HANDS ON!

A magazine for mathematics and science educators

TERC

SPRING/SUMMER 2019

03
Glossary Apps for Signing Science Exhibits

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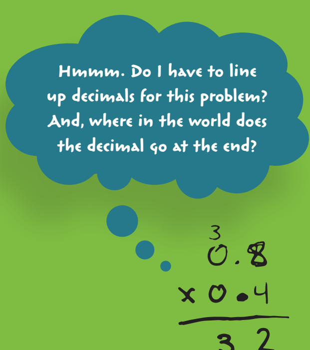

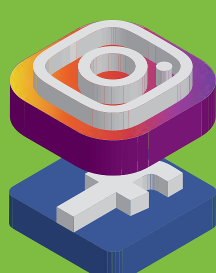

Letter from the President

The Spring/Summer 2019 issue of *Hands On!* provides a glimpse into the multitude of ways in which TERC provides access to critical STEM concepts and content to engage the learner and enhance the learning experience. When their learning style is the focus on how to best instruct, learners with disabilities of any type typically flourish and their labeled disability provides a window into how to best unleash their strengths. All learners can learn.

The feature article, *Glossary Apps for Signing Science Exhibits*, conveys our dedication to improving current statistics that show literacy levels of most children who are deaf and hard of hearing (DHH) leave high school with a grade five reading level or below. The science glossary apps were developed and tested to increase access for DHH learners who know American Sign Language. In various informal learning environments, the apps have been found to be easy to use, helpful, and fun for the learner and their family.

In *Debunking Math Myths Regarding Learning Differences, Difficulties, Disabilities*, TERC's SABES Mathematics and Adult Numeracy Curriculum and Instruction Professional Development Center works with teachers of adult learners to see math in everyday life. The math approach and instruction are founded in the belief that all learners learn differently, and that the materials and instruction should be delivered with this ideal at the forefront.

In *Online or In-Person: The Power of Collaborative Conversations*, the *Investigations* Center for Curriculum and Professional Development engages teachers as learners in K-2 mathematics, knowing this will translate into more enriching learning experiences for students. This team provides PD to teachers, coaches, and administrators. The power of collaborative conversation is leveraged to support learning via in-person and online courses and forums.

Data science, although not clearly identified as a discipline in classroom curriculum, is an increasingly essential area of learning. We are in the age of digital data with a strong desire to learn and make decisions based on that data. *Facebook or Instagram?* illustrates how data clubs can be a vehicle for introducing data science. Using a topic of great interest to their age group, middle school students review existing data or collect their own and, with data analysis tools, examine graphs and analyze the results.

Enjoy the issue.

Laurie

Laurie Brennan, *President*

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FEATURE // BY JUDY VESEL & TARA ROBILLARD

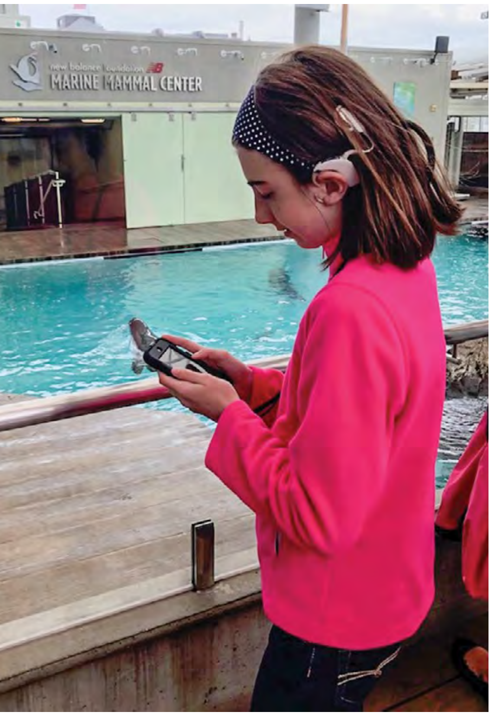
Glossary Apps for Signing Science Exhibits

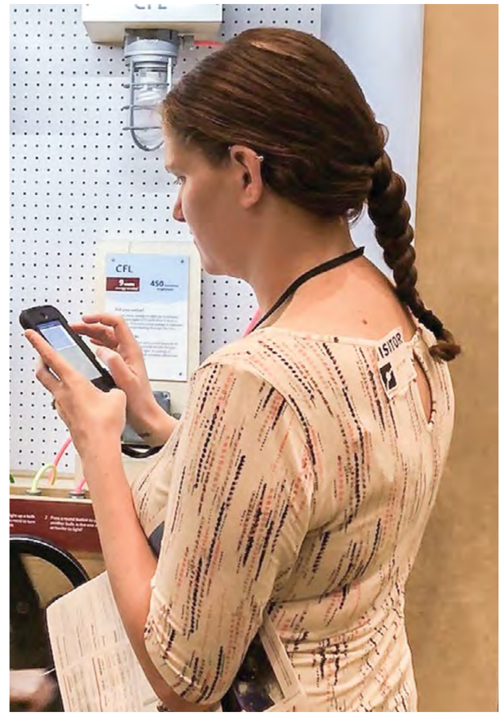
The glossary apps are six venue-specific signing glossaries that were researched and developed for deaf and hard of hearing individuals, age 5 and above, who visit informal learning venues. The glossaries enhance access to aquariums, botanical gardens, natural history museums, nature centers, science museums, and zoos for family visitors having at least one member who is deaf or hard of hearing and uses American Sign Language (ASL) for communication.

Why Are Signing Glossaries Needed?

In the US, approximately 105,000 children under five years old, and another 333,416 children ages five to seventeen, report having difficulty hearing, which affects communication, cognition, and educational development (U.S. Census Bureau 2014). As these children mature and progress through school, their literacy levels lag behind those of their hearing peers. This results in considerable literacy limitations that lead to the majority of deaf students leaving high school with a reading level at the fifth grade or below. In fact, the English vocabulary of the average 15-year-old deaf child is about the size of that of the average 9-year-old hearing child and will not improve significantly (Karchmer & Mitchell 2006; Qi & Mitchell 2012).

This lack of literacy is seen as part of an "academic puzzle" that is connected with early exposure to language in the home having a substantial influence on language development. One part of this puzzle is that approximately 90% of deaf and hard of hearing children have hearing parents, few of whom know ASL (Mitchell & Karchmer 2004). Another part of the puzzle is that most of these parents never develop strong signing skills, so that their children are isolated from information that hearing children of hearing parents and deaf children of deaf parents receive. An end result is that the use of informal science education venues is a low priority for persons who are deaf or hard of hearing and whose first language is ASL. The main reason for this is twofold: Most exhibits and activities at these venues rely on captions and labels that presuppose the ability to understand written English, so they are out of reach





Visitors Using the Glossaries at an Aquarium, Zoo, and Science Museum.

for many members of this audience. Also, ASL interpretation is not always an answer—it usually has to be arranged in advance or is only offered on certain days.

