An Experimental Math Space

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What is an Experimental Math Space?

In science courses like biology, physics and chemistry, there is often a laboratory component that accompanies the lecture portion of the course. This is not common in mathematics and an experimental math space can fill this gap. Such a space is a physical laboratory in which equipment in the room are for students to conduct experiments related to the mathematics courses they are taking.

Figure 1. Logo of the experimental math space at York University.

Connection to MACAS topics

While the experiments are mathematically inspired, they are also related to art, history, technology, other STEM fields and everyday activities. To illustrate this, here are two examples of experiments that are housed in the Experimental Math Space at York University.

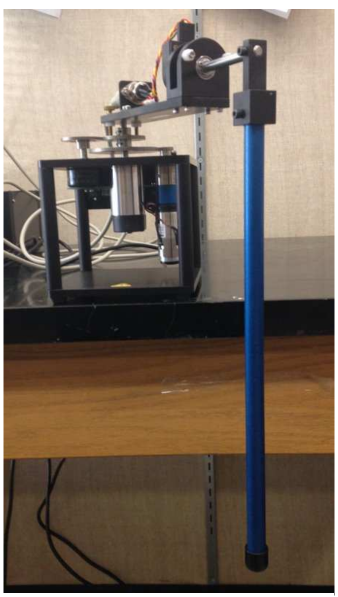

Figure 2. Pendulum, at rest, connected to the rotary base.

(a) Figure 2 shows a pendulum placed on a rotatory base. There is a motor in this base. The pendulum and base are connected to a computer, which can be operated via MATLAB's Simulink. One objective is to invert the pendulum and use feedback to keep it upright. This would require students to understand the physical components of the pendulum equipment, how to use Simulink to operate the system, and the mathematical concepts that model the dynamics of the pendulum and the mechanism of feedback control. Simulink is also able to measure such parameters as the pendulum angle over time and generate corresponding graphs for students to analyse as part of their learning. Applications of pendulums are commonly associated to engineering systems such as clocks, bridges, Segways, etc. but on deeper reflection, students realize non-engineering examples, like arms and legs, are also pendulums. Therefore, this experiment provides students a concrete example of the interdisciplinary nature of mathematical modelling and technology.

(b) Math students often learn about sinusoidal functions, oscillations in graphs, and the solution to the wave equation, but few have the opportunity to connect these concepts to vibrations, and even fewer connect vibrations to such worldly occurrences as sound, music, earthquakes, etc. There are a number of vibration experiments that students can explore to help solidify this connection. One experiment, shown in Figure 3, is that of dusting sand onto a vibrating plate. The sand collects onto regions of the plate that do not vibrate and this creates visually stunning stand patterns called Chladni figures, named after the physicist and musician Ernest Chladni (1756-1827) who first designed this experiment. The Chladni figures are also samples of symmetry. Chladni figures can be described by mathematical equations, and these were derived by Sophie Germain (1776-1831), who was historically denied the recognition because of her gender. Chaldni's experiment can be thought of as a "two-dimensional" vibrations experiment, while the vibrating string system shown in Figure 4 can be considered as its one-dimensional counterpart. The depiction in Figure 4 is a string fixed on both ends connected to a wave generator. The waves and stable regions are clearly visible against the red background. The third vibrating experiment is quite simple and shown in Figure 5, where students can "hear" (rather than see) the vibrations created by moving the slinky. There are so many different avenues and connections for students to learn about vibrations and mathematics.

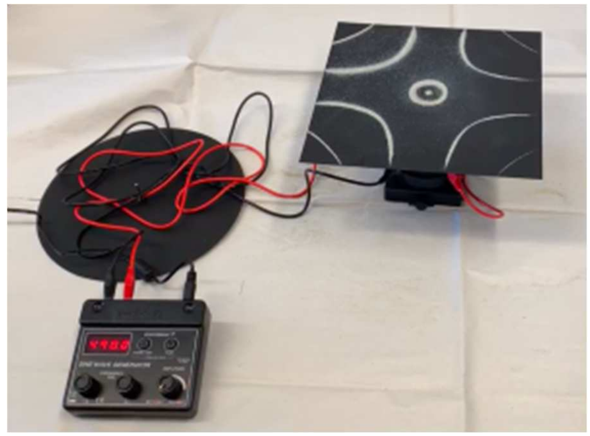

Figure 3. The square plate in the top right is placed on top of a vibrator which is controlled by the wave generator shown in the bottom left. The symmetric white sand pattern on the square plate is an example of a Chaldni figure.

Figure 5. Vibrations in a string. The string is fixed at both ends and the vibrations are caused by a wave generator (rectangular black box near the bottom left).

Figure 4. A simple activity fun students can make with a cup, a slinky and some tape. Tape the slinky to the bottom of the cup as depicted in the photo above. On the right is a math a student and on the left is the math professor who taught her about this. By putting the cups to their ears, once the slinky is released, they can "hear" the vibrations.

Benefits to Student Learning

Having students conduct experiments in a math course helps to develop such skills as:

- working in teams and developing their oral communication skills
- learning how to connect software and programming with mathematical concepts
- modelling real world systems using mathematics

- writing technical reports
- interpreting and visualizing experimental data, and also critical thinking
- designing experiments, which reinforces concepts related to mathematical reasoning

Figure 6. To the left is the pendulum system, and the three students are huddled in front of the laptop it is connected to.

In 2018, I received a teaching and learning grant to create and lead an experimental math space in the Department of Mathematics and Statistics at York University. As part of these efforts, I collected and learned about a wide variety of mathematically inspired experiments and equipment from various sources. To date, several York University math courses incorporate experiments into their course curriculum. In turn, students have learned about mathematics through experimentation and consequently the connection mathematics has with other STEAM disciplines, technology, the world we live in, and its impact throughout history.