the most difficult and traumatic times in my life!"*
>
> – Sheree Caminita, following Hurricane Katrina

You may remember Katrina, back in 2005, a Category 5 Atlantic hurricane that devastated Florida and the Gulf Coast. More than 1,800 people died and thousands were displaced from their homes. Schools faced a serious challenge; the hurricane had scattered their students as schools closed or were destroyed. The Louisiana Department of Education and the Louisiana School for Math, Science, and the Arts knew that more courses would have to be taught online. That's when the Concord Consortium stepped in to offer professional training to 75 additional Louisiana teachers on how to deliver courses in the Louisiana Virtual School. COVID-19 is causing an even more widespread need for online learning and for teachers who know how to provide those courses. And once again, the Concord Consortium has offered online training to teachers in several of our research projects.

Online learning is not new to us. In the 1990s we designed and built the first virtual high school (now VHS Learning). We pioneered new approaches to deepening online learning through the Concord Consortium e-learning model and books on designing and facilitating online courses.* We understand how to support teachers to deepen remote learning using tools that allow students and teachers to meet online in real time or asynchronously. Remote teacher professional development, when designed properly, can provide quality learning.

> *"Inquiry can be done anywhere, but inquiry in a remote setting is more challenging," explained Concord Consortium Teacher Ambassador and Falmouth, Maine, physics teacher Andrew Njaa, who has been collaborating with us since those early days. "What makes it easier is having a platform and online space to manage and carry out inquiry, plus the expertise to help make that inquiry clear and relevant to students. That's where the Concord Consortium shines."*

In June we began offering professional development workshops online for several of our National Science Foundation-funded projects, from inquiry-based learning and data exploration to mathematical modeling, watersheds, geohazards, and more. Building a successful remote learning workshop has three primary elements: 1) building caring, supportive learning communities at a distance, 2) facilitating inquiry learning over videoconference, and 3) deepening online discussion by design.

Building caring, supportive learning communities at a distance

Building a successful community online is about building trust and a sense of safety for the participants. Teachers know how to do this naturally in myriad ways in brick and mortar settings, but that sense of safety and trust can also be nurtured at a distance through simple, specific strategies:

- Reach out with informative emails early and often, to the whole group and individually to each participant to build a sense of caring, safety, and connection.
- Use a warm tone in written communications to mitigate the tonelessness of plain factual delivery.
- Disseminate a simple checklist of to-do's up front so participants can feel confident they are on track.
- Offer an optional virtual meeting to practice new communication skills and features, such as using chat, raising your hand, using reactions, etc.
- Before each session, open the videoconference room a half hour before the official start time. Invite participants to stop in early to chat informally.

- Establish group norms, such as starting on time, muting mics, and changing screen backgrounds or using other features to attend to privacy concerns.
- Begin each session with any clarifications or responses to feedback, setting a tone of mutual respect and collaboration.
- Establish regular videoconference "office hours" when participants can just drop in for a quick question.
- If possible, plan for flexible breakout rooms (and pre-assign staff roles) to provide extra support "on the fly" when just one or two participants have an urgent question, or if someone joins late and needs to get caught up.

Our teachers appreciated the deliberateness that went into building community. Judy Pavao, a biology teacher from Hudson, Massachusetts, liked all the pre-planning—*"Thank you all for the work you did in making this workshop seamless"*—and Ann Pottebaum from Carroll, Iowa, was enthusiastic about the GeoHazard workshop: *"I loved the breakout activities, very well planned and always kept our team engaged and active! We covered a lot in a small amount of time!"*

Adhering to these specific strategies builds trust and confidence in the group. But can you replace dynamic inquiry workshops in hands-on physics, biology, and chemistry, which would have met in university science labs, with remote learning? And how do you replace direct experience supported by discussions of pedagogy, Next Generation Science Standards teaching approaches, and our curricular design principles? Of course, you can't entirely replace the face-to-face experience, but there are multiple ways to make remote learning meaningful and worthwhile.

According to Njaa, the physics teacher from Maine, who also joined us for a July 2019 InquirySpace workshop, *"The pivot from the face-to-face workshop at Endicott College last summer to an online workshop was surprisingly painless for me."* But he recognized the amount of planning that was necessary in order to make every hour of online time useful. *"You created small, safe spaces to experiment and try out new materials, and to talk and share work in a virtual space. It was truly productive time, and refreshing after spending so many hours already since March in front of my computer."*

Facilitating inquiry learning over videoconference

Many of our workshops asked teachers to develop their own activity or project in a collaborative context where the learning also came from the exchange of ideas. For example, the InquirySpace project supported teachers in designing their own inquiry-based experiments that use data analysis with CODAP (Common Online Data Analysis Platform), activities students can do at home. A combination of independent work and live videoconferencing introduced teachers to our inquiry framework and design principles for developing inquiry-based activities. Working in small groups to build CODAP skills for biology, chemistry, and physics classes, teachers then designed and shared an activity they could assign at a distance for hybrid or remote classes.

Pam McDonald, a chemistry teacher from Hudson, Massachusetts, enjoyed *"seeing the ideas and lessons developed by others, which gives me more ideas for other lessons."* Shawn Guerrette, a physics teacher from Cape Elizabeth, Maine, also appreciated "*getting to share ideas for physics exploration activities for distance learning.*" Indeed, for Guerrette, this was *"the high point"* of the online workshop.