To help bridge the literacy gap that contributes to grade K-12 students who are deaf or hard of hearing missing many chances to learn STEM content, TERC and Vcom3D (developers of SigningAvatar® assistive technology) developed a series of grade-level and content-specific standards-based science and math sign language dictionaries for use in classrooms. An unexpected outcome of this line of research and development was that the dictionaries were being used in out-of-school settings by parents at home and during visits to zoos and nature centers. A subsequent research study focused on use of the dictionaries to access exhibit content at the Museum of Science in Boston. A key finding was that integrating the signing dictionaries, which were specifically designed for use with the core classroom curriculum, into informal programs is less than ideal, as this requires going from one dictionary to another and is time-consuming for visitors. It is also frustrating not knowing which dictionary to use to find a particular term. Visitors want a single tool that allows them to access terms with one click. The signing glossaries are a response to this.

How Are the Glossaries Designed?

The glossaries incorporate interactive features that are consistent with the three principles of Universal Design for Learning [UDL] (Rose & Meyer 2006). These are:

1. Visitors can acquire information in different ways.
2. Visitors are provided opportunities for demonstrating what they know.
3. Visitors are offered opportunities that make sense and are interesting.

Addressing Principles 1 and 3—Visitors can use icons to: access terms via an alphabet list, a category list, or a search box; listen to spoken English text; view signing of English text-based terms; access illustrations; view previously visited terms; change the text size. Addressing Principles 2 and 3—Visitors can: work individually or in groups; look up terms of interest to them; share ideas; make comparisons between glossary information and what they see or experience. Incorporating these interactive UDL principles into the visitors' experiences offers the target audience a glossary that avoids a "one size fits all" approach, thereby meeting the varied needs of individual visitors and families and giving options for personalized use.

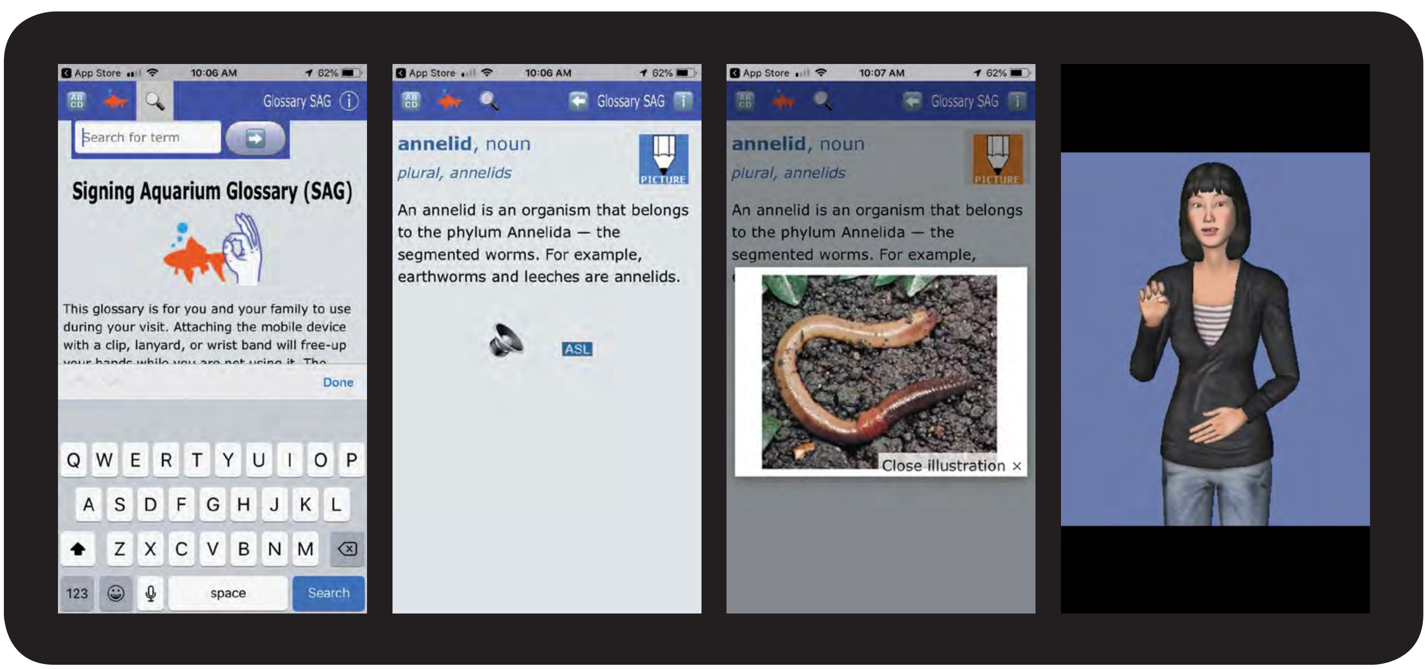
What Does Our Research Show?

Visitors used the glossaries at the type of venue for which each was designed. Results supplied answers to two primary research questions:

1. How do visitor groups that include members who are deaf or hard of hearing integrate and use handheld signing glossaries during visits?
2. What kinds of learning outcomes are made possible with use of the glossaries?

With regard to Question 1, members of all groups used the glossary in ways that met their individual needs in looking up terms related to the exhibits they were visiting. Observations of glossary use across all family groups revealed that each method for accessing terms was used—the search box, the category lists, and the alphabet list. Children in the family groups at each of the venues used the glossaries to look up signs for what they were observing or doing. Visitors in all the groups agreed that the glossaries were easy to use and that they were fun and helpful. For example, family groups who visited the zoo and the aquarium engaged in discussions about animal structures and behaviors. Parents in these groups found that using the glossaries enabled their children to engage in the exhibits more independently than they expected, and that the children spent more time at each exhibit than they would have without the motivation and support supplied by the glossaries.

With regard to Question 2, we organized our results around impact categories from the Framework for Evaluating Impacts of Informal Science Education Projects (Allen et al. 2008). For the first category—Awareness, Knowledge, or Understanding—children at multiple venues used the glossary to help them observe animals and plants, looking up names and structures as they went. For example, one child who visited a nature center with her parents told the researcher that she looked up the term *bear* and learned what bears eat. A child who visited an aquarium told the researcher that she looked up the term *penguin* and learned that they live where it is cold and that they can swim. For the second Framework category—Engagement—all the parents told the researcher that their children were more engaged in looking at the exhibits than had been the case during past visits to similar venues. The parents attributed this to their children being able to use the glossary to look up information about what they were seeing. For the third Framework category—Skills—children and parents alike told the researcher that they had learned new signs from using the glossary.



Examples of the Interactive UDL Glossary Interface.

One visitor summarized in her own words what our research shows when she wrote: “We were most impressed at the versatility of the signing glossaries in navigating various types of museums. [Our daughter] loves visiting these locations, but we often avoided them because we were unsure what value they’d have without the rich explanations we were able to give to our boys, who are both hearing. The glossaries enriched not only her experience but ours as well, helping us to feel more connected to her during those visits. Sometimes as a hearing parent of a child who is deaf, you can feel inadequate or ill equipped to provide your child the best educational support—especially in the areas of science and math. We are grateful to the work of TERC and the ASL apps. Our experiences have all been positive, regardless of the type of museum we are visiting.”

WHERE ARE DOWNLOADS AVAILABLE?

Apps for the Signing Zoo Glossary (SZG), Signing Nature Center Glossary (SNCG), Signing Science Museum Glossary (SSMG), Signing Natural History Museum Glossary (SNHMG), Signing Aquarium Glossary (SAG), and Signing Botanical Garden Glossary (SBGG) are available free through Apple’s App Store and from the Google Play Store. They can be used with iPhones, iPads, and iPods.

