

The Synergism of Mathematical Thinking and Computational Thinking

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EXECUTIVE SUMMARY

This chapter analyzes the nature of Computational Thinking (CT) and demonstrates the synergistic relationship between CT and Mathematical Thinking (MT). It cites commonly used definitions of CT and MT and discusses shared problem-solving techniques. The chapter discusses the roles mathematics plays in CT, including how specific mathematical topics interact with specific computing topics, and how mathematical reasoning complements computational reasoning. It explores some principles and practices of CT and performs an analysis of these principles and practices couched in their synergistic relationships to MT. The chapter also discusses a theory of learning for both MT and CT, the application of which suggests directions for pedagogy to enhance the learning of MT and CT concepts.

INTRODUCTION

Computational thinking (CT) centers on principles and practices that are fundamental to the computational sciences. It includes epistemic and representational practices, such as problem representation, abstraction, problem decomposition, recursion, iteration, modeling, simulation, verification, and prediction. However, these practices are also central to the development of expertise in scientific and mathematical disciplines. Although CT shares elements with mathematical thinking (MT), and draws on a rich legacy of related representational and mental frameworks from MT, algorithmic thinking, and engineering thinking, it also extends MT skills in a unique way (Lee et al., 2011). Denning et al. (2009) noted that although the computing paradigm “contains echoes of engineering, science, and mathematics, it is distinctively different because of its central focus on information processes.”

There is ample evidence that MT is central to computer science education. For example, Computing Curriculum 2001 (Roberts 2002) included discrete mathematics in the undergraduate CS core curriculum and most undergraduate CS curricula normally require discrete mathematics, calculus, linear algebra, and probability (Henderson 2001). The pedagogical implication is profound – mathematics, when taught and applied effectively, provides a set of powerful intellectual tools that leads to strong analytical skills. Mathematics is an indispensable tool for problem-solving and conceptual understanding in computing. CT inherently utilizes MT to model, derive, understand, debug, and document software systems. Many researchers have put forward convincing arguments that MT plays a crucial role in CT (Henderson 2001, Larson 1996, Sobel 2000), and it is the purpose of this paper to heighten awareness of this synergistic relationship.

Carnegie Mellon University’s Center for Computational Thinking says, “It is nearly impossible to do research in any scientific or engineering discipline without an ability to think computationally.... [We] advocate for the widespread use of computational thinking to improve people’s lives” (Denning 2009). “The metaphors and structures of computing are influencing all areas of science and engineering” (Wing 2006). Bundy (2007) provides ample evidence to show that computational thinking is influencing research in nearly all disciplines, both in the sciences and the humanities. There is a compelling case to be made for the infusion of CT skills into the K-12 education of everyone, given the pervasiveness of computers in all aspects of our lives. CT skills, like MT skills, are becoming essential for everyone to function in our modern society. As Fletcher (2009) states, “Just as proficiency in basic language arts helps us to effectively communicate and proficiency in basic math helps us to successfully quantitate, proficiency in computational thinking helps us systemically and efficiently process information and tasks.” In recent years, there has been a noticeable movement among computer educators to make “computational

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