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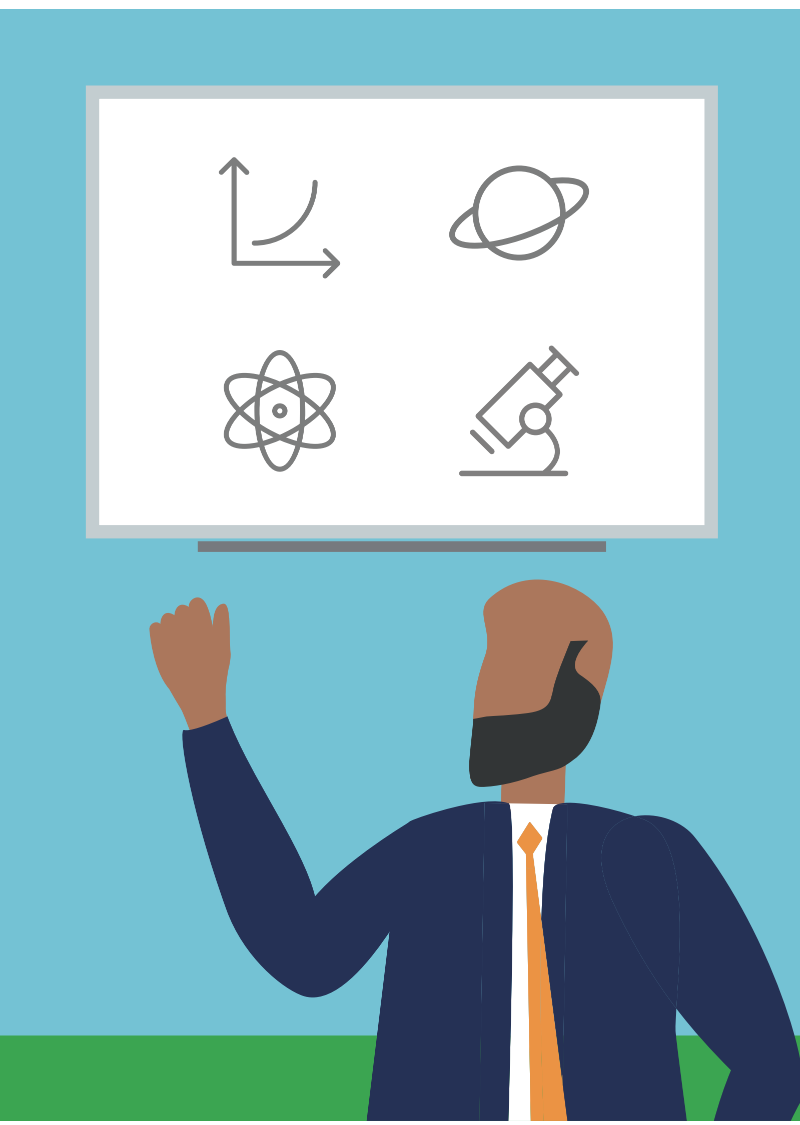
A few specific strategies help to ensure videoconference-based professional development is well received:

- Mix it up and encourage interaction. Use jigsaw grouping and design other small-group activities for cross-pollination of ideas and to increase learner input and voice.
- Use a shared virtual document to exchange resources with a "parking lot" section to temporarily table interesting ideas.
- Collect daily feedback using "exit ticket" surveys at the end of each day. Be open to feedback, responsive, and when possible, adjust plans based on suggestions.
- Structure opportunities for peer review that are designed to assure everyone gets timely feedback. Provide a rubric so reviews are supportive and less like critiques, valuing the positives and offering suggestions for how challenges might be addressed.
- Plan videoconference sessions for three hours or less, incorporating breakouts, active participation, varied activities, and regular breaks.
- Use polling where possible and hand-raising tools to quickly assess participant reaction.
- Purposefully build in networking opportunities.



Deepening online discussion by design

Many of our projects added an asynchronous professional learning community (PLC) to the workshop in order to model online activity designs for deepening online learning. For example, after teachers read an article, we organized conversations into discipline groups and provided specific instructions about how to contribute: "Please respond to at least two of your discipline group colleagues' initial postings by extending a thought, adding an example, sharing an experience, offering a caveat or consideration, asking a question for clarification, or otherwise interacting. Avoid evaluating your colleagues' contributions."

Other strategies make an online PLC useful for learning beyond just sharing resources and answering specific questions:

- Allow participants to find and practice their online voice in low-stakes conversations before talking "real science."
- Create separate "Teachers' Lounge" and "Help" discussion threads to keep content-based discussions focused. If appropriate, consider including discipline-based discussions for extended networking and idea exchange in specific subject areas.
- Optimize participant flexibility by specifying the asynchronous reading and discussion assignments up front so that tasks can be completed based on personal schedules.

The school year has started and teachers are feeling the strain of having to be flexible about how class is delivered each day. Only a few are back in school with their students daily. Instead, multiple hybrid models are emerging across the country and positive COVID tests have closed down schools with little warning. Pivoting our plans to offer remote summer workshops provided us with a small glimpse of the challenges teachers are experiencing this fall, and we commend their incredible efforts.

> *"I am grateful to be part of a collaborative team of experienced teachers who have diverse experiences and skill sets across various STEM disciplines," noted Emerlyn Gatchalian, a physics, chemistry, and biology teacher and Concord Consortium Teacher Ambassador from Hercules, California. "Together we hone our teaching skills in a way that sustains learning and builds craftsmanship and resilience to better prepare us in this new way of teaching and learning."*

And as Thomas Cooper, a teacher in our CodeR4MATH project, suggests, *"There are all these issues about how working online can highlight issues of equity, but technology can also give us a common place to start a journey towards understanding each other."*

For this reason and more, we hope that some of the strategies teachers have adopted from their experience with remote professional learning will prove useful beyond the pandemic and find a more permanent place in their pedagogical toolkits.

* https://concord.org/our-work/publications/books/

Monday's Lesson:
Finding Your Watershed

By Carolyn Staudt, David Kline, and Joyce Massicotte

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From filling reusable water bottles to taking showers, students use water all the time. But do they know where their water comes from? The Watershed Awareness Using Technology and Environmental Research for Sustainability (WATERS) curriculum helps middle school students explore the health of their local watershed, investigate the impact of humans on their watershed, and learn about water-related careers.

A watershed is a system defined by the area of land over which all water drains downhill through streams and rivers to a common outlet (river, lake, bay, or ocean). Water that runs over the land as runoff or in streams and rivers flows downhill, directed by the topography. A divide is a ridge of land where water flows in opposite directions and forms the boundary of a watershed. Each stream has a divide that separates the area of land that drains to that stream from other watersheds. As streams flow together, watersheds combine to form a larger land area that drains to a common river.

Model My Watershed

Model My Watershed® is a free web-based geographic information systems (GIS) app that includes U.S. Geological Survey (USGS), U.S. Department of Agriculture, and other scientific datasets for watershed modeling across the lower 48 states (Figure 1).