AUTHORS

Judy Vesel is a Principal Investigator at TERC. She has degrees in Biology, Linguistics, and Education. She was the Principal Investigator for the Leveraging Learning and Science for Today and Tomorrow projects (funded by NSF). She is the Principal Investigator for a body of work referred to as “Signing Math & Science”– funded by NSF and the U.S. Department of Education. Her experience as an educator and administrator extends from the primary grades through high school. She also leads another body of work that involves development of a stand-alone device that uses LED light technology and incorporates Web-based materials to offer blind and students who are visually impaired opportunities to learn core-based mathematics and English Language Arts content or skills included in the Expanded Core Curriculum. Ms. Vesel has presented her work at many recent conferences including annual meetings of the Center for Advancement of Informal Science Education (CAISE), American Association of Museums (AAM), Assistive Technology Industry Association (ATIA), and Closing the Gap. E-mail: judy_vesel@terc.edu

Tara Robillard is a senior research associate at TERC. She has degrees in Marine Science and Science Education and taught at the high school level. Her research interests focus on accessibility for students with low-incidence disabilities, especially the use of universally designed technology innovations to improve achievement in mathematics and science of students who are deaf or hard of hearing. E-mail: tara_robillard@terc.edu

REFERENCES

Allen, S., Campbell, P. B., Dierking, L. D., Flagg, B. N., Friedman, A. J., Garibay, C., & Ucko, D. A. (2008). Framework for evaluating impacts of informal science education projects. In *Report from a National Science Foundation Workshop*. The National Science Foundation, Division of Research on Learning in Formal and Informal Settings.

Karchmer, M., and Mitchell, R. E. (2006). Demographic and achievement characteristics of deaf and hard-of-hearing students. In M. Marschark and P.E. Spencer (Eds.), *Oxford Handbook of Deaf Studies, Language and Education* (pp. 21-37). New York, NY: Oxford University Press.

Mitchell, R. E., & Karchmer, M. A. (2004). Chasing the mythical ten percent: Parental hearing status of deaf and hard of hearing students in the United States. *Sign Language Studies, 4*(2), 138–163.

Rose, D., & Meyer, A. (2006). *A practical reader in universal design for learning*. Cambridge, MA: Harvard Education Press.

Qi, S., & Mitchell, R. (2012). Large-scale academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. *Journal of Deaf Studies and Deaf Education*, 17(1): 1-18.

U.S. Census Bureau. (2014). *American community survey*, tables B18101–B18107. http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

CREDITS

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FEATURE // BY KAREN ECONOMOPOULOS AND ANNIE SUSSMAN

ONLINE OR IN-PERSON:

The Power of Collaborative Conversations

INVESTIGATIONS 3
CENTER FOR CURRICULUM & PROFESSIONAL DEVELOPMENT

Twenty-first century professional development means choices, flexibility, and judicious use of technology. The *Investigations* Center for Curriculum and Professional Development at TERC, home to the *Investigations* curriculum, provides a variety of professional development resources and workshops for teachers, coaches, and administrators, with an eye towards supporting math teaching and learning, using technology as a tool to reach our diverse audience.

Investigations 3 in the K-5 Classroom can be taken as a four-day in person workshop or as a 7-week online course. Both experiences focus on computational fluency, 2-D geometry and measurement, models and representations for fractions, and more. Both experiences are active and experiential with participants engaging in mathematics, examining student work and video, and considering how the *Investigations* 3 curriculum supports mathematics teaching and learning. Both experiences emphasize learning with and from fellow participants.

Whether online or in-person, the INV3 professional development team knows the power of collaborative conversation to support learning. In the blogposts on the following pages, *Investigations'* staff share their reflections on how being in the room together — whether physically in a classroom, or virtually in the online space of a forum — generates conversations that produce new learning. These posts also demonstrate the commitment of the *Investigations'* staff to their own continual learning and to reflecting on the best tools and strategies for engaging and supporting adult learners.

Counting is More Than 1, 2, 3

Engaging Adults in K-2 Mathematics

By Karen Economopoulos

How do we engage adult learners in the seemingly simple yet complex mathematical ideas of the primary grades? Playing *Counters in a Cup* or solving a *How Many of Each?* problem aren't exactly engaging math tasks for adults. Though teachers might examine the mathematical focus of each task, think about what questions they might ask to assess understanding, and consider how they might support or extend the targeted math ideas, how can engaging in these K-2 level math tasks help teachers understand how complex they are from the viewpoint of young students?

A few weeks ago, I attended an *Investigations 3 in the K-5 Classroom* workshop. I observed a group of K-5 teachers and coaches immersed in a counting task, sharing their strategies, and then connecting how their experience brought out the complexities of counting. As I watched, I was once again reminded of why *How Many Butterflies?* is one of my touchstone tasks for engaging adult learners in the mathematics that is central to the primary grades.

Participants are instantly drawn to the large, laminated "Butterflies" poster as they find a butterfly they recognize or point out ones that are especially unusual. The display is interesting in that there is variability of color, size, pattern and orientation. Very quickly, a comment of "Wow I never knew there were so many types of butterflies!" is followed by the question of "I wonder how many there are?" and the investigation begins.

There are several factors that make this counting task challenging: the butterflies are randomly arranged on the poster so counting them in an organized manner requires a plan. The butterflies are stationary. You can't pick them up and move them as you count or organize them into convenient sized-groups, so determining how to keep track of what has been counted and what's left to count becomes a decision.

Since people are working in small groups, negotiating a plan of action becomes part of the task and once the plan is enacted, it is not unusual to hear comments such as "Could you count more quietly, I'm getting distracted" or "No, I think that butterfly is on my side of the poster and I counted it already." Inevitably someone catches wind of an interesting counting strategy being employed by another group and convinces their group to abandon their original idea and shift to a different strategy. Rarely do all groups arrive at the same answer. In fact, it is the result of different answers that spurs people into recounting and double-checking their work. These comments and experiences are remarkably similar to what you might see or hear when watching K-2 students engaged in similar work.

The debrief of the task brings out all of the complexities about counting that are in fact central mathematical ideas in the primary grades. These ideas include knowing the rote counting sequence and assigning one number to each object, keeping track of what has and has not yet been counted, and knowing that if you count smaller sub-groups and add those groups together, the total represents the number of butterflies on the poster.

Primary teachers often reflect on how adults' knowledge about counting and quantity influences their experience, citing things like "If we all have the same poster then we should all get the same number" and "If our group counts and then double-checks, the number should be the same" as being obvious to adults or even to older students. These ideas however, are not obvious to our youngest learners and are important parts of the mathematics they are working on. Inevitably upper grade teachers talk about their own "ahas" about the complexities of counting and reflect on how they can see aspects of these same ideas about counting by 1s and groups coming into play in the later grades in multiplication and work with fractions and decimals.

