APPLYING HPCC TECHNOLOGY TO SYSTEMIC DIVERSITY DILEMMAS

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Abstract

The authors present their decades of research and development experience in applying High Performance Computing and Communications (HPCC) technology to defence simulations and training. They discuss current dilemmas in education, including increasingly diverse classrooms and identify those for which HPCC technologies may hold the answer. Further they adduce evidence to support their thesis that such technology could be applied, resulting in attractive cost/benefit ratios, increased pedagogical efficacy, fewer teacher administrative burdens and, most importantly, more effective responses to diversity-related needs found in several disparate dimensions. They recount their hands-on experience in pre-college education environments, their compilation of data on classroom teacher perceptions and their justification and procurement of HPCC assets to meet otherwise daunting challenges. A special feature of this work is its concentration on teacher-centred services that are relevant, accessible and controllable by less technically sophisticated teachers, especially in early education environments. Rather than imposing that which is technically exciting, they focus on what teachers and learners want and need. Personalizing individual instruction, to both enable each student to learn and to address the identified classroom dilemmas, can arguably be best served by well-designed HPCC-supported platforms and modules. The extensibility of this approach to informal education is explored in the context of museum education.

Introduction

Most industrial nations are faced with critical challenges in their pre-college education systems. The United States is one country that is in a virtual panic concerning any number of issues in what is termed "K-12", *i.e.* Kindergarten through High School, ~ages 5 to 18. Technologically focused societies are particularly alarmed by any perceived short-comings in Science, Technology, Engineering, and Math (STEM) education. This has led to hyperbolic characterizations (contested by Greene, 2005), organizational scrutiny (Christensen, 2008) and radical solutions (Gatto, 2005). Arguably, one of the most distressing and disabling factors is the overwhelming multidimensionality of the diversity found in U.S. classrooms (Osborn, 2005 and Reid, 1998). Many of the so called "Grand Challenges" of Education (Davis, 2008) centre on or are exacerbated by diversity. These Education Grand Challenges

include:
- Instructing in heterogeneous classrooms, diverse in:
  - Learning styles
  - Intellectual aptitude
  - Achievement level
  - Cultural backgrounds
  - Native language
  - Personal interest
- Teaching STEM topics via teachers with limited STEM backgrounds
- Implementing effective performance-based evaluation
- Enabling teachers to automate growing data entry and admin tasks
- Providing technology without aggravation in a non-technical environment
- Facilitating the exchange of teaching insights, techniques and teacher materials
- Responding to ever-changing environments for learning and for life

These challenges are not uncommon, at varying levels of importance, in most industrial societies. At the heart of these diversity issues lies the classroom's single communications conduit: the teacher. Technology can allow teachers to make use of new insight and enhance their own talent for instructing each learner. However, this technology often brings its own burdens for the teacher that must personally manage the burgeoning computer-aided education tools and must deal with its own unbending structure (Davis, 2007).

Some of these burdens can be relieved by redefining, applying and centralizing advanced technology within the education context. The authors maintain that technology is not just the box on a classroom desk, into which information may be easily put, effectively stored and efficiently retrieved. It can and should be part of 21st Century learning processes, physically and cognitively. Technology can transform learning experiences for diverse learners. This will happen only if the educational community views technology as more than just hardware and software, or just an application (a math game) or a just new way of doing an old task (email instead of mimeographed memo), If the educational community includes in its definition of technology all the environments, the data tools, and the real-time connection to places and people around the globe, then opportunities for integrating teaching and learning with technology will create a new set of powerful processes. This is preferable to simply repeating existing teaching and learning processes with additional special effects. Not only should it make for a better content knowledge outcome (deeper, broader). it can also stimulate within the learner, a metacognitive revelation into how they learned what they learned. This is a category of knowledge that can transcend content areas and enhance learning of subsequent topics. Whether in the classroom, in the home or in the informal setting of a museum, technology can activate the prior knowledge of the learners about the subject. It can allow for more finely tuned, complex and robust data collection to support instructional decision-making. Finally, to close the loop, technology-enabled learning environments can contribute to the learner's knowledge and application of technology itself. High-performance computing can provide for the scale, speed and complexity required by this enhanced definition of technology.