1. Go to ModelMyWatershed.org. Enter your school's address and press return on your keyboard.
2. Click the "Basemaps" icon in the Layers box and select the different layers to explore the area around your school.
3. Identify the first body of water downhill from your school. This is your school's primary watershed.
4. Set the basemap to "Satellite with Roads" and click "Get started" in the left panel.
5. Click the down arrow by "Select boundary" in the left panel and choose "USGS Subwatershed unit (HUC-12)." The USGS uses the hydrologic unit code (HUC) to classify the size of watersheds.
6. Red lines appear on the map to outline local watersheds. Hover the cursor over your school to see the name of your watershed. (You may need to zoom out.)
7. Click on your school property to see its subwatershed. Zoom and scroll to explore the map.
8. To see how the subwatershed units combine to form larger watershed units, click "Change area" at the bottom of the Analyze panel, then "Select boundary" and choose "USGS Watershed unit (HUC-10)."

Ask students to reflect on:

- Where does water flow in a watershed?
- What is the closest body of water downhill from your school?
- If pollutants were added to the local watershed around your school, what other areas would be affected by the pollution?

To dive deeper, click "Delineate watershed" in the left panel, select "Continental US," and click the map to mark a point of interest. The app determines the path that water flows downhill from this purple button to reach a body of water (blue button). It also outlines the total land area where water drains to that location (the primary watershed), and analyzes this area with data on streams, land cover, soil, and more. (Note: If the landscape is too flat, the app may not be able to draw the watershed.) Download the data for even further exploration. Model My Watershed offers multiple opportunities for investigation, so students can explore just like water scientists.

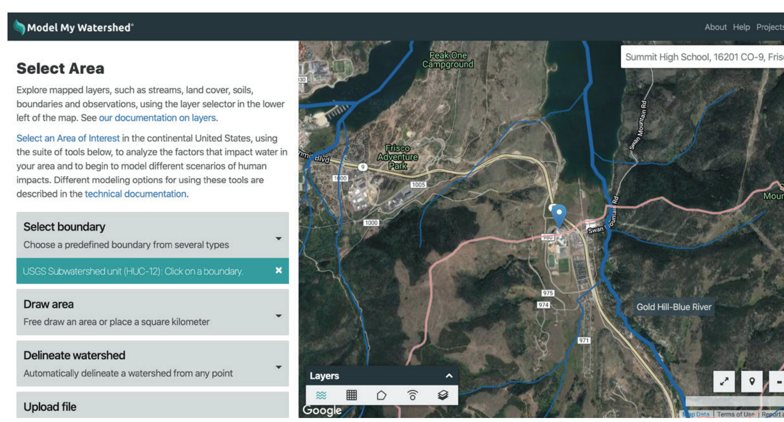
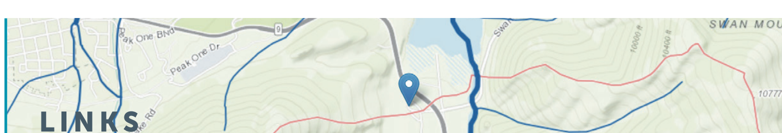


Figure 1. Model My Watershed® basemap for Summit High School, Frisco, Colorado, with Continental US Medium Resolution Stream Network.



LINKS

WATERS
concord.org/waters

Students Learn Genetics **with Geniventure**

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Our mission is to ignite large-scale improvements in teaching and learning through technology, so we're especially interested in how our free educational technologies fare in the classroom after the funded projects that produced them have ended. Recently, we have been studying students' learning of genetics through their interactions with Geniventure, an immersive digital game designed for middle and high school students that features a narrative about dragons.

In Geniventure, a war has broken out between kingdoms, endangering the dragon population. Each player breeds drakes—the model species for dragons—to help win the war and prevent dragon extinction. A diverse cast of characters in a scientific guild presents 65 challenges that require students to learn about drake genetics. As they progress through the game, the software logs each student's actions. Some actions are productive, moving the student closer to the goal, some are counterproductive, and some are simply redundant. Students' ability to discriminate between these possibilities, informed by their understanding of the underlying genetics, can be estimated by examining their actions. We applied this strategy to the analysis of a subset of the challenges.

The target-match challenges

There are 22 target-match challenges, each with a common goal: to change the genes on a drake to make it look like a target drake, randomly generated at the start of the challenge. The challenges also set a subsidiary goal—to achieve a match with as few moves as possible, where a move is defined as either a change to a gene or a sex change. The minimum number of required moves is calculated by the game, based on the phenotype (the set of observable traits) of the target drake and the initial genotype (the genetic makeup) of the manipulable drake (Figure 1).

Students who reach the target state making no more than two moves over the minimum number are rewarded with a crystal, the color of which denotes how successful they were. Achieving a match with the minimum number of moves results in a blue crystal—the most prized of all. One excess move results in a yellow crystal; two excess moves and the crystal is red. Matching the target drake with more than two moves over the minimum is counted as a success, but students are not awarded a crystal. If the drakes do not match, the student continues the challenge with the same target drake; if they do match but the number of moves exceeds the minimum, the student is offered the chance to try to achieve a better crystal by repeating the challenge with a different target. Thus a single challenge can give rise to multiple attempts.

The target-match challenges occur in four clusters throughout the game, separated by challenges of other types. Each cluster starts with the manipulable drake continuously visible to the student, sometimes changing its appearance after a move in accordance with an underlying model of drake genetics. (For instance, if the student changes ww to Ww, the drake transforms from wingless to winged.) In this condition, students can make as many moves as they like, observing the effect each time, and only submitting their drake when it looks exactly like the target drake. The fact that they can immediately observe the effects of their moves encourages students to experiment in order to work out the mapping between genotype and phenotype.

After two or more challenges with a visible drake, the challenge changes to the "hidden" condition: the manipulable drake is represented by an unhatched egg and becomes visible only when the egg is submitted (Figure 2). In the hidden condition students must match the manipulable drake to the target just by observing its genes and applying their knowledge of the genotype-to-phenotype mapping.

The visible-mode challenges are intended to prompt experimentation and inquiry, while the hidden challenges act as embedded assessments of content knowledge. The shift from visible to hidden conditions repeats in the four clusters of target-match challenges, each involving a different set of traits and a more complex mapping (for example, color is determined by more than one gene).

The target-match challenges are useful for inferring a student's mental state because they are not limited to correct or incorrect matches but involve the sequence of actions that resulted in that outcome, actions that reflect a student's understanding of genetics. To quantify students' performance we developed and automated a scoring rubric that takes into account both the number of times a student attempts a challenge and the best crystal color awarded on that challenge.

Two research cohorts

In order to assess the effectiveness of our Geniventure game to teach genetics, we compared two cohorts of students taught by teachers who had different preparation. The first group of teach-

Figure 1. A "visible" target-match challenge. When the student changes the genes in the left panel, the middle drake changes its traits accordingly. The challenge is to make it look like the drake on the right.