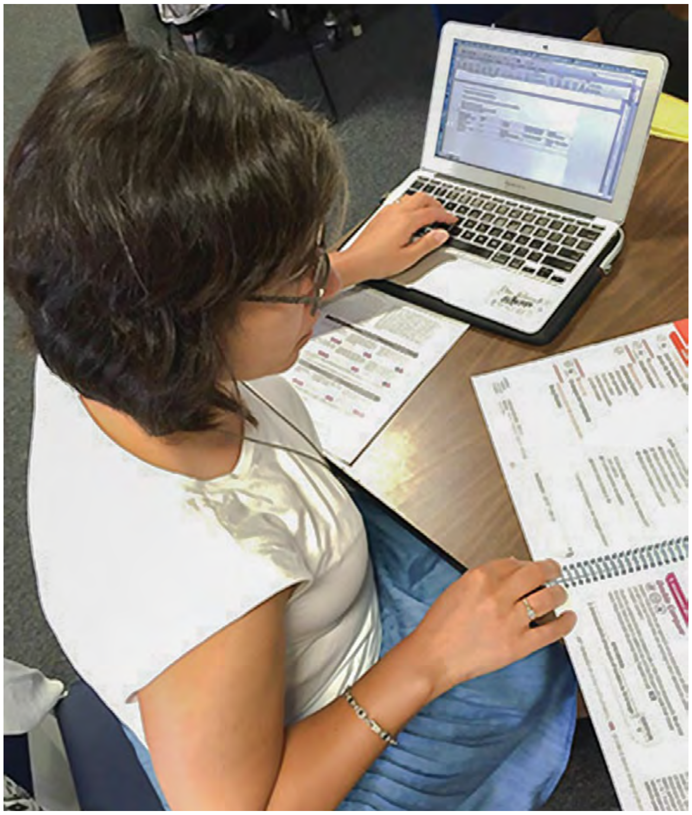
I am always searching for and playing around with K-2 games and activities that can be adjusted (e.g., adapting a material) or extended (e.g., changing the question) in such a way that the underlying math investigation shifts from being just right for a K-2 student to engaging for an adult. Part of the engagement is that the task is interesting and challenging, but equally important is that it offers teachers a new look at the math they teach and reaffirms the importance and complexities of even the "simplest" mathematics.

Workshop participants explore dIfferent ways of counting butterflies.

The Power of Discussion Forums for Online Professional Development

By Annie Sussman

My colleague, Arusha Hollister, and I facilitate the ***Implementing Investigations 3*** **(II3)** online course. The II3 course discussion forum, which essentially functions as an online community, is one of the most interesting and challenging aspects of the course from the standpoint of the facilitator. During the 7-week course, participants log in several times per week to reflect on, and ask questions about, the activities and readings in the weekly sessions. For each session, we pose a question for everyone to consider that highlights the key mathematical ideas in that session.



Creating an online forum in which everyone can connect with colleagues and engage in meaningful conversation requires lots of careful planning. Over the past year, Arusha and I have been thinking together about the factors that contribute to the development of the forum. Here are some key takeaways from our work.

Ask questions that encourage depth over breadth

We have found that questions that ask participants to think very broadly about a mathematical topic often encourage people to summarize information, which does not promote engaging conversation, so we've switched to questions that encourage participants to go deep. For example, we recently replaced the question, "What does it mean to be computationally fluent?" — which appeared at the end of the session about addition and subtraction in the early grades — to "What do you see as the key elements of the work students do in the early grades with addition and subtraction?" The former question tended to encourage a lot of summaries about the elements of computational fluency, while the latter has sparked conversation about a range of topics including the importance of flexibility in problem solving, mathematical language, the Standards for Mathematical Practice, and much more.

Create space to discuss the ideas and questions that feel most relevant to participants

The best conversations arise when people feel that they can use the forum as a tool to extend their learning rather than as a place where they must compose the "correct" answer to a specific question. Over time, we have come to describe the forum as a place for people to write about aspects of their learning, or ideas or questions that are coming up for them. While we do pose a question to consider, we now emphasize that this is meant as a jumping off point.

Help everyone make connections between new learning and classroom practice

Meaningful professional development happens when there are multiple opportunities to connect and enact new learning in one's professional work. We encourage participants to offer specific examples of the ways in which they plan to change their teaching practice in response to new ideas they have encountered in the course. Being specific helps participants really articulate how a new idea can be put into action. For example, one participant wrote the following in response to the session on multiplication and division:

> *"I expanded my knowledge regarding how helpful arrays are for developing meaning and solving multiplication problems. As a second-grade teacher, understanding the progression of this tool through the upper grades is helpful. Going forward, I will aim to be more purposeful in helping students notice equal groups and identify and describe the patterns they notice."*

Know when to respond as a facilitator

This is perhaps the most challenging aspect of facilitation. It feels important to give participants space to connect with each other and so we do try to limit our involvement on the forum. Sometimes, however, a response from us is warranted, particularly when a specific question about the curriculum comes up. For example, a question about how students are instructed to fill a ten-frame at the beginning of kindergarten is something our staff can answer quickly and unequivocally.

Looking Ahead to Continued Learning

While each new iteration of the II3 course presents new opportunities to learn more about online course facilitation and the teaching and learning of mathematics, the power of the discussion forum remains central to the experience for participants and facilitators as well.

FEATURE // BY DONNA CURRY

Debunking Math Myths Regarding Learning Differences, Difficultie , Disabilities

The "D" in LD (learning disabilities) does not stand for defici . Therefore, we should not think of students who learn differently as being deficient in some way, although that is often how they have been treated. The word "disability" suggests that someone is unable to learn or cannot learn the same material as other students. In reality, students with an LD diagnosis can learn; they just do so in ways that are different from the mainstream. The fact is, every person learns differently, depending on the subject, the way the material is presented, their personal experiences, and many other variables.

At the SABES Mathematics and Adult Numeracy Curriculum and Instruction PD Center (managed by the Adult Numeracy Center at TERC) we support teachers to better help adult learners understand how math is present and relevant in everyday life. For most of our adult learners, math was taught as a set of discrete skills to be memorized. If a student was adept at memorizing isolated facts and procedures, she could become "good" at math. If not, she may have had poor math experiences that got in the way of becoming an efficient math learner. Many of our adult learners are suspected of having learning disabilities, but we are cautious of applying that label, especially if they have not been tested for specific disabilities related to math.

Instead, we think about how to teach *all* our learners differently, so that we can help them no matter how they've learned to approach math. We need to give all of our students, whether or not they actually have a diagnosis of LD, the opportunity to become effective math problem solvers. So, how do we make sure we are being equitable with all of our students? The National Research Council (2001) sets out principles that encourage us to go beyond calculations and memorization *for all students* and notes that special-needs students lose out when these principles aren't followed:

> *"It is in the best interest of special-needs children to assume that the following principles apply to all children: (a) learning with understanding involves connecting and organizing knowledge; (b) learning builds on what children already know; and (c) formal school instruction should take advantage of children's informal everyday knowledge of mathematics... [L]earning difficulties among special-needs children stem largely from instruction that violates one or more of these principles." (p. 342)."*

There are two myths that seem to get in the way of teachers utilizing these principles and being able to teach all students to be effective math problem-solvers. The first is that teachers may think that LD students are not capable of conceptual understanding. However, recent research on the cognitive strengths of dyslexic individuals has shown that they sometimes have strengths in 3-D spatial thinking, as connected to mechanics and complex visualization, and in interconnected and narrative reasoning. They tend to make unique associations between concepts and excel in discerning patterns (Lambert, 2018). Perhaps one of the challenges that LD students face with traditional math instruction is too much focus on memorizing disconnected information, rather than on "connecting and organizing" (NRC, 2001) math concepts.