The authors' experience over two decades with very large Department of Defence systems has shown the utility of High Performance Computing in this arena and recent breakthroughs in cluster technology have delivered the power required at a cost that is attractive(Messina, 1997; Lucas, 2003; Barrett, 2004 & Davis, 2009). This can easily be achieved using personnel commonly available at the school district level.

Unfortunately, terms like High Performance Computing and SuperComputers conjure up images of Seymour Cray standing in front of a huge machine, with specialized cooling fluids being piped in and out of a mass of blinking lights and shiny panels. This is not the vision the authors advance below. While the new terminology may be daunting at first, practice has shown that the proposed implementation is effective, efficient and economical. Further, the power available is key to attacking

the Grand Challenges listed above, with the certainty of providing new approaches hitherto unavailable to the classroom teacher. The balance of this paper will be devoted to justifying these statements.

Background of HPCC

History

This section can be easily skipped by anyone who is familiar with the High Performance Computing discipline and who knows the terminology commonly in use.

High Performance Computing (HPC) is a rather general term, somewhat more in favour than the commonly used term "SuperComputing." There is a whole industry devoted to deciding who is biggest and fastest (Dongarra, 2009). HPCC has now been broadened to commonly encompass very affordable and easily supportable clusters of a few hundred processors. Virtually all of the familiar names in computing produce HPC-class clusters. Most of the current machines use commercially available off-the-shelf processors, not too different from the CPU in home computers. This trend was led by the work of Thomas Sterling's team on the *Beowulf* project (Sterling, 1999). Many use very common PC processors and the prosaic Ethernet switches, again, not unlike the ones found in most offices or schools. Three of the major benefits from this are:

- Low cost realized by using mass produced components
- Easy administration and support by ordinary tech-support personnel
- Straightforward portability of programs designed to run on PCs in the classroom

Definitions

HPCC – While a high-end workstation may easily contain up to eight computational cores, when the authors use the term HPCC they are referring to clusters with a few hundred cores or more.

High Bandwidth Communications – The authors use the term High Bandwidth Communications, when they are referring to those circuits that can easily handle a Gigabit per second (GigE,) for local networks and more than one mega-bit per second for wide areas.

Hardware options today

HPCC systems need not be prohibitively expensive. A cost-conscious school district could build a simple Beowulf cluster with 160 processing cores for something on the order of $20, 000. Such a cluster could easily serve several schools in the ways to be discussed below. While expensive operating system options are available, with enhanced support benefits, the installation disks of open source, free O/S's include the system software necessary for configuring the cluster and for establishing intermodal communications to provide the desired computational power.

JFCOM experience with HPCC and training

Mission and Needs

The United States military needed to simulate more than one million entities, *e.g.* pedestrians and vehicles, in an urban setting for training and analysis. All of these entities had to be capable of sophisticated behaviours, operating on a global-scale, variable resolution terrain database. (Ceranowicz, 2002). Experimenters were using large numbers of Linux PCs distributed across a LAN, but they found that communications constraints limited the simulation to tens of thousands of vehicles, about two orders of magnitude fewer vehicles than their needs. They also needed simulation programs to effectively interact with live humans in order to assess the true impacts on personnel and procedures. (Ben-Ari, 1998) This required several new methods to modelling human behaviour (Hill, 2000). Much of the military community did not report using the needed High Performance Computing (HPC).

(Davis, 2004 & Gottschalk, 2005) In order to make good use of the HPCC assets the authors applied approaches that had been developed in university research in the sciences. (Brunett, 1998)

