Chapter 16
Designing Elementary Mathematics Games using Effective Mathematics Teaching Practices

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ABSTRACT

Problem-solving digital games that make sense of mathematics do not happen by accident but by careful design. This chapter looks at a popular design framework, Game Network Analysis (GaNA), and examines how teachers can use it to turn popular digital games into strong mathematical experiences grounded in effective teaching practices that use play, purposeful explorations, and focused dialogue to make mathematical concepts more meaningful. The chapter involves a careful study of the GaNA framework in comparison with the eight Mathematics Teaching Practices of Principles to Actions: Ensuring Mathematical Success for All. The findings encourage further analysis of the GaNA framework in terms of specific academic areas. Explicit clarification is needed to use the framework to effectively move mathematics education toward its future potential.

INTRODUCTION

Technology is an inescapable fact of life that needs to be embraced as a powerful tool for doing mathematics. It can assist students in visualizing and understanding important mathematical concepts, and support their mathematical reasoning and problem solving (National Council of Teachers of Mathematics [NCTM], *Principles to Actions,* 2014). Researchers claim that games permit constructive, situated, and experiential learning, which is enhanced by active experimentation and immersion in the game (Hainey, Connolly, Stansfield, & Boyle, 2011; Squire, 2008). Their work highlights the great advantage of games

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over traditional methods such as face-to-face or pencil-and-paper teaching. In addition, the traditional linear approach to learning appears to be counter-intuitive to many students, and games allow them to escape the constraints it imposes (Tanes & Cemalcilar, 2010).

Game-based learning is rapidly gaining acceptance as researchers prove the advantages of using games for pedagogical purposes by showing improvements in academic achievement and motivation (Foster & Shah, 2015; Squire, DeVane, & Durga, 2008). While research has been dedicated to the effect of gaming on the learner, or on the design of games, little attention is paid to how teachers approach using and customizing games for mathematical purposes constructed using effective, research-based mathematics teaching practices (Tan, Neill, & Johnson-Wilder, 2012; Watson & Fang, 2012).

Recent research has indicated that the mere availability of technology, favorable attitudes, and school- and policy-level expectations toward technology use does not necessarily result in teachers integrating pedagogy with student-centered pedagogy (Chen, 2008; Kenny & McDaniel, 2011; Palak & Walls 2009). Teachers reported frustration with finding time in the curriculum to use games or even to learn how to operate the game (Friedel, Bos, Lee, & Smith, 2013). Some reported they did not understand how the platform and game options work, or how to adapt the games to the learning needs of their students (Bos, 2015).

Another growing concern is how games fit into effective mathematics teaching practice. Can games support and move teachers to accept change in their instructional practices, thereby helping to make mathematic achievement for all students a reality (Kena et al., 2015)? Work is needed to bridge persistent racial, ethnic, and income-achievement gaps so that all students have opportunities and support to achieve high levels of mathematics learning (Cowan, 2014). The profession has many challenges to move from "pockets of excellence" to "systemic excellence" by providing mathematics education that supports the learning of all students at the highest possible level (NCTM, 2014). To achieve this goal, according to the NCTM, the teacher needs to follow research-tested mathematical practices as outlined in Principles to Actions: Ensuring Mathematical Success for All (2014). Principles to Actions outlines in detail Mathematics Teaching Practices that are research-recommended.

The lack of an effective model teachers can use to help them meet curricular objectives and demands of the school day has become a barrier to implementation of digital games (Palak &Wells 2009; Mishra & Koehler, 2006). In response to the need to provide a working framework for teachers, Foster and Shah (2012) proposed a pedagogical model for integrating games into classrooms—Play Curricular activity Reflection Discussion (PCaRD)—and tested the framework in a year-long study. The PCaRD pedagogy includes opportunities for learners to experience activity for Inquiry, Communication, Construction, and Expression (ICCE) (Foster & Shah, 2012). The encompassing framework for PCaRD pedagogy and its accompanying ICCE model, along with the Technological Pedagogical Content Knowledge (TPACK) model, is called Game Network Analysis (GaNA) framework (Foster & Shah, 2012; Foster & Shah, 2015). Although the GaNA framework's components have helped to motivate and create a rich learning opportunity, how do its suggested guiding questions (Shah & Foster, 2014; Foster & Shah, 2015) relate to the Mathematics Teaching Practices of NCTM's *Principles to Actions* (2014)?

On initial examination, the ICCE components of gaming experiences—"Inquiry, Communication, Construction, and Expression"—appear to correspond somewhat to "sense making, reasoning, problem solving, and communication" found in Mathematics Teaching Practices. However, Inquiry is understood by mathematics and science teachers in many different ways. Some teachers see Inquiry as meaning