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NYC STEM STUDY TOUR

Learning and Inspiring Outside the Classroom: Museums of STEM in NYC

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When we think about learning, perhaps the first word that comes to mind is "school": a place where children congregate, spending hours in classrooms learning about a set of prescribed topics from an adult expert, the teacher. A ubiquitous experience, but not necessarily one filled with amazement and awe, leading many to have school memories that are less than inspiring. However, places of knowledge and learning exist beyond the neatly polygonal confines of the classroom and can serve as important, additional places of student learning (Malone, 2008). In New York City, a great resource that students, parents, and educators can leverage is the wide array of world-class museums dotted around the city. Two of these institutions are the American Museum of Natural History and the Museum of Mathematics (MoMath). The STEM Study Tour conducted by Teachers College, Columbia University, a tour designed to bring current and future mathematics educators to places of mathematics teaching and learning around NYC, visited these museums as they both of had rich, innovative, and inspirational learning opportunities for mathematics.

A day (or *Night at*) at the American Museum of Natural History is a staple NYC attraction. The museum offers a space to explore a dizzying array of fossils, artifacts, specimens, and samples from Earth's past and present, meaning there's a little something there for everyone. There are taxidermied animals and preserved insects for those looking for a biological adventure, plant samples and environmental displays for museumgoers curious about the ecology of the planet, dinosaur and extinct animal fossils for explorers looking to delve into mysteries of the planet's ancient fauna, and rock and mineral samples for the aspiring geologist, with many further undiscussed exhibits still. In terms of where these exhibits lie within the STEM space, the museum heavily leans into the S—Science—part of things, many of which have strong connections to core K-12 sciences such as biology, earth science, and ecology. However, the M—Mathematics—in STEM isn't excluded from prominence in the museum, something that can be seen in the Hall of Planet Earth and the Rose Center for Earth and Space.

In the Hall of Planet Earth, mathematics is a central cog to the interactive *Causes of Climate and Climate Change*. Guests can freely explore a multimodal wall of climate change data presented through maps, text descriptions, and a multitude of graph types. Mathematical concepts such as interpreting trends, rates of change, positive and negative graph values, and probabilities are woven in throughout, tacit requirements to understanding the messages being presented in the exhibit's data. To facilitate this communication of information, the museum also implemented accessibility features such as audio cues that correspond to graph values, colors to indicate positive and negative values, and tactile buttons for easier exhibit navigation. As shown in Figure 1, the whole package is tied together in a visually alluring display that encourages curious investigators to congregate around key parts of the exhibit.

Encapsulating how this all comes together for teaching was a jigsaw activity (i.e., an activity where students are divided into groups to investigate different phenomenon and then recombine into smaller groups to share their results) used by a museum guide during the STEM Study Tour as an example of a typical field trip

learning experience at the museum. In the activity, a "class" of students was divided into three groups, each group investigating a specific section of the *Causes of Climate and Climate Change* exhibit. This exploration phase involved many skills previously mentioned. Students engaged with the visual representations of climate data and noted that temperatures generally increased over time, with some latitudes increasing faster than others. More than the skills used, the process of exploration generated interest and excitement: Unexpected quirks of the exhibit caused bystanders to quickly surround each curiosity, one person's epiphanous moments started a chain reaction of realizations, and this all contributed to lively, engaged conversations when jigsaw pieces (the students) reconvened into small groups to share their findings of each part they were assigned of the Climate and Climate Change exhibit.

Another mathematically rich exhibit lying directly adjacent to the Hall of Planet Earth is the *Cosmic Pathway* in the Rose Center for Earth and Space. As its name suggests, this is a path that museum visitors walk through that physically represents a cosmic phenomenon, specifically the timeline from the birth of the universe to today. Mathematical topics such as scientific notation, ratios, and proportions are critical to understanding this exhibit. While the tie-in for scientific notation is straightforward due to the large numbers associated with the universe, ratios and proportions are, quite literally, embedded in the path. The path, 360 feet in total, is exactly proportional to the 13 billion years of the universe's history as can be seen in Figure 2, with significant events placed in the appropriate spots along the path. This includes all of human history, which participants of the STEM Study Tour (and likely any future learners who walk the *Cosmic Pathway*) were shocked to learn was the width of one strand of hair right at the end of the path, the exhibit using the subversion of expectations and established prior distances to create a sense of surprise and awe.

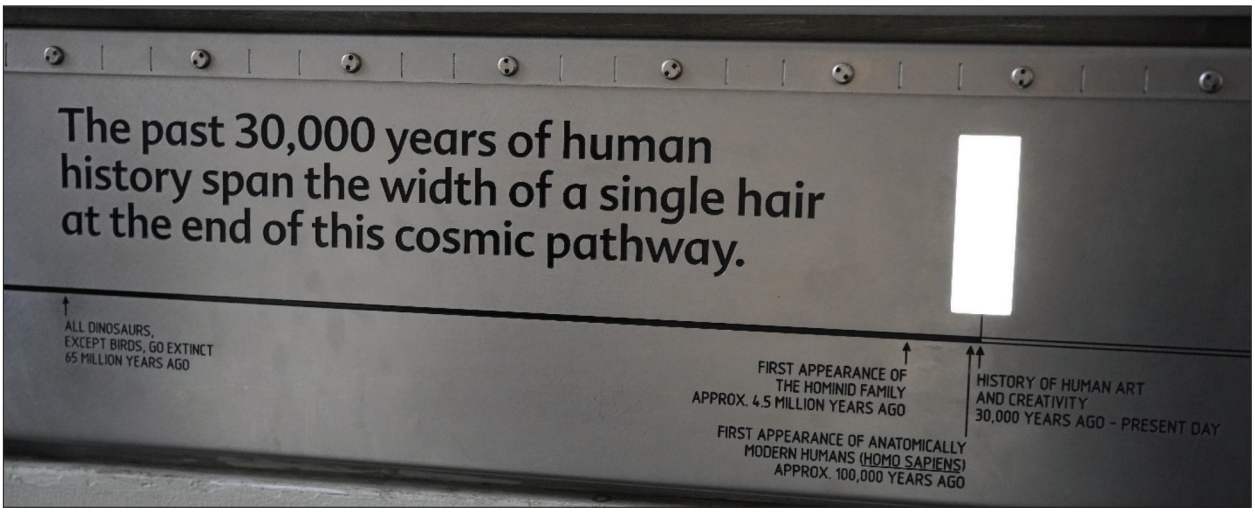
MoMath covers "only" one area of STEM: mathematics, but don't let that seemingly simple word deceive you. The exhibits show how mathematics goes beyond what is presented in a school textbook. Exhibits are inspired by a wide range of mathematical subtopics, some of which are familiar to students, some of which are far beyond the standard curriculum in typical K-12