Response of HPCC

HPCC has exceeded its original goals for simulations of at least two million simulated entities, including civilians and military forces. This was more than achieved in a major breakthrough in which ten million entities were simulated. (Figure 1)
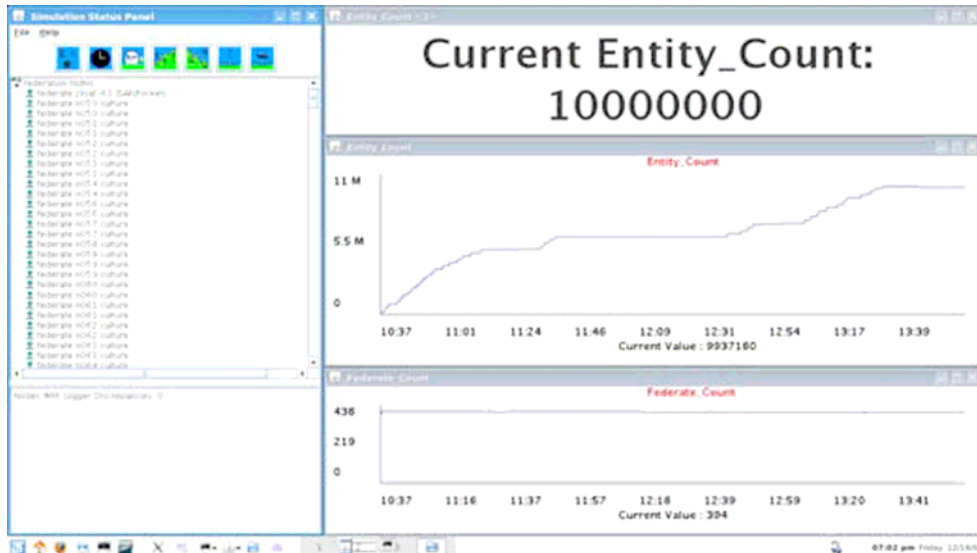

Figure 1. Screen Capture of Ten Million Entity Run

The technical and computational challenges were interesting, but not daunting. Similarly, the authors assert that many of the Education Grand Challenges continue to exist due to identical limitations of computational power, with interesting, but not daunting, hurdles.

Distributed

The DOD system the authors developed was effectively operated across North America. As many as 1,500 live participants were able to log into the system at one time. All that was needed was a Linux-loaded PC with the appropriate simulation program and access to the simulation network. As shown in Figure 2, even the long distances (~ 5,000 miles from Virginia to Maui) did not inhibit active, real-time participation.
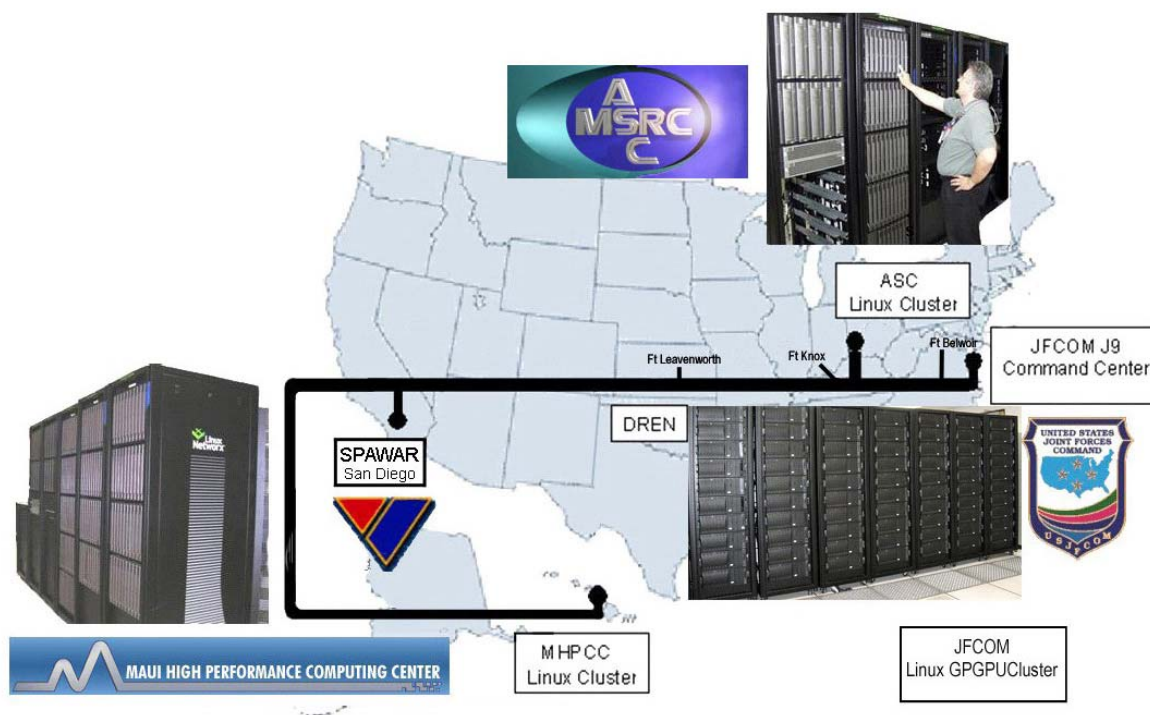
Figure 2. Notional Net Diagram of Transcontinental Training System using HPC

Again, this is not a suggested configuration for a local school system, but is laid out here to show the experience in successful operations using the principles set forth above. Distributed HPCC confers special power that can deliver needed interactivity and performance to remote schools just as it did to remotely-stationed military personnel.