Figure 2. A "hidden" target-match challenge. In this mode the drake is represented by an egg that doesn't "hatch" until the drake is submitted. To solve this challenge the student must understand how a drake's genes affect its traits.

ers took part in our research project and participated in face-to-face professional development while the second group of teachers registered independently and did not have additional training.

During the spring of 2019, the six teachers who participated in our National Science Foundation-funded GeniGUIDE research project implemented Geniventure in their classrooms. All had participated in a three-day workshop and were familiar with the game and its underlying science content and pedagogy. All administered identical multiple-choice tests to their students before and after they played the game. These students constitute our *research cohort*.

Later, between August 2019 and April 2020, 510 teachers outside our research project registered to use Geniventure. Of these, 22 administered both the pre- and post-test. Their students constitute our *extended cohort*.

After filtering out students who did not complete all the target-match challenges, as well as those who failed to answer at least 95% of the items on the pre- and post-tests, there were 338 students in the research cohort and 433 in the extended cohort. We matched the students' scores on the post-test to their pre-test scores and their target-match challenge scores in both the visible and hidden conditions.

Findings

- Based on a two-tailed t-test, the means of the students' post-test scores were significantly higher ($p < .001$) than the means of their pre-test scores. This was true for both cohorts. The effect size (Cohen's d) was 0.83 for the research cohort and 0.57 for the extended cohort.
- Using pre-test score, visible-challenge score, and hidden-challenge score as the independent variables, the post-test score was significantly correlated ($p < .001$) with pre-test score and with the challenge score in the hidden condition but not in the visible condition. This was true for both cohorts.
- Adding cohort as an independent variable to the regression analysis did not significantly improve the fit. Thus, on these measures the two cohorts are statistically indistinguishable.

Discussion

Students in both cohorts improved their knowledge of genetics as measured by a multiple-choice assessment, evidence that the research project is having a broad impact. Their post-test scores correlate only with performance on the hidden target-match challenges, consistent with educational theory in that the visible challenges probe for inquiry skills rather than content knowledge. The significant correlation between in-game performance and summative test scores justifies using one as a proxy for the other. This will enable us to analyze log data generated by students who use Geniventure but do not take the pre- and post-tests, including those who use the software remotely. Next, we will investigate the extent to which the Geniventure materials may be successful even in the absence of face-to-face contact with a teacher.

LINKS

GeniGUIDE
concord.org/geniguide

Mathematical modeling of real-world problems

By Kenia T. Wiedemann

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Insights from mathematical models make the headlines daily, though the accompanying numbers and graphs do not always make sense to the uninitiated. What makes it difficult for models to agree on climate change predictions? Why is it so hard to predict and mitigate the impacts of a pandemic?

Exposing students to authentic problems equips them with sophisticated problem-solving skills that are essential to succeed in future job markets and to thrive as global citizens. The Computing with R for Mathematical Modeling project (CodeR4MATH) is developing mathematical modeling activities within an interactive online environment that help high school students apply mathematical concepts and skills such as writing equations and reading and understanding charts to solve real-world problems. Students explore open-ended questions using real-world data and a powerful and popular programming language.

Mathematical modeling activities

Mathematical modeling activities are a common component of computer science (CS) courses. However, not every secondary school offers CS courses, and when they do, the courses are typically electives. By bringing real-world mathematical modeling experiences to high school math classrooms we aim to provide students and teachers with the opportunity to exercise computational thinking through math modeling using the R programming language, an environment for statistical computing and graphics that is widely used by academics and data science professionals worldwide.

CodeR4MATH activities are designed to help students explore how mathematics and computation can be combined to build models that represent and help make sense of the world around them. While CodeR4MATH activities mimic the types of challenges and learning processes that professionals face when solving problems, various levels of scaffolding are available to students through pre-populated code snippets, hints, prompts, and quizzes.

The CodeR4MATH activities follow a common pattern. First, they present a real-world situation and pose an open-ended question, then they guide students through the process of brainstorming the problem, making assumptions, and defining the essential variables. This culminates in a simplified description or model of the problem. Students then create algorithms to solve the simplified model, testing their algorithms and assumptions by coding in R. By the end of each activity, students have a mathematical model in the form of computer code, representing a solution to the simplified version of the original, open-ended problem. Students revisit their list of initial assumptions, with the goal of improving their models.

In the "Lifehacking with R" activity, each student assumes the role of a college advisor, responsible for giving financial advice to first year college students who need to decide whether to purchase a meal plan or pay for food on a per meal basis, called simply "meal plan" and "pay as you go." Students quickly realize that one size does not fit all. In addition to the financial aspect, the answer may depend on other factors, some of which are hard to quantify, such as personal preferences and values.

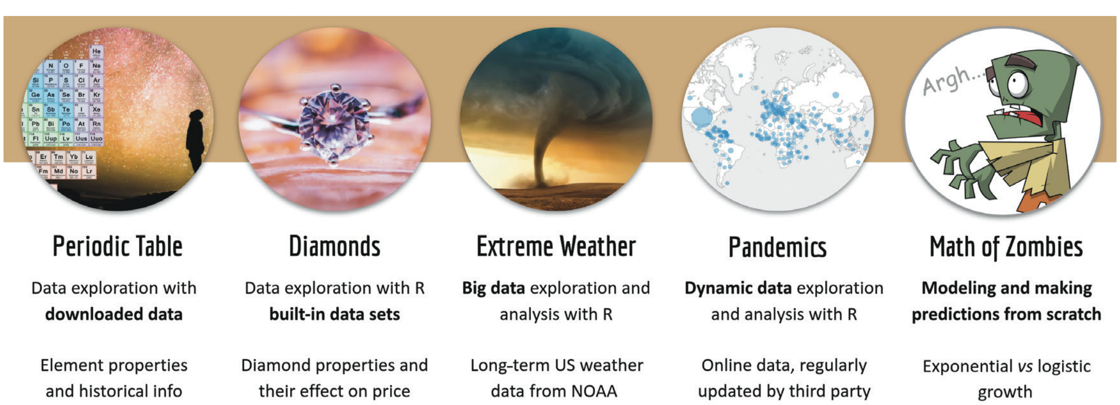

Figure 1. New CodeR4Math activities for secondary students.

