Using Mathematics & Computational Thinking

Science

In science, mathematics and computation are fundamental tools used for understanding and representing physical variables and their relationships. These tools are used for a range of tasks, such as constructing simulations, analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable predictions of the behavior of physical systems, along with the testing of such predictions. Moreover, statistical techniques are invaluable for assessing the significance of patterns or correlations.

Engineering

In engineering, mathematical and computational representations of established relationships and principles are an integral part of design. For example, structural engineers create mathematically-based analyses of designs to calculate whether they can stand up to the expected stresses of use, and if they can be completed within acceptable budgets. Moreover, design simulations provide an effective test bed for the development of designs and their improvement. (Framework, p. 51)

See A Framework for K-12 Science Education, 2012, p. 64 for the entire text for Practice 5: Using mathematics and computational thinking.
In the video below from BozemanScience.com, Paul Andersen explains how mathematics and computational thinking can be used by scientists to represent variables and by engineers to improve design. He starts by explaining how mathematics is at the root of all sciences.
https://youtu.be/vJatZZV0nE0?list=PLi8HVli-fejYMV_aB3-hYUwR14W7Ouran

Using Mathematics & Computational Thinking Progression through Gradebands:

Grades K-2	Grades 3-5	Grades 6-8	Grades 9-12
Mathematical and computational thinking in K–2 builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world(s). • Decide when to use qualitative vs. quantitative data. • Use counting and numbers to identify and describe patterns in the natural and designed world(s). • Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs. • Use quantitative data to compare two alternative solutions to a problem.	Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions. • Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success. • Organize simple data sets to reveal patterns that suggest relationships. • Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems. • Create and/or use graphs and/or charts generated from simple algorithms to compare alternative solutions to an engineering problem.	Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. • Use mathematical representations to describe and/or support scientific conclusions and design solutions. • Create algorithms (a series of ordered steps) to solve a problem. • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. • Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.	Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. • Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. • Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m^3, acre-feet, etc.).

Progression from NGSS Appendix F p. 10.

Activities

Four Conceptual Change Activities are included to help teachers and students Confront Beliefs:

- Using Mathematics Activity #1: A Helping of Pi
- Using Mathematics Activity #2: Pendulums are Mathematically Beautiful
- Using Computational Thinking Activity #1: Pendulum Simulation
- Using Computational Thinking Activity #2: Wind Power

Also refer to Student Work in the Practice for real-life examples of how MPRES teachers have applied this Practice.

The purpose of the activities is to engage learners in the Practice of Using Mathematics and Computational Thinking. The emphasis is NOT on the activity itself, but rather the conceptual change related to the practice. Consumers of the Toolkit are reminded to not get wrapped up in the activity, but rather continually reflect on the conceptual nature of the practice to gain deeper understanding.

Since the activities are NOT lesson plans, in some cases only a brief explanation of the activity has been provided. Professional development facilitators should encourage learners to direct their own investigations and only intervene as needed to redirect.

To facilitate conceptual change throughout each activity, you should consider the following questions. These questions are also repeated at key points in each activity to assist you.

Awareness Questions:

1. From the background information, what new awareness do you have about the practice of mathematics and computational thinking?
2. In a 3-Dimensional classroom, to whom do you think mathematics and computational thinking applies?
3. What questions did the background raise for you?

Expose Belief Questions:

1. What are your current beliefs about this practice?
2. In what ways do you think you are using this practice?
3. What challenges do you see to using this practice?

Debrief activities by focusing on the conceptual understanding of the practice using the following prompts.

Resolve Belief Questions:

1. In what ways did this activity change your beliefs about using mathematics and computational thinking?
2. How difficult was it to use mathematics and computational thinking?
3. What clarity was brought to the use of mathematics and computational thinking through these activities?

Extend the Concept Questions:

1. How do you currently help students to use mathematics and computational thinking in your classroom?
2. Review and evaluate a recent lesson you taught. How effectively does it engage students in using mathematics and computational thinking?

Go Beyond Questions:

1. Share lessons in which you could implement the practice of using mathematics and computational thinking.
2. Ask a colleague to observe one of your lessons OR video yourself teaching and reflect on using mathematics and computational thinking.
3. Use the EQuiP Rubric for Lessons & Units: Science (PDF format) to evaluate a recent science lesson you taught.