Collegiality

The interactivity allows for a collegiality that has been witnessed by the authors. After major exercises, the camaraderie of the participants on the same teams was evident in out-briefing segments. This collegiality has led the authors to believe that even remotely connected teachers and students would "bond" into loyal teams and resolve internecine issues as if they were geographically co-located.

Capable

All this leads the authors to the conclusion that these capabilities, systems and approaches could be applied successfully to pre-college education. The identification of the issues that are seen as amenable to these approaches and the explication of the experiences that have led the authors to think that these facilities would be cost effective, affordable, and rationally maintainable will now be set forth.

Observations on teachers and technology

Recounting early forays

In the earliest days of the Internet, two of the authors, Tom Gottschalk and Dan Davis were both on staff at a HPCC centre for the California Institute of Technology. They were involved in scoping technology needs with local K-12 districts, selecting services, installing networking, orienting staff, instructing teachers in HTML, trouble-shooting, and assessing results. This experience gave them unique, hands-on sense of the pre-college classroom, available skills, needs, and frustrations. Laurel Davis, on the other hand is an experienced K-12 teacher, teacher trainer and consultant. Author 2 is a museum professional from the National Museum of American History and the National Portrait Gallery

of the Smithsonian Institution

Discussion of attitudes today

The authors surveyed all of their contacts in the Los Angeles Basin to assess current attitudes and future visions about K-12 education. They have found the education Grand Challenges listed above still rank high with every interviewee: teachers, teaching educators, administrators and education activists. In addition, they find a distrust of technology and technologists, formed by years of having suffered the over-promising, under-supporting, over-burdening and under-training the classroom teachers. They see the future as being viable only if teachers are part and parcel of early vision creation.

Vision

The authors have been in many classrooms. The scene frequently is one of a single, over-burdened teacher responsible for twenty to thirty incredibly diverse students. Author Laurel Davis has experience of an instance of 32 students in her classroom on the Pacific coast with 6 different native languages being spoken in the homes of her students. These K-12 classrooms typically have three or four operating PCs, a great stack of software disks, inconsistently functioning internet connections (requiring constant monitoring to ensure students remain "on task") and scant access to technical assistance. Many of the PCs are noisy, hot, and present significant space and wiring intrusions.

The authors' hardware vision, supported by current technology, is a compact unit with a screen, keyboard, mouse, and earphone jack, with no moving parts, fans or hard disks to fail or make noise. Each unit would weigh less than 5 pounds and wiring would be restricted to a power cord. Network connection would be via wireless technology and connection would be to a school intranet, precluding net surfing, emailing or security violations. The keyboard would feature a fingerprint reader to identify and verify the student using the unit. If anything fails in it, a student could easily swap it for a backup.

The central, HPC-enabled computer would be programmed to recognize the student, greet them upon log-in, perhaps with an MPEG movie showing an appealing avatar-scholar. It would then select the appropriate topic for study, with an interface so that it is responsive to teacher input. Using proven AI techniques (Fogel, 2005), the server could then interface with the student, trying several different learning approaches and focusing on the one that provided the best evidence of learning achievement. (Davis, 2000) As before, the HPCC system would be open to direction, should the teacher believe that the student needs some special emphasis. The central computer would schedule, pace, record, and analyse the students' progress in all areas of instruction. By cross-referencing and data analysis, it would seek anomalies and alarm the teacher when appropriate.

This system could be used by the classroom teacher to individually tutor exceptional students (high or low achievers) who are not being optimally served by general classroom instruction, without isolating the students from the home room experience. It could also be called upon to lead small group learning experiences to subsets of the class divided up along any criteria the teacher thinks useful. Last, the system could provide classroom instruction, via projector and speaker, for any number of occasions.