Brainstorming bare necessities

The first step is to brainstorm the problem. Students are given the cost of a meal plan at a specific college as well as hypothetical costs for each meal. They are told that the college has many restaurants at its campus center, and receive a list of several. Students are free to use any search engine to browse these restaurants, the kinds of food they serve, prices, and more. They are asked to jot down anything they think would influence the decision. To start, they consider the financial aspect. What is the cheapest option? What factors control the costs?

Creating algorithms and the first steps of coding

Keeping the initial assumptions in mind, students experiment with several code snippets, already populated with a full or partial R code (Figure 2). The activity offers high scaffolding when the student runs existing code to check the output, medium scaffolding when the student can modify a small portion of the code and run it to check the new output, or minimal scaffolding when the student follows examples to add new elements such as new variables or mathematical expressions. If code changes prevent it from running, a "Start Over" button allows the student to reset to the original code. Students also have access to hints with templates that help them modify their code with new equations and graph outputs. After students submit their work, they can see the solution.

Data-driven models and the impact of visualizations

After exploring and working with some code snippets, students dig into real datasets. They are able to explore tables (which R calls "data frames"), extract statistical information from different variables, explore relationships and dependencies, work with data visualizations, and compare results. Figure 3 shows some of the elements that can appear in the CodeR4MATH activities, such as code snippets, outputs like statistics, graphs, and tables, and multiple-choice and open-ended questions.

Conclusion

Almost 140 students have participated in classroom implementations of CodeR4MATH activities. Our results have shown that even students who have never done any prior computer programming are able to understand mathematical modeling and how professionals use computer programming to create, test, and validate models.

Through CodeR4MATH activities, students learn to apply the iterative process of mathematical modeling: defining the problem, making assumptions, simplifying the problem, defining variables, getting solutions, validating the model, and reporting results. Throughout the process, students engage in computational thinking while learning the basics of coding in a widely used programming language. The teacher's role is to spark and facilitate brainstorming, control the pace of the activity, provide feedback to students, coordinate group or individual projects, and evaluate student work.

With a new set of activities, we hope even more students will have the opportunity to make sense of real-world problems through math modeling (Figure 1, see page 10). Teachers and students can access free web-based CodeR4MATH activities without downloading software or registering for accounts using any computer with a current Web browser.

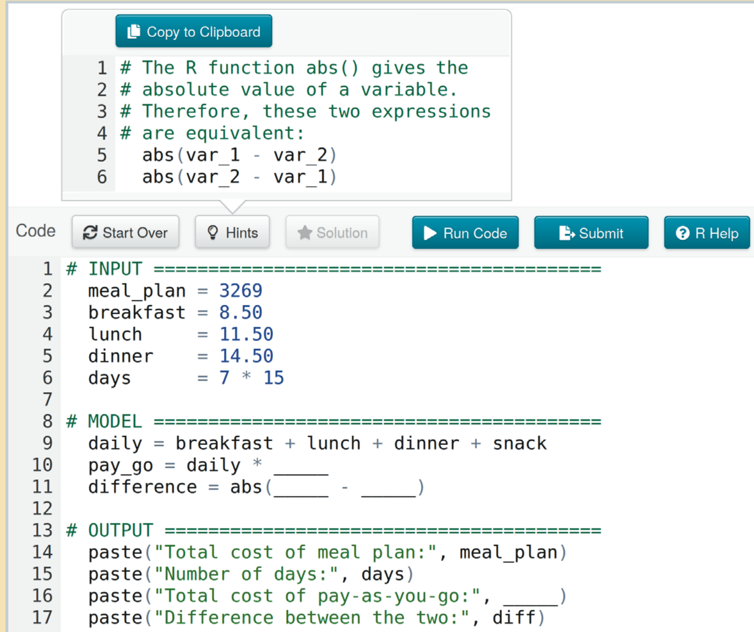

Figure 2. Example of an exercise from a CodeR4MATH activity with an R code snippet for students to complete and run. They can start over or check hints at any time, and the solution becomes available after they submit their work.

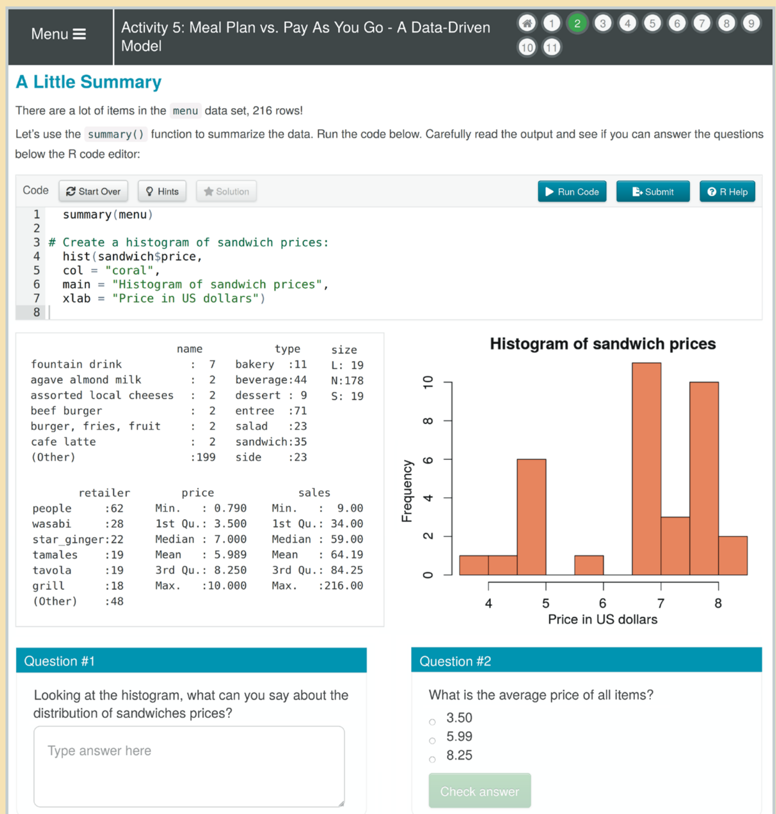

Figure 3. R code snippets and their outputs, including graphs, statistical information tables, and open-ended and multiple-choice questions.