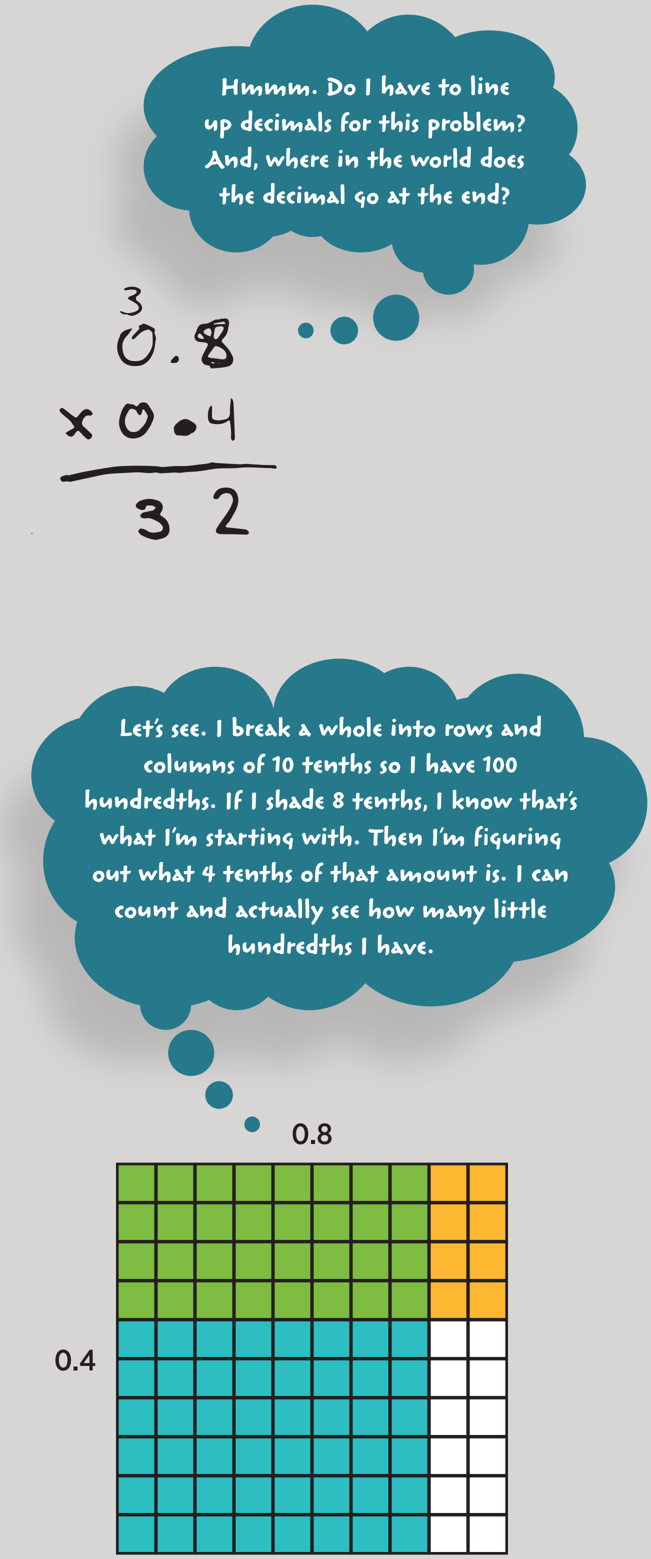
A second myth about LD students is that they are not capable of developing and using their own strategies; hence, teachers have to show students what to do, model it, and have them practice it again and again. Most early research studies on LD students had been focused on explicit, direct instruction of mostly rote procedures. When researchers tested whether explicit instruction helped, the answer was yes. However, there was no research suggesting that discovery-based learning would be therefore ineffective. New research on having LD students develop their own strategies has shown that students are capable of creating their own strategies (Lambert, 2018). In fact, doing so, rather than trying to remember those modeled by a teacher, eases the strain on students' memory.

We need to remember that all of our students can learn, and that it's up to us as instructors to figure out how best to reach them. There are other ways of thinking conceptually and problem-solving beyond memorizing procedures. After all, it is not necessary, in life or in work, for students to be able to solve problems with a particular procedure. They do need to be able to make sense of problems and get reasonable answers. That is something that every student can learn.

The more that teachers provide different strategies to reach all students, the more successful students will be. At our SABES Center, we teach powerful strategies that are appropriate for all learners and that can support students with learning differences, difficulties, or disabilities. A great example is visualizations, which includes strategies such as area models, number lines, and Singapore strips. Following are some examples of how these visual representations can help any student who has struggled with memorizing procedures. We hope these examples spark your desire to learn more so you can better help your students.

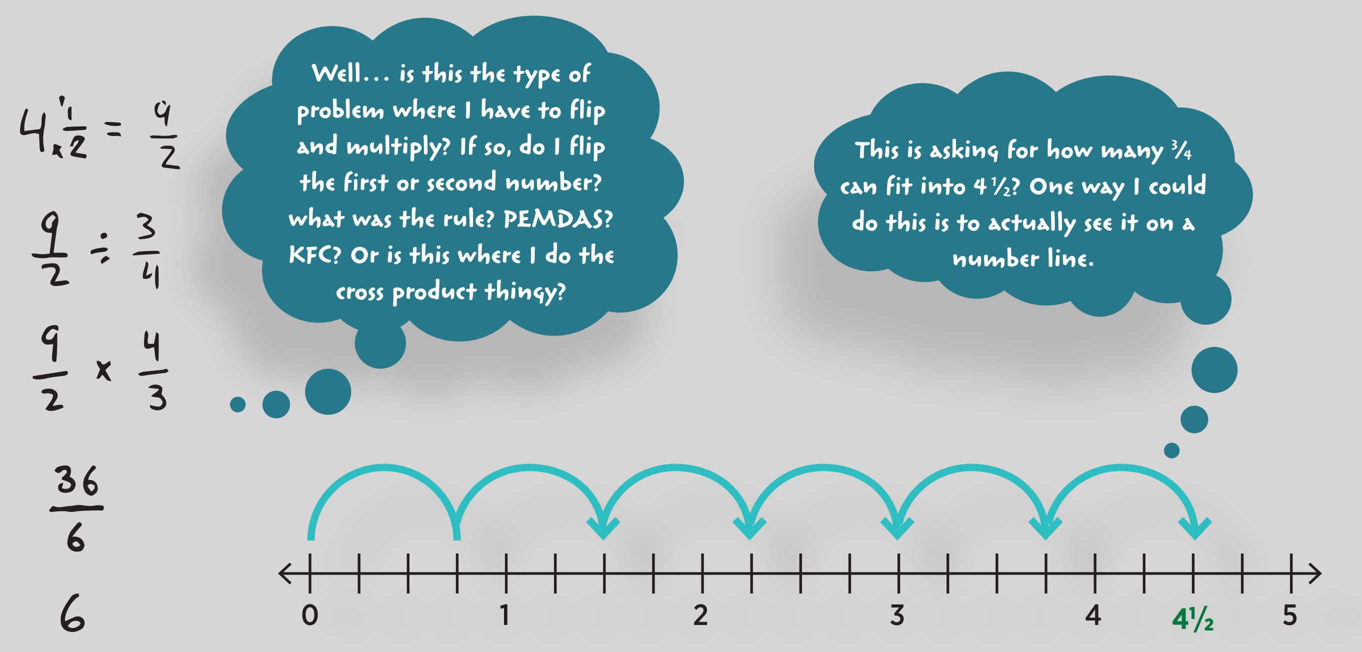
For more information, visit adultnumeracy.terc.edu