In this vision, the teacher is relieved of most of the classroom clutter, the software to administer, the systems to learn, the progress to monitor, the equipment to maintain, and the records to keep. They could focus more on pedagogical decisions that have to be made and scholars ready to be made. There would always be an interactive and engaging alternative assistant teacher for any student or group of students

Pedagogical issues mitigated by HPCC technology

Learning styles

Whether viewed through the lens of "learning styles," "elements of the classroom" or "multiple

intelligences," a review of the literature on learning modalities points to the benefits of a match between the student's learning profile and the instructional approach. (Kolb, 1984; Dunn & Dunn, 1978; Gardner, 1999.) While there is much research that needs to be done to understand the total impact of modality on learning, it is now clear that the current ratio of students to teachers in most schools makes it challenging for teachers to set up and manage instruction in a way that is customized to each student's learning style (OECD, 2005). Although most teachers make some effort to provide different methods of learning sometime during the school year, the overwhelming daily approach to instruction reflects the way they themselves were taught (Pajares, 1993). The class has a significant number of students who would learn best only if receiving instruction suited to each one of the individual's particular textual, visual, aural or kinaesthetic modality. Recent research seems to support the notion that, even if a teacher has a learning-style-segregated group or a single student with a learning style that is different from the teachers, that teacher cannot optimally instruct that group or student (Stitt-Gohdes, 2001).

Here, distributed HPCC could bring its power to bear in two ways 1) by performing a real-time assessment of learning style characteristics of the individual student and 2) then presenting that style to that student, regardless of styles of the other students in the class. As always, it is the vigilance and sensitivity of the classroom teachers that will ensure the proper goals of educating their charges, which raises the resultant need for easy and sensitive controls for the teacher to customize the computers' interactions with the students. By using a centrally located HPCC asset, these carefully collected preferences and any external control inputs would be permanently in play. It would not matter at which terminal the student sat, even at home, should the intranet be open to remote log-in from student residences.

Intellectual ability

Using techniques developed by the Artificial Intelligence community, the HPCC system could quickly assess the degree of subject matter competence, learning pace, and weak areas for the student. This data would be retained and used to analyse optimal starting points the next time the student logs on. The teachers' inputs would again be invaluable and would be facilitated by an intuitive interface in any truly well designed system. As has been argued earlier (Davis, 2007), the system could be programmed to take the top performing students and deepen their knowledge of the specific topics being covered by the rest of the class, while avoiding the undesirable effect of having one student leaping ahead, *e.g.* to study long division while the rest of the class is struggling with simple addition.

Social and familial input

In a problem that may be more serious in the U.S. than it is in more homogeneous societies, HPCC could assist the classroom teacher when the diversity faced is a mix of different cultural assumptions, and family influences (Diaz-Rico & Weed, 1995). Their CLAD manual refers to some communities of origin that are manifestly rural and are largely illiterate. One of the issues noted was a commonly seen social norm that frowns upon daughters' publicly exceeding their fathers in areas such as education. These young students may be in the same class with students with more progressive and egalitarian visions of gender capabilities and duties. Managing effective instructional approaches simultaneously among these groups might be made easier if students spent some substantial time on HPC-served terminals responding to their individual sensitivities and allowing them a private area in which to grow, un-observed by critical classmates. This plan would also serve to answer the need to give late grade school (ages 10 to 12) girl students a way to become interested in and show excitement and capabilities for "nerdy" subjects like math and science. (AAUW, 1992).

Performance based evaluation

Another area ripe for HPCC assistance is that of performance-based assessment or evaluation. While this may be one of the "Holy Grails" of teaching, it is manifestly out of the question to suggest one teacher can constantly and effectively monitor each and every individual action of more than a few

students, let alone the entire class. However, the HPC-enabled system can not only constantly monitor each key stroke and each change in the pace or content of learning, it can update performance analyses of progress, adjust goals and report advances to the teacher.

Given the unavoidable mandates for high stakes testing in many countries (NCLB, 2002), and the distaste with which many teachers receive such mandates, a performance-based analysis of young scholars would have the possible impact of showing such a high correlation to and advantage over the high stakes tests, that the requirement for these classroom disruptions may be obviated in the future.

