Implementing New Educational Technology for 21st Century DoD Leadership Development

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ABSTRACT

In educating emerging leaders to meet the challenges of tomorrow's non-traditional conflicts, the DoD must take advantage of new pedagogical and technological methods and venues that provide the learner with perceived risk reduction during education processes. The authors discuss how budding commanders must deeply and effectively experience geopolitical, historical, sociological and psychological material to improve their risk analyses and management to produce decisiveness in complex, diverse situations. An environment is described where they can engage regularly with lower thresholds for taking risks**:** emotional, intellectual, social and (virtual) physical. This will drive them to truly expand their "live" knowledge base. This paper sets out how High Performance Computing (HPC) is the catalytic enabler for creating complex innovative learning environments in which young leaders can most thoroughly engage with the dynamic situations that they must master to be most effective. The ability of HPC to manage manifold complex factors will allow the DoD to create learning modules that recognize and ameliorate the elements of risk-taking that the learner undergoes when faced with new knowledge. Didactic instruction should be almost entirely provided by this advance in computer-aided education, with the live instructor focusing on the role of coach and guide for the preparation before, and reflection after, the use of the virtual learning environment. There is a valuable cadre of highly experienced leadership instructors who are skilled in integrating didactic material with successful field experience. The DoD can develop the technology to leverage the capabilities of those few instructors to make their talents universally available by capturing their input for HPC-enabled virtual learning environments. The goal is to radically alter instructional interfaces to enhance vital pedagogical processes and thereby improve educational outcomes in fundamental and transformational ways. Documented support for the stated propositions and detailed analyses based on experience are set forth.

ABOUT THE AUTHORS

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INTRODUCTION

Given the DoD's need for distributed educational capabilities that are dynamically responsive to the changing demands of the global situation, the authors use current pedagogical theory and practice to recommend design of a High-Performance Computing (HPC)–driven educational simulation model that would enhance the DoD's ability to retain, motivate, shape, and mentor its young leaders. Advances in cognitive science, educational and organizational psychology tell us that leadership can be most fully developed through collaborative environments with rich contexts in which learning leaders can take risks and improve their understanding of their own and others' learning and decision-making processes. The use of HPC technologies in creating such learning environments can mediate the challenges of the diverse geography, time and expertise factors that characterize the "student body" of young DoD leaders. HPC has been used effectively for operational training; the authors set forth a vision for how HPC can support unique, relevant curriculum design for engagement with the nuanced historical, geopolitical, and tactical knowledge, as well as knowledge about knowledge, that impact a leader's ability to lead.

BACKGROUND

Before the landings at Tarawa in 1943, then Colonel, later General and Commandant of the Marine Corps, David Shoup is reported to have asked his Chaplain to pray, " … that I not make a mistake on the beach that kills any of my men." (PBS 2002) More than a thousand Americans died in the next few days on that tiny speck of land. Colonel Shoup, though wounded, saved most of his men and accomplished his mission. Later, as Commandant, he was a vociferous, but not always successful, opponent of rash military adventures. Both of these career segments required superb leadership. Some of his peers failed at both. (Kernan 1993)

In *The Passion of Command*, (McCoy 2007), Colonel Bryan McCoy recounts his experiences in preparing a Marine battalion for combat in Iraq and then analyzes the efficacy of that preparation. He states with succinct brutality the difference between civilian endeavors and military action: "The leader is entrusted with the lives of his men and accepts unlimited liability for their welfare." Many of his points take on the mantel of eternal truths, as may also be reflected in the more historically founded books of other analysts (Keegan, 1987). Professor John Keegan argues that history has taught us the necessity of the post-heroic leader, one who is given more to restraint and introspection. Nevertheless, the nation still selects, trains and commissions its officers to both act decisively and coolly as Colonel McCoy advocates and with a restrained temper and a well-informed *zeitgeist* as per Dr. Keegan. Their objectives are not necessarily antagonistic.

