

## Chapter 2

# Design and Implementation Principles for Dynamic Interactive Mathematics Technologies

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### ABSTRACT

*Design and implementation principles are described for choosing and using dynamic interactive mathematics technologies in support of mathematics learning and teaching. The design principles value technologies that enable meaningful and purposeful actions by students resulting in immediately visual consequences. The implementation principles emphasize using these technologies for important mathematics to pose rich tasks and ask good questions that demand sense making and reasoning and engage students in the mathematical practices. Illustrative examples are drawn from a collection of the Building Concepts dynamic interactive documents (available online) designed to support the teaching of mathematics consistent with the Progressions for the Common Core State Standards for Mathematical Content and Practices. Technological Pedagogical Content Knowledge (TPACK) provides a framework for considering how teachers' knowledge must be transformed to best realize the potential of these technologies, and to shape recommendations for professional development and directions for future research.*

### INTRODUCTION

In the introduction to the National Council of Teachers of Mathematics (NCTM) *Focus in High School Mathematics: Technology to Support Sense Making and Reasoning* (Dick & Hollebrands, 2011), a distinction is made between *conveyance technologies* and *mathematics technologies*. Conveyance technologies include presentation, screen sharing, and monitoring software and hardware (clickers, document cameras,

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interactive presentation boards) that can be useful in a mathematics classroom, but are not intrinsically related to mathematics. In contrast, mathematics technologies are software and hardware with explicit mathematical purposes, such as computer algebra systems, graphing calculators, spreadsheets, dynamic geometry environments, or applets focused on mathematical concepts.

The Conference Board of the Mathematical Sciences (CBMS) recommends in *The Mathematical Education of Teachers II* (MET II, 2012) that:

*Teachers should have experiences using technology as a computational and problem solving tool. When technology is used as a computational tool, learners use it to perform a calculation or produce a graph or table in order to use the result as input to analyze a mathematical situation. They should also learn to use technology as a problem solving tool, or to conduct an investigation by taking a deliberate mathematical action, observing the consequences, and reflecting on the mathematical implications of the consequences. (MET II, 2012, pp. 33-34)*

It is clear from this recommendation that the authors of the MET II document specifically had mathematics technologies in mind, and they suggest two valuable but very different “tool” roles these technologies should play in the mathematics education of teachers:

1. As a computational/representational tool in the service of performing calculations or analyzing mathematical situations,
2. As a tool in the service of problem solving, investigation and exploration.

We claim that these two roles, while both valuing mathematics technologies, indicate two very different perspectives that have important implications for teacher education as they learn to incorporate appropriate tools for learning mathematics.

In the first role, as a computational/representational tool, the technology is viewed as a kind of mathematical servant that performs specific mathematical tasks on request. The user chooses or creates a mathematical object (expression, equation, function, geometric figure, etc.) and then requests a mathematical task (factoring, solving, graphing, measurement, etc.) to be performed on that object. The technological servant performs the desired task and then reports a result or makes a transformed object available to the user. This perspective is supported by studies that suggest the strategic use of technological tools can enhance the development of procedural skills and proficiencies (Kastberg & Leatham, 2005; Roschelle et al., 2009; Roschelle et al., 2010).

The second perspective suggests a view of mathematics technologies as providing special opportunities for students to engage in inquiry and reflection. Rather than simply performing computational tasks, mathematical technologies can provide scenarios of interaction, where a student takes actions and the technology system responds with consequences. Making sense of the implications and connections between those actions and consequences could enhance conceptual learning. This perspective is supported by research that suggests models and manipulatives can be important in developing conceptual understanding (e.g., Chance, et al., 2007; delMas et al., 1999; Drijvers, 2012; Lane & Peres, 2006; Suh & Moyer, 2007; Suh, 2010).

In this chapter, the focus is decidedly on the perspective of mathematics technologies as a tool for conceptual learning, and we highlight a very distinctive class of digital resources - *dynamic interactive mathematics technologies*. These technologies have special promise for positively impacting mathematics

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