Pathways to Petascale: A Strategic Plan for Cyber-enabled Education

“Computational science – the use of advanced computing capabilities to understand and solve complex problems – is now critical to scientific leadership, economic competitiveness, and national security.” –J. H. Marburger, Science Advisor to the President and Director, OSTP.

As a fundamental component of the Blue Waters Petascale Computing Facility project, Shodor is leveraging resources to support a comprehensive effort integrating student research, pedagogy, materials development, faculty enhancement, and evaluation. Built on the National Computational Science Institute (NCSI) model of national dissemination of effective resources for curriculum and faculty development, Shodor provides the infrastructure to accomplish the significant goal of incorporating petascale-computing-enhanced computational science education across the undergraduate science, technology, engineering, and mathematics (STEM) curriculum. A multi-scale collaboration supports a national community during the classroom implementation, evaluation, and revision of interdisciplinary and multidisciplinary computational science education modules, interactive models and tools, and courses.

The community will consist of faculty at community colleges, predominantly undergraduate institutions, minority-serving institutions, schools of education, and the undergraduate colleges of research universities, in addition to the pre-college schools that are served by these institutions. Based on a cycle of research, implementation, evaluation, and revision, the NCSI model for EOT will sustain its Push of petascale computing onto the working agenda of regional and national meetings of professional societies, it will Pull faculty into training opportunities to improve the content and method of their teaching, and Permeate the National Science Digital Library (NSDL) with curricular materials that have undergone a rigorous vetting through verification, validation, and accreditation for the highest quality materials. The goal is to persist as a dynamic community of scientists and educators fully capable of incorporating the impact of the petascale tools, techniques and technologies at all levels in education, and a community fully capable of mentoring and supporting their colleagues in incorporating these methods.

The march to petascale comes at a time when so many computer science departments have reported that “programming has lost its luster” and that fewer students want to go into computer science, per se. At the same time, computational science continues to attract more students since context-based computing – including everything from systems dynamics, to agent-based modeling, to data analysis, and visualization—enable the student to model the world. Students want to focus more on content-driven disciplines, and that is the strength of petascale to transform education, because modern math and science are more about pattern recognition and characterization than mere symbol manipulation, opening avenues of exploration for students in ways that even direct
observation cannot. The observation is paramount, but the observation is made in the context of a scientific model that is implemented on the computer. Science is the **heart** of computational science, and petascale will set the heart rate. GIS investigations are one of many environments enabling direct student observation, experience, and active-learning.

The three principle components of **petascale thinking** are a) quantitative reasoning, b)analogical thinking, and multi-scale modeling. We have observed that computational models and numerical simulations are so attractive that they can motivate students to understand the mathematical foundations that enable them to fully explore the models. GIS investigations should go beyond merely displaying large data sets to exploring models that explain and promote numerical experiments Quantitative reasoning is the **lifeblood** of computational science, and as such, the impact of petascale computing must be addressed at all levels of education to produce scientists capable of fully utilizing these resources.

Improving the competence and confidence of undergraduate faculty in petascale computing and computational science should be the passion and forte of the cyberinfrastructure effort. In the first place, undergraduate faculty prepare future K-12 teachers, future graduate students, and the future work-force. If we want to have the biggest impact on educational reform and improvement, undergraduate education is the **pressure point**. Secondly, as research universities advance in their use of petascale computing resources, transforming their methodology in scientific discovery and in their use of HPCC technologies, a greater emphasis is required for adaptations for the undergraduate educational experience. Otherwise, the gap between the predominately undergraduate institutions and the nation's research institutions will widen, even though across the country most graduate students still start in predominately undergraduate institutions, and a growing number of the four-year institution graduates start in two-year institutions. We seek to increase the number of qualified students who apply to graduate school or who can transfer to four-year institutions, with a special emphasis on students who are underrepresented in the areas of science, mathematics, engineering, and education. To reach these students, we have to reach their professors first. Petascale will transform everything it touches, and petascale will touch everything.

We cannot be either researchers or educators. We are working to apply the rigor of our research methodology to leverage, extend, and deploy an evidence-based approach in petascale-enhanced education.

**References**


R.M. Panoff, "The Four As of CSE Education: Application, Algorithm, Architecture, and