Technology Tools to Build a More Accessible STEM Program: Visualizations, Representation and Modeling

Center on Technology and Disability
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Use accessible technologies and authentic STEM experiences to encourage "STEM for All"

Mainstream technology tools with built-in accessibility features, and the availability of virtual reality, simulations, and augmented reality present new opportunities for students with disabilities to access and engage with STEM (science, technology, engineering, and math) content. This brief presents ways for educational leaders to incorporate accessible technologies and STEM tools with principles of Universal Design for Learning (UDL) to create STEM programs that are more accessible for students with disabilities to prepare them for a lifetime of scientific literacy and STEM-related careers.

Introduction

STEM education serves as the foundation of innovation in our society. Innovative products often derive from a problem or challenge that requires a unique solution, making it imperative that all students, including those with disabilities, have access to a rigorous STEM curriculum. Thanks to more accessible technologies and a concerted nationwide effort to address underrepresented populations in STEM fields, more individuals with disabilities are pursuing careers in science and engineering.[1] However, many students with disabilities still lack access to a rigorous and accessible STEM curriculum, and may get the message that STEM careers are not for them. This situation places these students at a disadvantage given that STEM jobs are among the fastest growing and highest paid occupations, with STEM jobs expected to grow to more than 9 million by 2022.[2]

In an increasingly complex world, all students need to be scientifically literate. While some students may go on to pursue advanced careers in the sciences, basic scientific literacy is critical for all students. They need to understand what it means to think like a scientist, and how to evaluate information that is called "scientific". Many of the careers of the future will require that students can collaborate and solve problems using STEM skills. Struggling students are no exception — they will need the same types of knowledge and skills, and will often require additional supports to be successful.

Research has shown that the most meaningful learning happens when students are engaged in authentic activities that ask them to think and behave like chemists, computer programmers, mathematicians, engineers or archeologists — that is, when they are engaged in activities that mirror the real-life tasks of STEM professionals. These activities might include the use of virtual environments and simulations, developing models of scientific phenomena, and using collaborative tools like Google

[1] Sparks, S.D. Students With Disabilities as Likely to Enter Science Fields, New Fed Data Show. (2017). EdWeek. Retrieved from http://blogs.edweek.org/edweek/inside-school-research/2017/02/students_with_disabilities_in_college.html?cmp=eml-enl-eu-news3

[2] STEM 101: Intro to tomorrow's jobs. (2014). Occupational Outlook Quarterly. Retrieved from https://www.bls.gov/careeroutlook/2014/spring/art01.pdf

docs, video conferencing, and online communities. These types of activities can present new challenges for struggling students and those with disabilities.

Visualizations, representation and modeling

Science learning often involves creating abstract representations and models of processes that we are unable to observe with the naked eye. This learning is built by more complex processes than just logical reasoning; an imaginative and communal process of creating models and representations helps students develop new ways of understanding the world, especially with digital tools.[3] For example, chemistry texts often use images to represent atoms and molecules, and the processes and changes in them. Because these reactions occur at a very small scale and are difficult to observe, we must use visualizations and representations to help us understand what is occurring. Likewise, we use models and graphics to represent natural processes such as the carbon cycle, which occur over long periods of time and are similarly difficult to observe. Static figures — illustrations, diagrams and images — provide students with opportunities to see relationships in ways that language alone cannot express.

An important component of scientific learning is the ability to "mentally transform 2-D objects into dynamic 3-D objects,"[4] which can be challenging for many students, particularly those with learning or cognitive difficulties.[5] Additionally, for students with cognitive or visual impairments, the critical information contained in the representations may be inaccessible if presented in a traditional textbook (i.e. text and static graphics).

Students can benefit from creating their own models, using both high and low-tech solutions. When students create models, they are making representations of their world, often based on their knowledge, or on data that they have collected, which encourages them to demonstrate and deepen their understanding of the concepts.[6] While the physical aspects of creating models and visual representations may present some challenges for students with disabilities, the basic concepts of modeling can be made accessible to a variety of students. For example, a food web or food cycle that shows the interconnection of food chains in an ecological community is used to reason about relationships between consumers and producers and to understand the impacts of various ecological changes. The food web can be represented as a web or as a table without losing meaning, making it accessible to students using screen readers to access text.