LINKS

CodeR4MATH
concord.org/codeR4math

Independent Experimentation for the Remote Classroom

By Tom Farmer

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Every teacher has heard the student plea—"Just give me the answer!" As practitioners, we often want to provide that answer and move on, since we know there's content "to be covered." Of course, we also want students to experience the joy of discovery for themselves. One of the first hurdles to "doing inquiry" in the classroom is overcoming the urge to focus on content over practice. In a strange twist of fate, it seems "the year of COVID," which has restricted education—for instance, by keeping teachers and students physically separated—may be allowing teachers to reframe their curricula in entirely new ways and opening up more possibilities for student investigation.

The InquirySpace project seeks to couple the power of technology with the Next Generation Science Standards (NGSS) focus on science and engineering practices. This year, our goal is to help teachers and students across the country design and run scientific investigations in classrooms, homes, and backyards. We focus in particular on the following NGSS practices: *Planning and Carrying Out Investigations, Analyzing and Interpreting Data*, and *Constructing Explanations and Designing Solutions*. (The NGSS practices all work together, constituting a broad definition of "inquiry.")

InquirySpace uses a set of design principles and technologies. The most important of these principles, and a hallmark of Project-Based Learning (PBL), is to first explore a system or phenomenon that is both a common everyday experience and also engaging and relevant to students. This phenomenon should create a "need to know." Teachers are getting creative, considering phenomena accessible in everyday life (e.g., a paper car race, metal oxidation, cricket chirps, and more) and encouraging students to explore a driving question related to relevant, local content.

Explore your phenomenon

Our curriculum and experimental scaffolding model starts by adopting elements of an article in *The Physics Teacher* that introduces students to the concept of the Control of Variables (COV) strategy in experimentation.[1] As students explore, they are asked to consider, 1) What do you observe?, 2) What can you change?, and 3) What can you measure? We have expanded these questions in every investigation to include development of an investigable question and a corresponding set of procedures that produce data proving or disproving a related prediction.

Students are asked to consider:

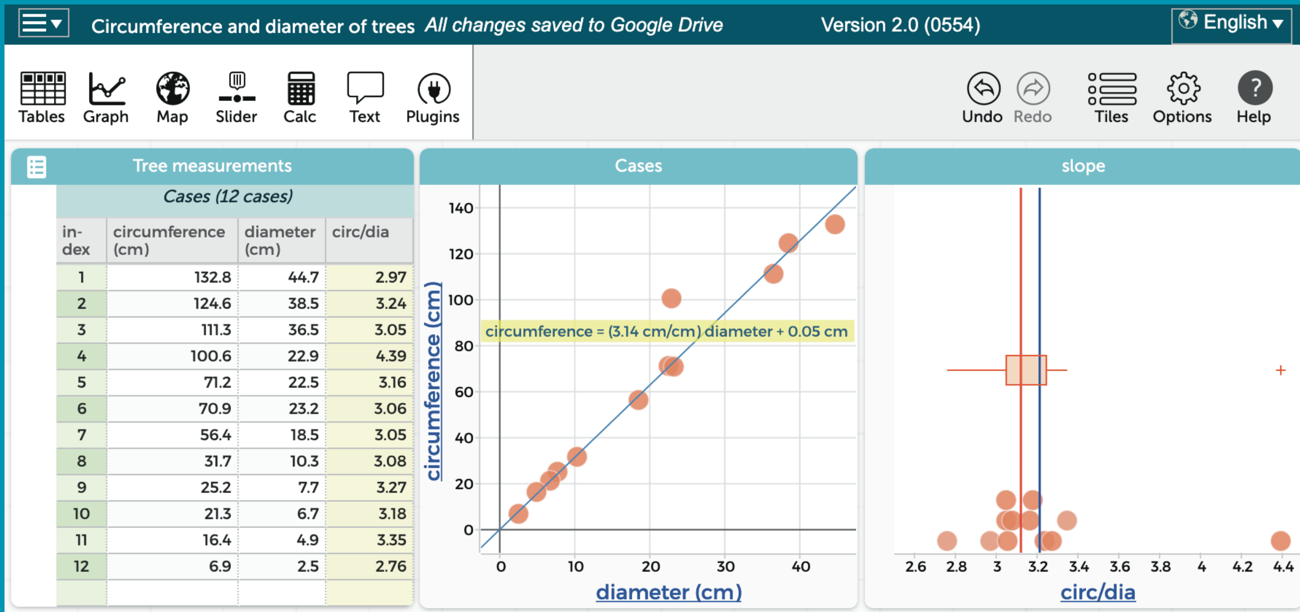
1. What did you observe?
2. What variables can be changed?
3. What variables can be measured and how?
4. Choose and write an investigable question. Write your question in the form:
   How does changing ______ affect ______ ?
5. Make a prediction about the answer to your question.
6. What data would you need to collect to answer your prediction? Consider sketching/building a data table to help answer this question.
7. What variables will you make sure to keep constant during data collection?

Helping students get to the point of developing their own investigable questions takes time, thoughtful scaffolding, and practice. Typically high school students have little experience asking their own questions or independently developing and carrying out experiments to answer them. Teachers have found that doing science through physical and simulated experiments throughout the school year leads to increased teacher and student comfort with experimentation skills, especially when paired with questions around measurement and data collection.

Design and run your experiment

Once students have developed their first iteration of an idea for an investigable question, they design their experiment with the goal of collecting enough data to prove or disprove their prediction. The process of designing an experiment and then collecting and analyzing data is iterative. Persistence in experimentation is often a new skill for both teachers and students.

Students are encouraged to problem solve on their own as much as possible, and teachers are encouraged to provide just enough support to move students to the next level of comfort with independent experimentation. Given limited classroom time, especially during COVID teaching and learning, this process is made easier by reducing both the number of investigable



Cases (12 cases)

index	circumference (cm)	diameter (cm)	circ/dia
1	132.8	44.7	2.97
2	124.6	38.5	3.24
3	111.3	36.5	3.05
4	100.6	22.9	4.39
5	71.2	22.5	3.16
6	70.9	23.2	3.06
7	56.4	18.5	3.05
8	31.7	10.3	3.08
9	25.2	7.7	3.27
10	21.3	6.7	3.18
11	16.4	4.9	3.35
12	6.9	2.5	2.76

Figure 1. Group data from students measuring the relationship between tree circumference and diameter as an introduction to both experimentation and CODAP data analysis.

questions and the time allowed to try to answer those questions. For example, we recommend focusing on how many trials "are enough" in an experiment before moving on to having students test multiple values of a variable or, ultimately, multiple variables.