The situation faced by today's commanders is radically different from that of their immediate predecessors (Barnett 2004). But, the more things change, the more they stay the same, as Alphonse Karr is often quoted as having said. Perhaps that *conundrum* is the real message in Max Boot's book on U.S. involvement in small and vicious local wars (Boot 2003). He examines the amazing success of some of America's most colorful and intrepid leaders. Leaders, interestingly enough, who were frequently scholarly and were intellects of note.

All of these authors' works support the thesis that education and training are important in the creation and maintenance of the officer corps and the senior NCO ranks. The central thesis of this paper is that new technology and advanced pedagogy can enable and enhance the type of education that would be most beneficial to emerging military leaders.

Special Constraints on DoD Education

Most targets of education, both formal and informal, are already collected in a central site or campus. Those that are not can be assembled for the purpose of education. In the DoD environment, that assembly takes the form of various War Colleges and the like. As the authors have noted in a previous article, General Bob Scales is less than sanguine about the efficiency of this method (Scales 2004). But it is obviously a matter of fact that the typical service members live in a distributed and time-stressed environment. For most of their careers, officers and NCOs operate under severe time pressures, with many duties affording less leisure time than their civilian counterparts. The time for the broadening education they require is interrupted with activities as diverse as planning retirement ceremonies to leading their troops in a fire fight in Iraq or Afghanistan.

This makes the military environment especially ripe for distributed and individually paced education, so as to be able to serve the defense personnel in a way that they can afford themselves of needed education on their own schedule, not the educators', and yet not lose out on opportunities to be part of a network of other learners with collective knowledge assets and experiences that enhance the individual's growth.

USC has some significant experience in a seemingly analogous situation, in that they have developed the Nation's largest granter of distance education Masters Degrees in Engineering (Schorr 2007), serving largely the aerospace community, which does not rival, but approaches the DoD for a professionally driven *Diaspora* and an un-schedulable lifestyle. In this case, the interruptions are career threatening, not life threatening. But this Distance Education Network (DEN) technology is still dependent on live instructors and uses traditional didactic techniques. The authors assert that a new and more flexible system must be developed to serve the DoD.

PEDAGOGY AND PERFORMANCE

Leadership in any large organization today must lead to the "dynamic fit" between changing external circumstances, internal capabilities and the need to both create and dismantle structures in order to adapt (Itami, 1987; Fiegenbaum, Hart & Schendel, 1996). Nowhere is this more critical than in military operations, where the need for the unit or organization to be able to improve and thrive is not motivated by competitive market share but by the fact that individual lives and international alliances hang in the balance.

In educating emerging leaders to meet the challenges of tomorrow's global conflicts, the DoD must take advantage of new pedagogical and technological methods and venues that provide leaders with opportunities for risk-taking during learning processes, and for learning about the learning process itself so that they can better support the development of those in their command. Risk-taking is a fundamental in developing knowledge that can be transferred to multiple contexts. The most potent insights are made when an individual is willing and able to take decision-making risks intellectually and emotionally, and in the case of the modern soldier, physically, in a virtual environment where outcomes can be safely experienced, reflected upon and shared with others to increase the knowledge base.

What are some of the "risks" a learner must be willing to take in order to develop as a leader?

If the ideal state of engagement for meaningful leadership learning is to be engaged in inquiry about one's own professional practice, operating just beyond an individual's competency (Ball, 2000; Cochran-Smith & Lytle, 1999; Krashen & Terrell, 1983; Smith-Maddox, Cooper, Davis, Manby & Moore, 2001), a learner faces self-oriented risks:

- having to change the way one thinks, the way one's culture or *zeitgeist* drives one's actions, and what the implications of such change for one's complex identity
- trusting the input of someone else, versus one's own experience
- not feeling successful even after making a great effort to grapple with the new knowledge.