Educational and assistive technologies can make a difference by giving students ways to access and engage in visual representations and modeling using these materials:

- Universally designed instructional materials

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[3] Tytler, R. (2016). Drawing to learn in STEM. *Research Conference 2016.* https://research.acer.edu.au/cgi/viewcontent.cgi?article=1286&context=research_conference

[4] National Science Foundation, National Center for Science and Engineering Statistics. 2017. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017*. Special Report NSF 17-310. Arlington, VA. Available at www.nsf.gov/statistics/wmpd/

[5] https://www.bls.gov/careeroutlook/2014/spring/art01.pdf

[6] STEM 2026: A Vision for Innovation in STEM Education. (2016). Office of Educational Technology. U.S. Department of Education. Retrieved from https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf

- Accessible Education Materials and Education Technology

Universal Design for Learning materials

Universal Design for Learning (UDL) recommends that concepts be presented with multiple means of representation, action, and engagement.[7] This helps to ensure that students with perceptual disabilities are not limited to one modality (e.g., visual information) to access critical content information. It also gives students opportunities to engage with tasks such as modeling by using the methods that are most appropriate for their abilities instead of limiting them to only a visual representation.[8]

Accessible educational technology and accessible educational materials

Recently, there has been a shift in mainstream technology tools and devices to include embedded supports and built-in features that support accessibility for all users, with a wide variety of needs. Features such as zoom, touch screen, text to speech, captions, and voice recognition, improve the user-experience for everyone.[9] In addition, there is a growing focus on accessible educational materials. Using Accessible Educational Materials (AEM)[10] and accessible technology features allow students with a wide-range of abilities multiple pathways of engagement. AEM materials come in different forms – print (e.g., Braille, large font), digital (e.g., ebooks, audio, video with captions), and physical (e.g., 3-D printers). Providing accessible options for all students is especially useful for STEM topics, which often include abstract models, that may be difficult to conceptualize.

Implications for educators

To accommodate struggling students for whom visualization and modeling may be challenging, teachers can consider the following:

- Look for technological resources in the media center and on the Internet, which can expose students to more ways of representing the phenomena they are studying; the more representations of a concept, the better.
- Ensure that students understand that scientific visualization and modeling are more than graphical and visual approaches.
- Encourage students to discuss and critique some of the approaches to models in textbooks. Ask them why conventions in a particular book or website are used.
- Challenge students to think outside of the typical hypothesis-method-results-conclusion method; support them in constructing and exploring their ideas through drawings, models, and digital simulations.[11]

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[7] About Universal Design for Learning. CAST. Retrieved from http://www.cast.org/our-work/about-udl.html#.WqrDFSjwaUk

[8] The UDL Guidelines. CAST. Retrieved from http://udlguidelines.cast.org/?utm_medium=web&utm_campaign=none&utm_source=udlcenter&utm_content=site-banner

[9] Digital Accessibility Toolkit: What Education Leaders Need to Know. (2017). Center on Technology and Disability. https://www.ctdinstitute.org/library/2016-10-11/digital-accessibility-toolkit-what-education-leaders-need-know

[10] About Accessible Educational Materials. Retrieved from http://aem.cast.org/about#.WqrD1ijwaUk

[11] Tytler, R. (2016). Drawing to learn in STEM. *Research Conference 2016.* https://research.acer.edu.au/cgi/viewcontent.cgi?article=1286&context=research_conference

- Consider creating a classroom maker space with simple objects or tools to help students create their own 3D representations from 2D visuals and find ways for struggling learners to meet their goals or work outside of the allotted time to work through challenging steps.[12]

Technology resources

Academo 3D Surface Plotter
A free, interactive online tool that allows users to enter a mathematical expression in terms of x and y. When you hit the calculate button, the demo will calculate the value of the expression over the x and y ranges provided and then plot the result as a 3D surface. The graph can be zoomed in by scrolling with your mouse, and rotated by dragging around. Clicking on the graph will reveal the x, y, and z values at that particular point.