Using the area model to multiply with decimals — Example: 0.8 x 0.4

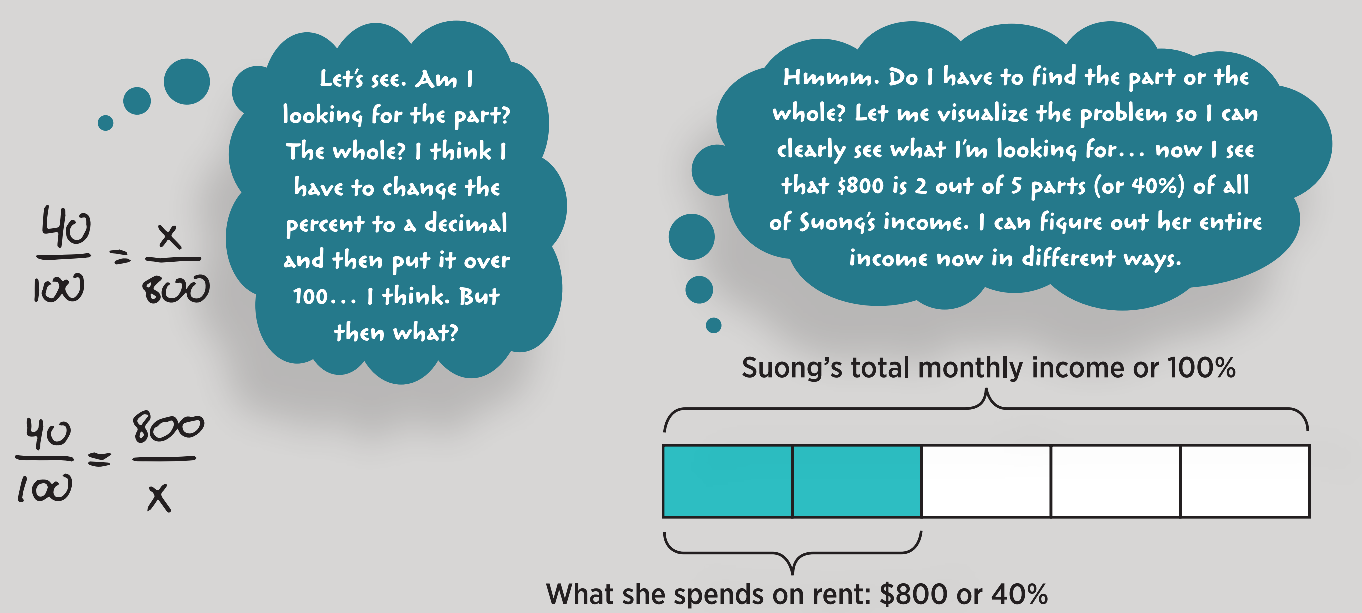


Debunking Math Myths Regarding Learning Differences, Difficul ies, Disabilities

Using the number line to divide with fractions — Example: $4\frac{1}{2} \div \frac{3}{4}$



Using bar models (tape diagrams, Singapore strips) with percents — Example: Suong spends 40% of her monthly income on rent. Her rent is $800. How much does she make per month?



References

Lambert, R. (2018). "Indefensible, Illogical, and Unsupported"; Countering Deficit Mythologies about the Potential of Students with Learning Disabilities in Mathematics. *Education Sciences, 8*(2). https://doi.org/10.3390/educsci8020072

National Research Council. (2001). *Adding It Up: Helping Children Learn Mathematics*. Washington, DC: National Academy Press.

National Council of Teachers of Mathematics. (2014). *Principles to Actions: Ensuring Mathematics Success for All.* Reston, VA: Author.

Full article can be found at:
Curry, D. and Nicole McNeil (2019). Strategies That Support Learners with Disabilities, Differences, and Difficulties in the Mathematics Classroom https://www.sabes.org/sites/sabes.org/files/resources/LD_math_strategies_2019.pdf

STEM Sparks at TERC

What sparked your curiosity or interest in science, technology, engineering, or math?

The National Science Foundation posed this question on Twitter to draw peoples' attention to the power of STEM education. Using the hashtag #mySTEMspark, thousands of people replied, sharing a moment, an experience, or a special person that inspired their interest and their careers in STEM.

It made us wonder — what were those moments that inspired the passionate math and science professionals right here at TERC? What set each of them on a path toward working to create STEM sparks for others? ***Find out below.***

"Today's learners are the innovators of tomorrow. They will solve our toughest problems and fulfill the U.S. need for a skilled, technical workforce. But first, we need to create moments that inspire people's curiosity about the world around them. As demonstrated by #mySTEMspark, those moments can come from anywhere."

THE NATIONAL SCIENCE FOUNDATION ON MEDIUM: HTTPS://MEDIUM.COM/@NSF/MYSTEMSPARK-CATCHES-FIRE-23CA6262B36A

"In 1963, I was in a 6th grade classroom that piloted a new pond water curriculum. I still remember how astonished I was when I looked through a microscope and saw living things. I also remember when my brother, my father, and I hunted for fossils among the rocks on a dam. This kind of experience led me to civil engineering and the study of soil and dams."

SARA LACY, SENIOR SCIENTIST

"I knew I was interested in science before junior high, but still, the experience that sticks out in my head is going to a geology or rock show with my seventh-grade science teacher. It wasn't a school trip, just a teacher sharing her passion for science with any of her students who wanted to go to this weekend event."

TEON EDWARDS, CHAIR OF THE CENTER FOR STEM TEACHING AND LEARNING

"I remember studying plants on hikes with my family, making fish prints at the local science center, and programming with our elementary school computer teacher. Both in-school and out-of-school experiences have been critical!"

SCOTT PATTISON, RESEARCH SCIENTIST

"I have always loved the outdoors and animals, and I wanted to be a vet for a long time. My parents didn't let me have a pet as a child, so I kept the snails that I found in the lettuce in a shoe box and observed them, fed them, and played with them for months."

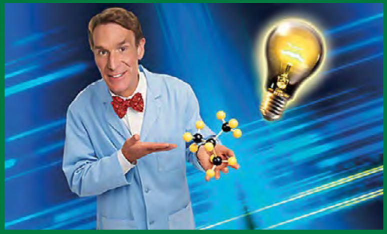
NURIA JAUMOT-PASCUAL, RESEARCH SCIENTIST

"I went to a summer science sampler program at University of New Mexico and was inspired to make my own 'bug box.' My mom kept opening plastic containers in the freezer only to find my specimens awaiting pinning."

KELLY PAULSON, WORK UNIT MANAGER OF THE CENTER FOR STEM TEACHING AND LEARNING

"I very specifically remember watching an episode of Bill Nye the Science Guy about volcanoes. I was already kind of interested in science before then, but that really cemented it and focused my interest for a while!"

