Chapter 3
Generating Transferable Skills in STEM through Educational Robotics

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ABSTRACT

This chapter aims to present guidelines, suggestions, and ideas for designing educational robotics programs, which help participants generate skills useful in science, technology, engineering, and math (STEM) as well as in other career paths. A list of skills areas is presented, categorized either as highly STEM-relevant or more universal, and each skills area is discussed in the context of the content and delivery methods of robotics programs. Examples are provided from several existing curricula to demonstrate how robotics can be leveraged for generating these useful skills. A set of suggestions is then presented for guiding future robotics curriculum development, in formal or informal settings.

INTRODUCTION

As modern society becomes more dependent on a strong science/technology/engineering/math (STEM)-literate workforce, there is an ongoing and increasing need to ensure that educational programs, both formal and informal, emphasize the set of skills that will support STEM learning and lead to STEM careers (Barger, Gilbert & Snyder, 2010; Porter & van Opstal, 2001). Here we take an engineering design approach to identifying future directions in educational robotics programs in support of these goals. The first step in performing any kind of design is to establish clear goals or intended outcomes; therefore, we will begin by identifying the types of skills outcomes that are important for students who will continue into STEM-related undergraduate programs and careers, and then discuss ways of pursuing these outcomes in educational robotics settings. Skills considered more universally important across career categories will also be addressed. Specific examples of how robotics programs can address these goals will then be detailed.

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The main premise posited in this chapter is that the desirable skill set for STEM careers is entirely learnable, and one need not rely on innate ability in students to adequately prepare them for such careers. By the time they reach middle school or high school, students are fully capable of being taught these skills. By engaging with students, teaching them established methods and techniques which support the scientific method and engineering design, and leveraging their interests, students can emerge from K-12 robotics experiences well prepared for future STEM education and professional activities as well as for other varied careers. The main objective of this chapter is to point out strategies that can be employed in designing curriculum for K-12 robotics activities, formal or informal, to achieve this desired outcome.

BACKGROUND

In many ways, most youth robotics programs fit the description of student-centered education (Waterhouse, 2005). Lectures are deemphasized in favor of problem-based approaches, and students can have more choices, may create portfolios, perform self-assessment, and so forth. One important rationale in favor of this type of approach is the link between these student-centered education practices and the development of desirable skills and traits, not just discipline-specific knowledge. These programs can serve as platforms from which to reinforce positive existing traits and skills and to encourage their development in the program participants. In fact, research points toward the idea that free-choice or informal science experiences of this type may have a much stronger effect on science literacy than in-school experiences (Falk & Dierking, 2010). Because of this, influencing career choice can be an important motivator for development of informal education programs (Fairley, Prysock & Archer, 2009; Shurn, Hardnett & Kearse, 2008; Verma & McKinney, 2009). However, this does not imply that such positive skills- and career-related outcomes cannot be achieved with well designed curricula in more formal educational settings.

Various programs and curricula have been developed using robotics as a means to convey STEM-related knowledge and associated skill sets to youth, generally from about age 10 and onward (Carnegie Mellon Robotics Academy, 2011; VEX Robotics, 2011; GEAR-Tech-21, 2011; Yanco, Kim, Martin & Silka, 2007; Botball, 2011; FIRST, 2011) and some aimed at younger children (Bers, 2010; FIRST, 2011). One major impetus for this type of program is to influence career interest. Tai, Liu, Maltese and Fan (2006) showed that in 8^{th}-graders, interest in or expectation of having a career in a STEM field was a much stronger predictor of actually achieving a STEM career by age 30 than (math) proficiency scores. Although a desire to boost interest (Avanzato, 2009; Hirsch, Carpinelli, Kimmel, Rockland & Burr-Alexander, 2009) and/or increase performance (Zeid et al., 2007) in science and math is often cited as a key motivating factor for using these and other robotics curricula in youth programs, the skills development aspect is not to be undervalued.

DESIRABLE SKILL SETS

Although formal education can provide great preparation in terms of general and subject-specific knowledge, there are many other less tangible forms of preparation. Many would agree that these can be difficult to teach and even harder to track. In some ways, informal education settings, such as those in which robotics curricula are often implemented, may be in some cases more naturally effective venues for this kind of skills transfer because of their “student centered-ness.” However, by implementing effective strategies in curriculum development, whether designed for formal or informal settings, similar positive skills-transfer outcomes can be achieved.

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