Range of cognitive activity

Research in cognitive science and education indicates that meaningful learning, that can be transferred to multiple settings, occurs when high-quality instruction is integrated with frequent opportunities to 1) apply abstract knowledge in multiple authentic contexts (Gick and Holyoak, 1983; Cognition and Technology Group at Vanderbilt, 1997; Bransford *et al.*, 1998), 2) receive feedback on the validity and success of the application (Bransford *et al.*, 2000), and 3) re-engage in instruction with refined knowledge targets. However, due to time, budget, training and material constraints, the majority of learners still work passively from a textbook or in a setting of diminished rigor (Bransford *et al.*, 2000; Scales, 2004) and rarely engage in the content in the depth described above for the critical understanding that will allow them to actually use the knowledge in varied contexts.

Advances in HPCC technology provide a welcome opportunity to engage learners in real-time authentic contexts most relevant to their desired training outcomes. Use of HPCC would accelerate the learning curve and raise the competency of trainees by providing immediate, repeated and user- or variable- influenced simulation experiences in which learners must synthesize and apply their developing content knowledge. Use of HPCC would also provide an infrastructure for incorporating the newly honed knowledge of student who had been given a chance to apply concepts to a real-world problem, and could return to the instructional setting and inform the learning community or process further.

Effective use of collaborative learning environments

An optimal way to facilitate and intensify engagement with knowledge and the quality and frequency of feedback provided is through collaborative learning environments. The recent explosion in social networking technologies indicates the potential for increased engagement of students through use of high-quality virtual communities. Not only does this allow for access to "distributed cognition," (Vye *et al.*, 1998); it promotes superior problem-solving and cognitive development in ways that individual exercises may not (Evans, 1989; Newstead and Evans, 1995; Kobayashi, 1994). Collaborative learning environments enabled by HPCC would allow for the participation of experts and novices in complex contexts in tandem, thus providing opportunities for conflict, internalization (absorption of knowledge by novices exposed to experts) and self-explanation (attempts by experts to convey knowledge to novices), all of which serve to expose misconceptions, deepen understanding and lower affective filters that may inhibit learning (Dillenbourg and Schneider, 1994).

One criticism of collaborative learning environments is that peer-centred learning is not always as effective as knowledge-centred learning because experts who have a mastery over the knowledge are not necessarily as knowledgeable about strategies for helping novices understand those concepts. (Shulman, 1986). Scalable HPC-supported collaborative learning would help to address this liability in collaborative learning. HPCC can provide the communications bandwidth and computational power to manipulate not only the variables of the learning contexts themselves, but also to respond to the variable factors of the learners in the group (Davis, 2000). This would deliver not only an environment

that would be modifiable from a content perspective, but an environment that could be modified both by expert students and skilled instructors to meet the pedagogical needs of all learners in the group.

Strawman plan for elementary education application

Capabilities'

The goal is to provide the kind of computing power and data space required to achieve the above assistance to the classroom teachers without burdening them with onerous system administrative duties. It is the authors' experience in the DoD and in the classroom that indicates a Linux cluster of something on the order of 128 nodes of four core processors and associated disks and networking would be sufficient to serve a school system of about 1,000 students (Lucas, 2009). Again the authors do not propose to make the HPCC system the only, or even the major, pedagogical instrument. The suggested hardware is clearly within the capability of the existing technology. The data management is similarly available and tested (Yao, 2006). The system design and scalability is a matter of record (Davis, 2006). The major issue to be overcome before implementation is that of the AI analyses, teacher input interfaces, data analyses programs, and student interface optimization for learning style and cultural differences. The authors do not see any insurmountable hurdles to the early fielding of such a system.

Construction

The specification of the hardware system itself is not beyond the technical ability of any competent Linux system administrator. Even the construction of the system from commonly available component parts like motherboards, hard drives, cases and Ethernet switches is within the realm of possibility for them. The "bricks and boards" equipment rack can be utilized, but most organizations opt for a commercially provided rack of servers, already configured for cluster computing. Additionally, it should be noted that all of these installations can be incrementally established and adopted. Especially with the "home-built" systems, one can start with only a few nodes and add to the system as funding and support facilities allow and as use and population growth demands. The authors have built several successful clusters with as few as four PCs as nodes and effectively used these for high school instruction. (Gottschalk, 1999)
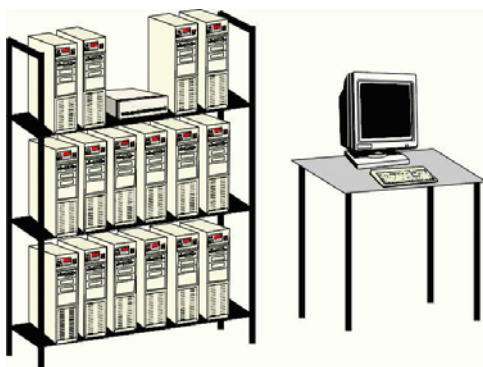