Collect and analyze your data

InquirySpace emphasizes a combination of physical and simulated experiments and, when possible, automated data collection through either sensors (in classrooms) and/or simulations. Students use Concord Consortium's Common Online Data Analysis Platform (CODAP) to collect, clean, organize, and analyze their data (Figure 1). Analyzing and interpreting data is a fundamental experimentation skill and NGSS practice that takes time and varied contexts to master.

Explain your findings

Constructing explanations and designing solutions is the "final" step in experimentation. In a classroom using PBL pedagogy, answering driving questions typically leads to the next content topic (and related phenomenon) in a curriculum sequence, reinforcing the nature of iteration in the scientific endeavor. For example, describing a falling object speeding up (acceleration due to gravity) naturally leads to questions such as "Why do (some) falling objects, like a parachute, stop speeding up?" (forces).

Students are encouraged to revisit their prediction prior to experimentation and use a Claim, Evidence, Reasoning (CER) framework to explain their findings. We scaffold explanation by asking students to reflect on the following:

1. Based on all of your observations so far, make a claim that answers your question.
2. What evidence (observations, measurements, etc.) supports your claim?
3. What is your reasoning? How does your evidence support your claim?
4. How confident are you in your evidence? Did you collect enough data?
5. Did your prediction match your claim? Explain.
6. What are some things you might do differently next time to better answer your investigable question?
7. What new question(s) might you investigate next?

The goal in asking and answering these questions is to practice the "art of science" as scientists—making observations, asking questions, designing experiments to test hypotheses, and sharing findings with scientific peers to review, argue, and possibly replicate or refute. While InquirySpace does not focus on argumentation per se, opportunities for practicing listening and speaking from the stage of initial ideas through explanation abound. We use grounded research in "talk science" from TERC[2] and University of Washington's Tools for Ambitious Science Teaching[3] to get students to share ideas and engage in lively discussions, in effect externalizing and iterating their mental models of a phenomenon. From the start of the school year, teachers aim to build collaboration into their lessons and set a tone that all ideas are important. Over time, students deepen their listening and talking skills.

While classrooms in the 2020-21 school year have changed, teachers are more committed than ever to three-dimensional teaching and learning, using the NGSS disciplinary core ideas, crosscutting concepts, and science and engineering practices. The InquirySpace project offers design principles to help teachers develop activities that support students doing science, wherever their "classroom" is located this year.

1. Blanton, P. (2009). Three questions can change your labs for the better. *The Physics Teacher*, 47, 248–249.

2. Michaels, S., & O'Connor, C. TERC Talk Science Project. https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf

3. University of Washington, College of Education. *Tools for Ambitious Science Teaching*. https://ambitiousscienceteaching.org/tools-scaffolding

LINKS

InquirySpace
concord.org/inquiryspace

CODAP
codap.concord.org

Under the Hood:

Improving Accessibility of Activities

By Kiley McElroy-Brown

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is the scrum master and a project manager.

According to figures from the U.S. Department of Education, over 7 million or 14% of students in the U.S. received special education services in the 2018-2019 school year under the Individuals with Disabilities Education Act (IDEA)*. Fortunately, assistive technologies that help many classroom students are becoming built-in tools for most operating systems and web browsers. Many accessibility features—for example, text to speech, word prediction, and optical character recognition—are included in Apple's macOS and iOS and Google's Chrome. These tools can significantly improve the quality of learning for students with low-level vision, color blindness, low mobility, and hearing impairments.

While these features are becoming increasingly standardized for most operating systems, accessibility is not always included in web technology development. The Concord Consortium is redoubling its efforts to improve the design of our online activities. After reviewing the W3C criteria for accessibility conformance, known as the Web Content Accessibility Guidelines (WCAG), we focused initially on three accessibility guidelines and incorporated these features into a new design framework for activities in our STEM Resource Finder.

Distinguishable

Distinguishable features include those that make it easier for users to see and hear content, including color, text spacing, button size, and separating foreground from background. For example, WCAG recommends that the size of the target for pointer inputs is at least 44 by 44 pixels, so we increased the size of the buttons for navigating between pages in an activity. We also adjusted the background and foreground colors to meet the minimum contrast ratio. This improves usability for students with visual impairments and limited mobility by increasing the visibility of the button on the page and increasing the clickable area of the button.

In addition, we added features that ensure that media on the web page are perceivable by all. These features include text alternatives (also known as "alt tags") for any non-text content like images or videos that are read aloud with the use of screen readers and closed captions for videos that can be turned on or off by the user.

Keyboard accessible

Keyboard-accessible features include those that make all functionality available from a keyboard. They are especially useful for students with mobility impairments who may have difficulty making the precise hand movements required to use a mouse. The WCAG guidelines require that all web page elements are operable through a keyboard interface by using the tab key, without requiring specific timing for individual keystrokes. We used HTML form controls and links to ensure the correct and logical tab and reading order for all elements displayed on activity pages (Figure 1).

```
<div className="activity-page-links" data-cy="activity-page-links">
    <div className="pages" >Pages in this Activity</div>
    { this.props.activityPages.filter((page) => !page.is_hidden).
map((page, index: number) => (
      <div className="page-item" key={`index ${index}`}
        onClick={this.handlePageChange(index + 1)}
        onKeyDown={this.handlePageChange(index + 1)}>
       <span>{`${index + 1}. `}</span>
       <span className="page-link"
          onClick={this.handlePageChange(index + 1)}
          onKeyDown={this.handlePageChange(index + 1)}
          tabIndex={0}>{`Page ${index + 1}`}
       </span>
      </div>
      ))
    }
    <button className="button begin"
        onClick={this.handlePageChange(1)}
        onKeyDown={this.handlePageChange(1)}>
        Begin Activity
    </button>
  </div>
```

Figure 1. HTML form controls and links provide the correct and logical tab and reading order for all elements displayed on activity web pages.

Navigable

Navigable features help users navigate, find content, and determine their location on a web page. We assessed the internal structure of the interactive page elements and updated the order of these elements in the underlying code to ensure that they follow a logical sequence within the content. We made the keyboard focus indicator always visible to students who navigate activity pages using a keyboard. We also improved the display of the user's location within the activity by updating the page breadcrumb trail to use visible separators and navigation arrows.

Most assistive technology is driven by thoughtful formatting and inclusion of assistive tags that are otherwise invisible to everyday users. While color contrast and button size are obvious, screen reader tags, hierarchy, and consistent labeling are not. Implementing these features is one way we are emphasizing our dedication to advancing STEM inquiry through technology and creating activities that are usable by all learners.