—BENJAMIN GOSBEE, STAFF ACCOUNTANT



Facebook or Instagram?

TEENS EXPLORE DATA ABOUT TECHNOLOGY USE

Data science has caused a major shift in how scientists from all disciplines approach their research. Data analysis tools are as central to modern science as a lab bench and Bunsen burner. As schools prepare the next generations of scientists, logically we should be seeing a seismic shift toward teaching data science in STEM classrooms. Yet this is not happening, as data science doesn't fit clearly into the disciplines around which the curriculum is currently organized.

Data Clubs participants use CODAP to investigate data about teens' use of social media.

To bridge this gap, informal settings will be critical in preparing youth for a data-intensive future, at least in the near term. TERC, together with Science Education Solutions, is studying how to introduce middle school students, especially girls and rural youth, to data science through Data Clubs activities designed for after-school or summer camp programs. Funded by the NSF STEM+C program, the Data Clubs team is partnering with community organizations to offer 10-hour Data Clubs modules; TERC's community partners are the Malden, MA, YMCA and the local chapter of Girls Inc.

To design our modules, the Data Clubs team started by deciding on criteria in four categories: topics, datasets, tool, and activities.

Topics: We wanted the topics of our modules to be both a "window" and a "mirror" for participants; that is, to provide a window into the experiences of others, as well as a mirror of the students' own reality. We looked for topics that were familiar to students, so that they could contribute data about their own lives, but we also wanted students to discover the variety of experiences people have, as this variability is at the heart of data science.

Datasets: The rise of data science is at least partly due to the ease of generating and sharing large data sets, so for the centerpiece of each module we used a "big data" set that is publicly available. Big data sets by definition have a large amount of information and are often quite complex. Much like Goldilocks looking for a comfortable chair, we had to find data sets that were "just the right size"; we customized each data set to make it accessible to middle school students by limiting its size, but making sure there were still interesting patterns for students to discover in the data.

Tool: We wanted to use a data analysis tool that would make data exploration and graph construction easy, so that participants could focus on making meaning of the data, rather than on spending time learning how to use the tool. CODAP (Common Online Data Analysis Platform, https://codap.concord.org) works well in this regard. It is freely available, web-based, and designed for students in Grades 6-14. Even novice users can make graphs easily, so they can explore a variety of relationships quickly and fluidly.

Activities: While the bulk of time in each module is spent analyzing data using CODAP, we interspersed non-computer activities in many sessions. In particular, we felt it was important for students to have an opportunity to collect their own data related to the module topic. The insights students gain from collecting their own data are less likely to arise when the data to be analyzed have been already collected by someone else.

Teens and Technology

The first module we developed and tested dealt with teens' use of technology. This topic (not surprisingly) had great appeal for middle schoolers. Technology plays a big role in teens' lives. Much of their interaction with the world is conducted through social media, and they are familiar with both its advantages and pitfalls. This topic easily met our criterion for a module topic, as it gave students a chance to compare their own social media usage (mirror) to other people's usage reflected in the dataset (window).

In the summer of 2018, almost two dozen middle school-age participants showed up for our first club at Malden High School to explore data about Teens and Technology. We introduced them to a dataset that the Pew Research Center collected in 2014, asking teenagers about their use of technology, especially video games and social media.

One of Pew's focal areas is Internet and Technology (pewinternet.org); the Pew team collects data from American families on this topic multiple times a year, writes analytical reports on trends in the data, and then makes the data public — but the data are only made available 2 to 3 years after they are collected.

The Pew dataset is truly big, consisting of responses from over 1000 people to several hundred questions. From this dataset, we chose a small subset of questions that had interesting relationships among them and a random set of 200 people's responses. Then we presented the Club with the graph below of teens' answers to the question: "Which social media do you use most?" Each dot in the graph represents a single person's response.

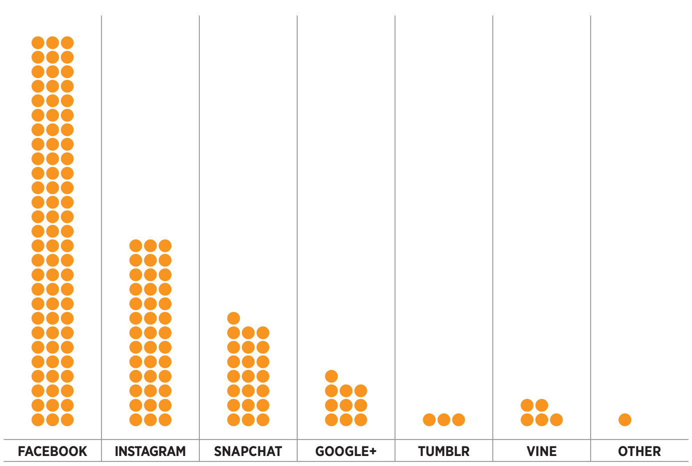


Figure 1. Which social media do you use most?

Club participants' first response to the data was, "Wait, that's not right! Our friends don't use Facebook; they all use Instagram and Snapchat. Only our parents use Facebook!". The conversations that followed provided a good example of the kind of inquiry we would want our students to cultivate as future data scientists. They wanted to know the story behind the data: "Who did the researchers ask?", "How was the question phrased?", and "When were these data collected?"

When the Club facilitator said that the data were collected in 2014, the mystery was solved. Clearly, these were old data!

Participants noted that social media use changes quickly, often over a period as short as a year or two. To look into this phenomenon further, the teens used CODAP to see if there was a relationship between age and social media use. They wondered if older teens use different social media than younger ones. Starting with Figure 1, and adding "age" on the Y-axis, Club participants produced the following graph:

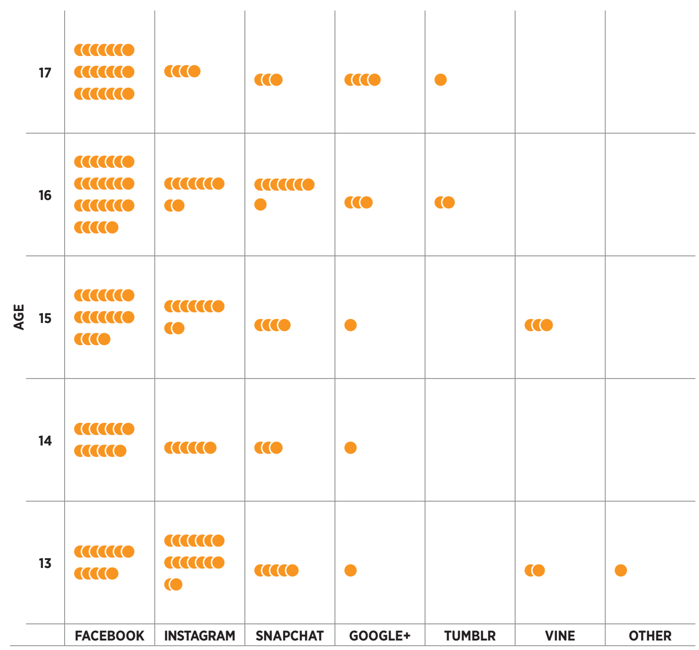


Figure 2. Which social media do you use most, by age of user

The graph showed them that 16 and 17-year-olds are more likely to use Facebook than 13-year-olds, and that Instagram is more popular among 13-year-olds. Participants had a well-reasoned explanation for why this difference exists: Since Facebook was more popular several years ago, older teens started using it and didn't change their habits as time went on. Younger teens, on the other hand, starting using social media when Facebook was already in decline, so they started with Instagram.