Figure 3. "Home Built" Beowulf

Figure 4. Large Commercial Installation

Costs

In these two styles of cluster, the 512 core machine suggested as a strawman above would cost from $128,000 (for a home-built, jury rigged system) up to something on the order of four times that much (for a "bells and whistles included" commercially configured system.) *Caveat*: equipment room cost,

power, cooling and maintenance are often estimated as equalling the cost of the installation. Those additional costs vary from area to area.

Survey of informal education issues of note

Informal education: museums, libraries, zoos, and community-based organizations.

While informal education occurs outside of the classroom environment, informal and formal education face many of the same challenges. This analysis starts from the premise that informal education is that which relies on an object of art or history, science or biology, to tell the story rather than the teacher. The major distinction is that museum visitors and zoo viewers are not interfacing with a more-learned instructor, in person, but rather being given the material and the object directly in order to take the lesson. Another difference is that their attention is not being actively monitored by the instructor and they are more free to attend to or ignore the information proffered.

Diversity in Informal Education

Diversity is as much, if not more, of a problem for the informal educator to solve. The goal is the education of the student or visitor in issues of importance via the study of the subject or object on display. As with the classroom instructor, maintaining interest is critical, as visitor's presence, support, learning and participation are all almost invariably voluntary (Lampi, 2009).

Much of the amplifying data, *e.g.* exhibition introduction labels, those next to paintings, biographical details about a subject, that are presented by informal education are static and not geared to the particular participant. Being able to respond effectively to each group or individual would potentially yield benefits in return visits, continued support, enhanced learning and fuller participation as called for above. Research as to how effective the technology insertion might be would be challenging, as exit testing seems untenable. In any case, it would be illuminating to consider how to use the above described HPCC technology to enhance museum goers' taking advantage of objects in the exhibition. It would be especially gratifying if the objects could be seen by the visitor more in context, noting that the meaningful context might differ from visitor to visitor. The vision is to utilize electronic communication tools (earphones, flat screen video images, LCD text devices …) to put objects into the appropriate interpreted spaces for each visitor. An example would be to put historical art in historical contexts that matched the visitors' interests, *e.g.* a visitor with a political enthusiasm might be more interested in the impact of the work of art on society, while an artist might be much more interested in the artist's technique in relation to the practice of their contemporary artists.

Technology Potentials

Several artificial and sensor technologies might make it possible to asses interest and focus of the visitor, followed by the HPCC system's adjusting the information interface as appropriate. Other dimensions such as learning style, age, preferred language, and cultural centrality might also be amenable to such an analytical and dynamic system. This is also quite feasible for the interested student who cannot come to the museum, but could visit via the internet (Davis, 2000).

While the museum population may be even more diverse in culture, the problem is not in which language a museum goer speaks natively, but in what condition they come to the museum, *e.g.* how much do they already know about an object and how accurate that fore-knowledge is. A major research topic will be at what point in the context spectrum should they communicate with the object? More directly put, how should they interact (Vowell, 1994) with the object? HPCC assets, given the appropriate input, could help design the optimal approach for each in real-time, be they visitors at a museum or informal learners on the Web. There now is a better understanding of how to use technology on the web with a diverse audience (Wright, 1996), but many sites still are using the web to give the same relatively static information to this heterogeneous audience. What is needed is to create this context spectrum with variable entry-points into online technology and then study how to best put it to use in the museum for physical visitors.

Another important research topic to be addressed is how this technology can enhance and not replace the object. Many museum professionals "believe" in the power of the object and would certainly want to make clear to educators in general that they are proposing technology that will heighten the learning experience based on an object and NOT a simulated or virtual object implementation in lieu of the museum experience, but as an enhancer of it. Nevertheless, when the potential learner cannot come to the museum, technology may be able to bring a simulated museum to the learner (Davis, 2000). The intent is to avert bad visions of a "big brother" kind of moment in a halo-deck or "this is what you should look at, think about and decide on" or "pay no attention to the man behind the curtain!"