*National Center for Education Statistics, U.S. Department of Education, https://nces.ed.gov/programs/coe/indicator_cgg.asp

LINKS

STEM Resource Finder
learn.concord.org

Innovator Interview:
Leslie Bondaryk

Leslie Bondaryk (lbondaryk@concord.org) is Director of Technology.

The idea of domain experts and students using transparent technology suited to the environment and subject has resonated with her.

A self-described "cross-discipline weirdo" with an interest in science, math, and art, Leslie spent her freshman year in high school at a magnet arts school. She now thinks back to her early interest in sculpture as a springboard to her later interest in engineering. She also credits her father, who wrote operating systems at IBM, with giving her an early glimpse into that world.

Leslie now laughs about her major at MIT—electrical engineering—saying, "I would love to say it was a beautiful, inspirational choice." Alas, its appeal was financial: electrical engineers made the most money. But it was also a challenging and interesting field. When she was told that electrical engineering was the hardest major and that she'd have to "crank on the math," she thought, "bring it on!" And she learned to love it, especially the design aspects.

At the University of California Santa Barbara, she received a master's in electrical engineering and solid state physics, and learned about the intricacies of making silicon into semiconductor electrical and optical switches. In her thesis work, Leslie made vertical-cavity surface emitting lasers, where the trick was to grow a mirror on the surface of a semiconductor using molecular beam epitaxy, rather than cleaving the wafer. "It's like sculpting with atoms," she says.

After moving back to Boston, Leslie landed at MathSoft. These were the early days of the Web and publishers were just beginning to realize that paper texts would have to work hand in hand with websites to teach STEM subjects. She directed their Mathcad product line, and headed up the Schaum's Interactive Outline series, one of the first legitimate uses of software to teach STEM from a professional publisher. Her team also developed the notion of a metadata system around dimensioned, experimental values that could be copied into other worksheets and documents.

In another publishing stint, Leslie worked at Pearson to develop an online platform capable of asking and answering STEM questions. She recognized that students, instructors, and authors all needed to express the same kinds of concepts—with graphs, equations, and pictures—and that demonstrating the links between representations was critical to science communication. One physics curriculum included a strobe picture of someone shooting a basketball, a graph of the positions, and an equation. "I try to make software that allows students and authors to communicate these representations in the way they think about them, then let the software link them together." Leslie sees great potential in models that students can manipulate to respond to questions in their preferred representation.

One key colleague during Leslie's professional journey was Apple's Jim Spohrer, who fantasized about the power of technology, unbounded by the traditional classroom, "sitting under a tree with a computing device that would help you learn about the world." The idea of domain experts and students using transparent technology suited to the environment and subject has resonated with her ever since. She's now making some of these ideas reality with mobile data acquisition apps at the Concord Consortium. "We finally did it!"

Leslie's love of art, science, and personal expression inspires her work and hobbies alike. In 2013, she and her husband converted an arcade on Cape Cod to demonstrate game physics, such as the friction effects in air hockey and the AI built into the Addams Family pinball game. Although they had to close Wackenhammer's Arcade STEAMuseum due to the pandemic, Leslie still has some of her favorite games in her home. She treasures memories of museumgoers and their curiosity as they explored the exhibits. Leslie approaches her work here with the same sense of excitement and discovery.

The Concord Consortium
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The Concord Consortium is happy to announce the following new grants from the National Science Foundation.

Geological Construction of Rock Arrangements from Tectonics

Earth science classes typically present plate tectonics and the rock cycle as separate, unrelated concepts. A new project is designed to change that. With Pennsylvania State University, we are developing and researching an innovative new multi-scale simulation and related curricula to bridge the tectonic system and the rock cycle and to engage Earth science students in grades 6-9 in authentic scientific practices. Using the Tectonic Rock Explorer simulation, students investigate the evolution of rock sequences by changing tectonic conditions and watching rock layers form. Students will be able to predict what types of rocks are generated under specific tectonic situations and infer what causal mechanisms can lead to rock arrangements found in real-world examples. Project research will shed light on the role uncertainty plays in reconciling simulation-based evidence with real-world phenomena when students build scientific arguments.

Fostering Deep Learning, Identity, and Agency

Minoritized students often do not see themselves as belonging in science or even see science as relevant to their lives, and minoritized groups continue to be underrepresented in science careers. The Concord Consortium, Rutgers University, and the University of North Carolina Greensboro aim to deepen our understanding of how to support minoritized youth in three interlinked aspects critical for success in school science and beyond: authoring science-linked identities, negotiating epistemologies, and learning core science ideas and practices. We are collaborating with teachers, community members, and seventh grade students in New Brunswick, New Jersey, to develop an instructional unit that engages students in addressing a local health-related problem they identify. Using community-based ethnographies and powerful technologies, students will explore and explain the underlying biological and environmental mechanisms and develop possible solutions that can be implemented in the community.

Enhancing the Teacher-Curriculum Relationship in Problem-Based Mathematics Classrooms

With Michigan State University, we designed a digital platform for middle school students to collaborate when solving mathematical problems. A new project now focuses on the role of teachers as learners by enabling teachers to plan, enact curriculum, and reflect on student learning in networks within and across schools. Teachers will work in a professional learning community to discuss problem-based curriculum materials and classroom artifacts and to share resources. Project research will study how the use of teaching resources within a digital teacher collaborative environment can strengthen the teacher-curriculum relationship and explore how the cyclical and dynamic use of teaching resources can foster teacher understanding and promote student learning.

Empowering Informal Educators to Prepare Future Generations in Wireless Radio Communications

BSCS Science Learning, the Concord Consortium, Georgia Tech, the Children's Creativity Museum (CCM), and museums from the National Informal STEM Education Network (NISE) are launching a new project to develop an innovative mobile suite of resources to support public understanding of modern radio and radio frequency communications. Resources include digital apps, a craft-based radio toolkit, and activity guides for youth in a range of informal learning settings, as well as mobile online professional learning for educators to expand new knowledge and practices in facilitating youth and public experiences. Three NISE Network museums (CCM, Sciencenter, and the Museum of Life and Science) will disseminate the mobile suite of resources and technology innovations. Project research will identify gaps in public understanding and perceptions of radio frequency communications and examine changes to interest, self-efficacy, content knowledge, and STEM-related career interest for youth.

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