Adaptive Curriculum
This interactive visualization and simulation software for middle and high school science features many different activities and simulations linked to national science standards. It also features virtual labs, simulations, quizzes, built-in glossaries, lesson plans, and other classroom materials.

Augmented Reality Sandbox
A hands-on sandbox exhibit combined with 3D visualization applications created by researchers at University of California, Davis. Simply mold the sand by hand and the landscape comes to life! The sand is augmented in real-time with an elevation color map, topographic contour lines, and simulated water.

Discovery Education – Free Virtual Field Trips
Take students beyond the classroom and into some of the world's most iconic locations for rich and immersive learning experiences. Explore upcoming educational events.

eTouchSciences
The Information Research Corporation developed eTouchSciences, an integrated software and hardware technology platform that includes devices that provide multiple forms of feedback, including tactile, visual, and audio, to the student.

Filament Games
Filament Games developed a suite of learning games, aligned with the UDL principles referenced previously, which are designed to introduce middle school students to scientific concepts using multiple means of representation and provide real-time assistance based on what a student may be struggling with, such as in-game glossaries.

Google Cardboard
Google cardboard is an affordable approach to the virtual reality (VR) experience that works with a variety of apps and several viewer types at various price points. Google cardboard can be used to

[12] Bevan, B., Ryoo, J. (2016). Making as a strategy for afterschool STEM learning, report from the California Tinkering Afterschool Network Research-Practice Partnership, *Research & Practice Collaboratory*, exploratorium.edu/ctan.

explore many scientific concepts in an immersive way and can even be used by students to take their own 3D images and create accompanying audio content.

Howard Hughes Medical Institute BioInteractive: Virtual Labs
HHMI's virtual labs are fully interactive laboratory simulations that include a bacterial identification lab, a cardiology lab, a neurophysiology lab, and a virtual ELISA (Enzyme-Linked Immunosorbent Assay) using human antibodies to diagnose disease. It features built-in glossaries, quizzes, background information, and other materials for the classroom.

JASON Mission Center
The JASON Mission Center is the online repository of related educational content associated with the JASON Project. Students can make use of online games, simulations, virtual labs, and other multimedia resources; teachers can access curriculum materials, and purchase curriculum units for fifth through eighth grade students.

Mathlets
Building on simulations used at MIT, Professor Haynes Miller created the Interactive Mathematics Project, which encouraged and enabled MIT students to make observations and measurements with “mathlets.” These interactive Javascript applets, runnable under any browser, were designed to illustrate mathematical concepts. Students can use these apps to visualize how changing variables affect systems.

NASA's Virtual Microscope
The Virtual Microscope is a NASA-funded project that provides simulated scientific instrumentation for students and researchers worldwide as part of NASA's Virtual Laboratory initiative. The virtual microscope presents the user with a method for exploring these pre-captured image data as if they were using the real instrument in real-time. It includes educational materials and training animations.

NASA Virtual Field Trip
The Virtual Field Trip is an immersive multimedia application developed to support student and user exploration of areas on Earth that have been identified as analog sites to regions on Mars. Analog sites are those areas that share some common traits with sites on Mars and have been identified based on their significance and importance to NASA.

OrCam MyEye 2.0
For blind and partially sighted people, this artificial vision device with a lightweight smart camera instantly reads text aloud from any surface (newspapers, books, restaurant menus, signs, product labels, computer and smartphone screens) and recognizes faces, products, and money notes in real time. This tool could be used in the classroom to help students with low-vision gain access to visually represented materials.

Osmo
Osmo is a technology system that bridges the physical and digital worlds by taking gameplay beyond the screen, encouraging creative thinking, learning, and play with physical objects. Some Osmo products focus specifically on math and coding.

PhET Interactive Simulations

The PhET Interactive Simulations project at the University of Colorado Boulder creates free interactive math and science simulations. PhET simulations are based on extensive education research and engage students through an intuitive, game-like environment where students learn through exploration and discovery.

Stellarium
Stellarium is a free open source planetarium program. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars, or a telescope.

“Assistive and Instructional Technology Supporting Learners with Disabilities”

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