Technology Implementation Issues

However, the problem is how to provide the optimally personalized context to objects in informal learning situations. This should begin with how best to ascertain the visitors' characteristics, then to modify the information interface to address these, further to evaluate the efficacy of the preliminary analysis and finally to optimize the interface based on a feedback loop. HPCC provides the power required; distributed computing puts that power were it is needed; and AI can manage the analysis. The major obstacles are the input and output interfaces, especially making them as non-intrusive as well as making them effective.

Part of this interface conundrum is how to teach museum visitors to use technology and enhance their science and technology capability while not alienating such a diverse audience. The authors believe that the effort should start with the assumption that there is a diverse audience, including its being diverse in familiarity with the use of technology and diverse in the understanding of the object, and then provide the technology to help museum visitors or Web surfer to come to a greater understanding of both the technology and the object, all the while exploiting the use of HPCC technology.

Dynamic changes in focus of users

Currently, informal educators in museum settings try to respond to the differences in visitors by changing out exhibitions, creating exhibitions relating to current issues and events, adding objects to standing exhibitions, providing programming (like lectures, children's activities, learning options, *e.g.* painting in an art museum, "saving stuff"), and offering involvement opportunities like boards and volunteer groups. It is the authors' experience that these approaches show little individuation and have slow reaction times.

Potential of group use of single interactive portal

When the HPCC learner assessment plan is in place in a museum, the humanities museums will serve as a learning ground for technology - giving all museum visitors exposure to, training in, and excitement for computing advancements. This training can be another arena which allows girl students to focus on the "nerdy" subject of technology that she may have a natural proclivity for, all the while learning about art, fashion, or history. The object in the museum and its subject matter may be reflective of a social norm allowing the girl student who visits the museum to attend to the expectations of her peers and/or educators. The subject matter may also simply be her preference. A girl student who cares about fashion and its history, and is gifted or inclined to computer science, will be educated on both fronts when the HPCC learning style technology is incorporated into informal learning situations.

Future Research

Planned

Research into centralized, HPC-enabled servers is currently under way at the Information Sciences Institute of the University of Southern California. with the goal of standardizing both an intranet and data interoperability for K-12 use. Early scoping of issues and assessment of technology has shown that the visions set forth above are putatively obtainable within the next few years. This project should yield

a plan for future development of these systems which would be independent of the constraints found with proprietary systems being proffered to the educational community. The authors prefer the open-source, standards-based successes of the internet to the constricting and constraining limitations of proprietary systems.

Concepts still to be tested

A number of research issues remain open. One is the potential impact on students if they are given a series of attractive technologist as role models that contradict the medias' more typical portrayal of scholars and scientists as nerds or villains. Another is the receptivity of the classroom teacher to avatar presented instruction, especially in areas that are not the teachers' forté. Also, what will be the societal acceptance of computer-enhanced evaluation, especially if the computer suggests a student does not really rise to the level hoped for by the parents? Can the private opportunities for intellectual exploration and manifest achievement overcome the social pressures on girl students to not excel? What are the students' reactions to "live" human computer interfaces (via MPEG clips) versus animated teaching avatars of humanoid or cartoon-character styles? The reader doubtless will think of a wide range of new research topics that would be enabled or greatly facilitated by the controlled content delivery and extensive data collection capabilities of the systems suggested.

Summary and conclusions

The authors have significant experience in the K-12 classroom and the Defence Department training environment that has driven their vision for HPCC enhancements to K-12 learning. They see opportunities to successfully address many of the Grand Challenges in Education with this approach. Informal education has similar issues and may be amenable to similar methodologies. Advances in computer and systems design have made the computational power necessary to implement these approaches both affordable and maintainable. HPCC can enable the characterization of existing preconceptions and the optimal responses to those diverse features. It can be transformative in enhancing the learners' appreciation and understanding of the content, the learning experience itself and the use of the technology that accomplished the first goals. The techniques for programming the system envisioned are well-known and attainable. The authors' preferred approach is to develop and instantiate standards and utilize open source capabilities; they eschew proprietary systems and monopolistic control. Progress in the identified areas is held to be a *sine qua non* for the maintenance of a successful technical society.

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