As the module progressed over two weeks, participants explored many relationships among the variables in the data set. Several participants were drawn to explore gender differences in technology use, especially around video games. While the participant group was approximately half male and half female, there were some single-gender groups who hung out together during the sessions. One group of boys was interested in whether the data showed that boys played video games more than girls, so they created the graph in Figure 3, in which each dot is colored according to the gender of the respondent:

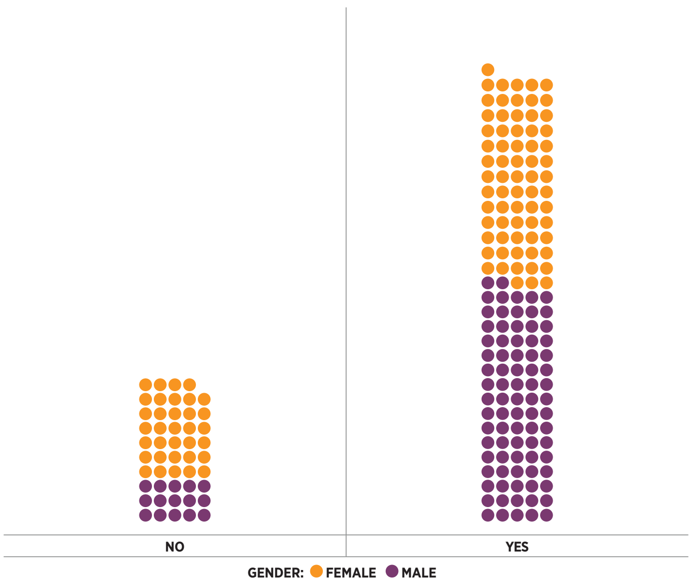


Figure 3. Gender difference in video game playing

This group was surprised by how many girls do, in fact, play video games, but they noted correctly that, proportionally, boys in this dataset were more likely than girls to play video games.

Because participants had noticed immediately that the Pew data were old, and thus probably not representative of current trends of technology use by teens, they decided to collect data from their own peer group to compare with the Pew data.

Data Clubs participants collect data around Malden High School on different types of sneakers they see.

While their sample size was very small compared to the Pew sample, some of the differences were striking. Indeed, among their own friends, Facebook was a distant third to Instagram and Snapchat in terms of social media use.

After several sessions in which we suggested questions, participants struck out on their own, choosing their own investigations for a final project. During the last two-hour session, they explored the variables they found particularly interesting and chose a graph that showed a relationship that made sense to them. They then built a final presentation by adding explanatory text to the graph. Several participants chose to include the comparison between the online data (Pew) and their own data (Malden), as well as continuing to investigate gender differences. The final project illustrated in Figure 4 investigated how teens talk to their closest friend, looking at differences between the Pew and Malden data as well as differences across gender. The text bubbles were added using the text function in CODAP.

> Definitely, texting is the most popular way of communicating. I assume just because of how easy it is to use, and how quickly and simply the receiver will get the messages.

> We certainly have to acknowledge the fact that the Pew interviewees outnumber the Malden ones 191 to 12, so we can't really assume a lot about Malden.

> Social media is the second most popular way of communicating, which I assume is because of how big and trendy social media has become, especially Instagram, Snapchat, Twitter, and Tumblr.

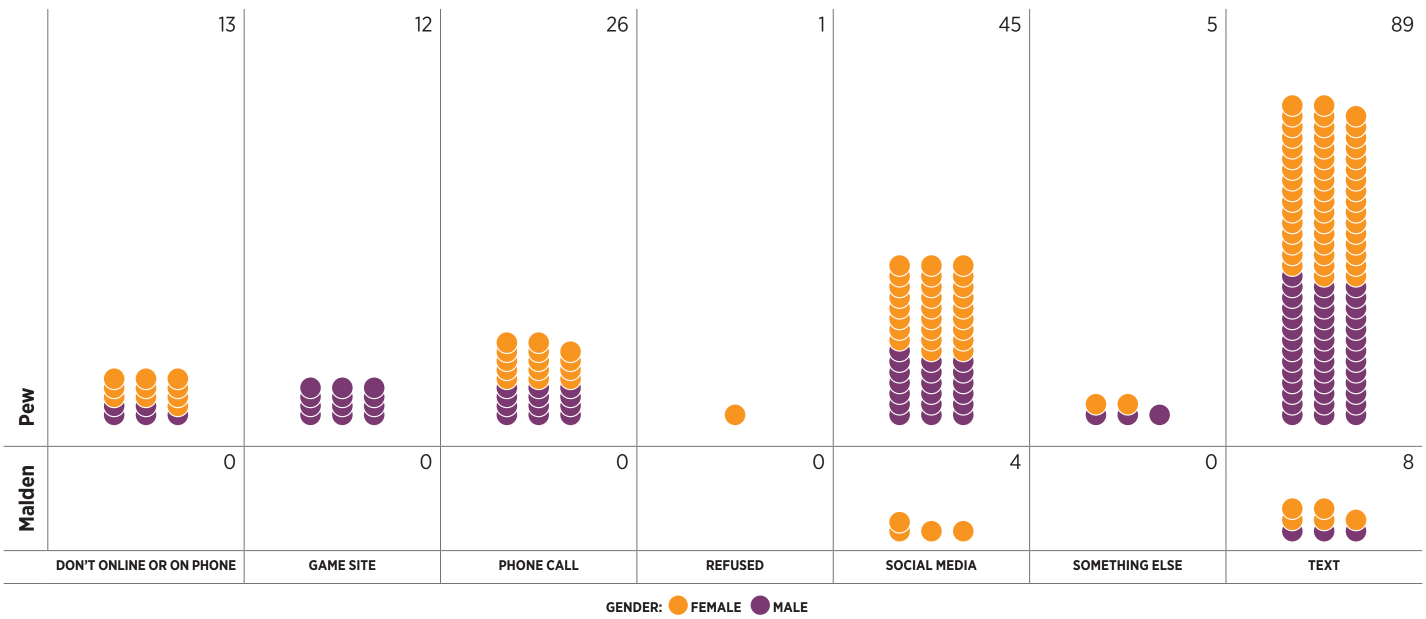


Figure 4. Final project exploring how teens communicate with their closest friends

Data Clubs 2019

In the Summer of 2019, we'll be offering a second Data Clubs module in Malden using data on the occurrence of Lyme disease and other tick-borne illnesses. Data includes state-by-state rates of Lyme disease from the Centers for Disease Control and a variety of climate variables such as summer high and low temperatures and annual rainfall. Students will explore where Lyme is increasing and what environmental factors might be related to this phenomenon. We will also be trying out new instruments to assess participants' dispositions toward data analysis and their understanding of basic principles of data science.

AUTHOR

Andee Rubin is a mathematician and computer scientist at TERC who has been combining expertise in technology design, math education, and artificial intelligence to improve math and science education both in and out of school for over 30 years.

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Watch Andee present her findings at https://bit.ly/2U0kxZl

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