Figure 1

Causes of Climate and Climate Change Exhibit in the Hall of Planet Earth

Figure 2

Cosmic Pathway Walkway Length to Time Scale

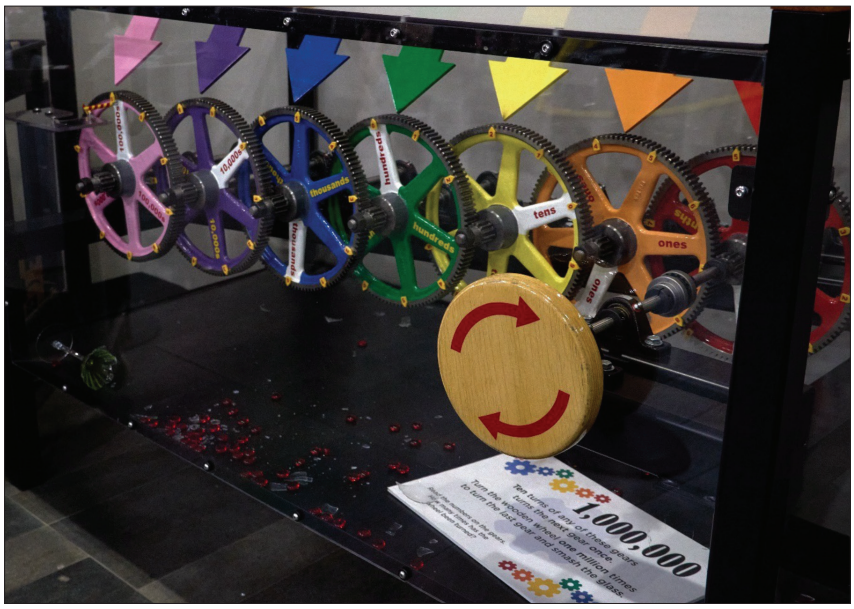


education. All of them are interactive, meaning students can come to grips with a subject that is predominantly thought of through pencil and paper abstractions. While every exhibit in MoMath is replete with rich mathematical connections that inspire mathematical exploration, I will highlight two that have close ties to curriculum taught in New York State's K-12 mathematics curriculum: *Done in a Million* and *PolyScope*. *Done in a Million* is an exhibit where museum goers use a wheel to turn a series of interconnected gears 1,000,000 times to break a drinking glass. The size of the machine and the way the gears are laid out entranced the entrance to the museum, causing many visitors to see how they could get the wheels to spin. As the wheel turned and turned though, machine operators quickly realized that while some of the wheels with lower powers of 10 turned swiftly, the wheels with larger powers of 10 required significantly more effort and to get moving. The physical, tactile method of representing the differences in size between powers of 10 is a non-traditional approach to the topic, a kinesthetic method to develop a person's number sense that importantly exposes students to different representations of the same topic (Kilpatrick et al., 2001). As it happens, realizing the size disparity between 10, 100, 1,000, and higher powers of 10 is a realization that one of the museum's staff noted is a common epiphany experienced by those who operated the *Done in a Million* machine.

PolyScope, on the other hand, is a geometric exhibit where small wooden objects are placed into a mirrored crevice to create three-dimensional shapes through reflections. Reflections are a topic often covered in K-12 geometry but almost exclusively with two-dimensional figures. This exhibit acts as an extension opportunity, posing the question to learners of what reflections look like with 3D shapes and what happens when multiple

Figure 3

Done in a Million Exhibit



reflections are applied to the same figure. Museum goers and members of the STEM Study Tour were drawn to this, trying to figure out how many and what figures could be created, with a handy list of 3D solids as scaffolding available to all who want it.

Throughout the discussion of these museums, the emphasis has been on both the learning opportunities and the spectacle and inspiration they present to visitors. The latter, in particular, is critical to the museums' success as, in education lingo, museum exhibits and experiences serve as powerful ways to motivate people who find it difficult to get excited in a traditional classroom setting. At the time of writing, for example, *Mathemalchemy*, an exhibit with various mathematical art pieces created by artists and mathematicians, is hosted at MoMath. This offers a rare glimpse into the potential for math and art to fuse, something which may serve to motivate those unconvinced by the logical skew mathematics is usually given in schools.

In conclusion, learning doesn't just happen in the classroom! The STEM Study Tour's museum stops, the American Museum of Natural History and the Museum of Mathematics, offered a small glimpse into some informal locales for STEM learning with both institutions providing opportunities for multimodal exposure to STEM, deeper exploration of K12 topics, and STEM spectacles that inspire and motivate learning.

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