Chapter 65

A Novel Strategy to Improve STEM Education:
The E-Science Approach

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ABSTRACT

Undergraduate traditional instructional delivery that does not utilize computation is linked significantly to students' low performance and thereby attrition. Over the last two decades, new computational technologies, information, and communication have emerged, creating comprehensive cyberinfrastructure-based service systems, or what is termed here e-science. E-science environments are virtual systems that support data management, data mining, information acquisition, visualization, computing services, and people collaboration over the Web. Although a number of attempts have been successful in utilizing e-science environments to change how research is conducted, using e-science environments for education has been rarely realized. This chapter describes a project that aims to transform Science, Technology, Engineering, and Mathematics (STEM) education through using e-science systems at the undergraduate level. The strategy is built on three arms: (1) injecting Computational Thinking (CT) in STEM education; (2) using e-science for STEM learning; and (3) building a community-of-practice around e-science. By using e-science resources and services, an inquiry-based approach to learning can be the key to students' motivations, achievements, and enthusiasm for science.

INTRODUCTION

Without Change there is no innovation, creativity, or incentive for improvement. Those who initiate change will have a better opportunity to manage the change that us inevitable. - William Pollard

The fact that students in the United States lag far behind their international peers in Science, Technology, Engineering, and Mathematics (STEM) has been well publicized and documented. The United States is not meeting its current and projected needs for scientists and engineers. As noted by President Barack Obama, "Reaffirming and strengthening America's role as the world's engine of scientific discovery and technological innovation is essential to meeting the challenges of this century" (White House, 2009). At the

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undergraduate level, and across all disciplines of STEM, students who started in STEM fields were less likely to complete degrees in any fields than students who intended to major in non-STEM fields, with a percentage of 15 to 17% of STEM bachelor degrees to the total bachelor degrees (AAU, 2011). As such, with no surprise, active scholarship began to research methods to improve STEM undergraduate education suggesting techniques to engage students and enhance the learning experience.

In addition, diversity in STEM is crucial to contribute to educational and research environments that reflect and draw on diverse perspectives for stronger science (NAS/NAE/IOM, 2011). However, women and ethnic populations, remain highly underrepresented populations in STEM fields. According to the Census Bureau projections, the aggregate US minority populations will become the majority by 2042 (Vincent & Velkoff, 2010) and these fast-growing populations are the most underrepresented in higher education in certain STEM fields (Garces & Espinosa, 2013). As a result, new scholarship on teaching and learning has led to the development of techniques that have been demonstrated to be more engaging and more effective at helping students from underrepresented populations to learn and succeed. Building on this work, Philander Smith College, which is the oldest Historically Black Colleges and University (HBCU) in Arkansas, developed a five-year project to inject e-science systems and resources to improve undergraduate STEM learning and teaching, as discussed in the following sections.

BACKGROUND

With advances in computation, information and communication technologies, there has been a move toward creating cyber-based service systems that support and facilitate scientific research (e-science systems). E-science systems enable computationally-intensive research that requires using large datasets, distributed grids, and/or visualization (Bietz & Lee, 2012; Biswas et al., 2001; EDUCASE, 2009; NSF, 2007, 2013). As other service systems, e-science systems are formed of advanced technologies, networks, groups of people and other sub- systems (Swaid & Wigand, 2009). Although a number of e-science systems has emerged (e.g., TeraGrid, XSEDE, NBCI, and iPlant), limited number of researchers know how to utilize these powerful resources for scientific research and education. Therefore, it is imperative to train next generation of STEM investigators on the concepts and resources of e-science systems. According to NSF (2013),

[S]ustaining this revolution across all areas of science, engineering, and education requires the formation of a citizenry and workforce with the knowledge and skills needed to design and deploy as well as adopt and apply these cyber-based systems, tools and services over the long-term. The opportunity for such preparation should be available at all stages of formal and informal education (K-16 and lifelong), training and professional development, and must be extended to all individuals and communities.

In order to begin the process of training on e-science systems, computational thinking skill set should be developed first. To think computationally, or Computational Thinking (CT) is a skill set that STEM graduates need to demonstrate (Wing, 2006). Although the concept of using computation to solve problems is old, injecting CT in a systematic way across STEM fields to develop analysis and problem solving skills that are essential to succeed in today's workforce of STEM, is the new direction by most academic institutions (NSF, 2013). Wing (2006) describes Computational Thinking (CT), a set of thinking skills, habits and approaches that draws on the

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