Chapter 28
Robotics and Problem-Based Learning in STEM Formal Educational Environments

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ABSTRACT

Some of the best learning may occur in the context of a problem, whether in life or in the formal educational classroom. This chapter focuses on the use of educational robotics as a rich context for real-life applications and problems that can encourage the teaching and learning of science, technology, engineering, and mathematics (STEM) in formal K-12 educational environments. The chapter presents research related to the compatibility of educational robotics with problem-based learning, as well as two years of field test results from a National Science Foundation (NSF) project that is developing, testing, and refining an educational robotics curriculum. This curriculum has a foundation of problem-based learning strategies. The national curriculum effort uses an open-source programmable, robot platform and a Web-based cyber-infrastructure delivery system that provides teachers with a flexible lesson structure, compatible with national standards and engaging students in problem-based learning.

INTRODUCTION: ROBOTICS AND PROBLEM BASED LEARNING

Personally I'm always ready to learn, although I do not always like being taught. - Winston Churchill, British Prime Minister, 1945

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Winston Churchill's quote (The Quotations Page, 1945, Accessed 2011) may well align with the thoughts of many students in today's science, technology, engineering, and mathematics (STEM) classrooms. Many students come with a natural curiosity and joy for learning that is often not well aligned with the traditional STEM teaching process, and thus, these same students may not enjoy "being taught." It has not been uncommon for students to sit passively in a STEM classroom and to watch their teacher write mathematical symbols or scientific terms on the board, while they quietly take periodic notes. Although some learning may indeed occur in this traditional classroom setting, this instructional process may do little to excite students to study the STEM disciplines. Such a passive classroom experience has been said to have contributed to a significant national crisis in STEM education, where the United States is struggling to graduate the needed professionals within the STEM fields to stay competitive internationally (National Research Council, 2010).

There have been many national calls to reform STEM education through new instructional innovations, new strategies, new curriculum and new standards. The integration of national educational standards (Singer, Marx, Krajcik & Chambers, 2000), supported by engaging and exciting technology (Putnam, 2002) has been a key component of STEM instructional reform (ISTE, 1999; ITEA 2000; NCTM, 2000; NAS, 1996). Building student awareness and understanding of engineering is also an important context reform for STEM coursework, since engineering applications have often not been included in science and mathematics coursework and the reintegration of engineering with science and mathematics instruction is consistent with various calls for STEM education reform from that discipline (Coppola & Malyn-Smith, 2006; National Academy of Engineering, 2004; 2005)

The concern that the United States is not producing enough STEM professionals for our needs, especially as compared to many other countries around the world, is growing. National reports, such as the 2010 *Rising Above the Gathering Storm Revisited*, paint an alarming picture. For example, 51% of U.S. patents now go to non-US companies (Donohue, 2010) and the U.S. is now 27th among developed nations in the proportion of college students graduating in science or engineering (Organization for Economic Cooperation and Development, 2009). National and international reports illustrate the need for rapid reforms. For example, as of 2010, the World Economic Forum has ranked the United States as 48th in the quality of mathematics and science education (World Economic Forum, 2010). Further, the ACT now reports that 78% of high school graduates were not ready for many entry-level college classes (American College Testing, 2008). The United States government is becoming increasingly concerned with the need to undertake rapid reforms in STEM education. President Obama, in his 2011 State of the Union Address called this our nation's new "Sputnik moment" where STEM education needs to be a focus for educational innovation.

We know more today about how curriculums should support the student learning of STEM concepts than we ever knew even a decade ago (National Research Council, 2007). For example, a comprehensive report by the National Research Council entitled *Taking Science to School* summarizes how science learning and proficiency should be supported by curriculums in Grades K-8. Four key learning strands discussed in the report suggest that:

1. Students should know, use, and interpret scientific explanations of the natural world,
2. They should be able to generate and evaluate scientific evidence and explanations,
3. They should understand the nature and development of scientific knowledge, and
4. Their work should include active participation in scientific collaboration and discussion (National Research Council, 2007, Executive Summary p. 1-2).

Other reformers suggest a richer context for STEM learning and reasoning (Gotwals & Songer, 2006; Metz, 1995) and a more limited and sequenced set of the mathematics topics (NCTM, 2006). In an earlier NRC research summary report published in 2002, *Helping Children Learn Mathematics*, a national goal of mathematical