Learning is also inherently social (Bransford, Brown & Cocking, 2000), and learners' maximum capabilities may best be discovered in their zone of proximal development, or the setting in which they are able to work beyond their "actual" current ability during scaffolded (pedagogically designed) interaction with a teacher or other expert (Vygotsky, 1978; Krashen & Terrell, 1983). The social nature of learning thus involves external risks as well:

- feeling or appearing unknowledgeable or incompetent, particularly if the learner is in a high-stakes or performance-oriented environment
- losing face or social status
- difficulty of synthesizing knowledge in order to make sound decisions in a high-emotion, fluid or life-threatening situation
- having to acknowledge and refute held assumptions that may be the basis of decisions, especially in delicate cultural

conflict situations to which the modern soldier must mediate and respond daily.

Technology has been developed to “customize” and “individualize” instruction, but not for the tremendous social impact and potential power in enhancing the social and cultural aspects of instruction and decision-making, especially for the field of leadership development, which involves many nuanced, context- and trust-dependent knowledge bases (Kaptelinin, 1999; O’Malley, 1995; Jarvenpaa & Leidner, 1999; Davis & Fu 2004).

There is strong evidence that collaborative learning environments are an effective way to facilitate and intensify engagement with knowledge, bringing out aspects of risk-taking that do not surface in individual processes (Clark, 1971). The recent explosion of social networking and multiplayer gaming technologies reflects the potential for improved engagement of students through use of high-quality virtual environments. This allows for access to “distributed cognition,” (Vye *et al*., 1998) and it enables problem-solving and cognitive development in ways that single-student exercises may not (Evans 1989; Newstead and Evans 1995; Kobayashi 1994).

Collaborative learning environments also allow for learners to fill changing roles as they move along the novice-expert spectrum. The participation of experts and novices in tandem in complex contexts provides opportunities for conflict, self-explanation (attempts by experts to convey knowledge to novices) and internalization (absorption of knowledge by novices exposed to experts). These serve to deepen understanding, expose misconceptions, and lower affective filters that may inhibit learning (Dillenbourg and Schneider 1994; Krashen, 1983). Learners who engage in strategic alliances with a joint goal and shared action routines tend to monitor the group effort for efficiency, equity and adaptability (Doz, 1996), three highly desirable operational characteristics of any unit.

Collaborative learning environments have been criticized as not always being as effective as knowledge-centered learning because subject matter experts with whom the students would collaborate are not necessarily sufficiently knowledgeable about strategies for facilitating novice understanding (Shulman, 1986). However, collaborative learning using technology can be more effective in contributing to learner performance on both standardized and authentic task measures of acquired knowledge. The effectiveness of collaborative learning environments designed with computer technology support is heavily dependent on the appropriate use of pedagogical design and scaffolding of tasks, group size, presence of both interdependent and individual accountability measures, and the use of open-ended, multiple solution tasks rather than known-answer problems (Slavin, 1989; Cohen 1994; Scardamalia & Bereiter, 1991).

Collaborative learning using scalable computing can help to address this liability in collaborative learning. HPC can provide the communications bandwidth and computational power to manipulate the variables of the learning contexts themselves and the different capabilities of the learners in the group (Davis and Davis 2003). An environment thus created would be modifiable from a content perspective and could be modified both by expert students and skilled instructors to meet the pedagogical needs of all learners in the group. An HPC-enhanced system would also increase the quality and frequency of feedback provided.

Metacognition, or one’s ability to think about one’s own thinking, affords the mental platform for the risk management involved in intensive learning (Flavell, 1979). HPC-driven educational simulations can provide the kind of control over scenario features, pacing and methods of knowledge delivery that stimulates development of metacognition. The authors assert that leaders who receive regular opportunities to increase the sophistication and depth of their own metacognitive strategies will be better prepared to guide the knowledge acquisition of their troops, including supporting their metacognitive growth.

In a diffuse command environment common to modern warfare, where subsets of warfighters encounter situations that call for their judgment away from the rest of their unit, metacognitive skills can make the difference between strong and poor decisions up and down the ranks. High Performance Computing can create a powerful in-the-moment experience that will allow leaders to analyze their thought processes more accurately than relying on their memory of an experience or a theoretical example alone.

TECHNOLOGICAL ENHANCEMENTS

There are many enhancements that are needed to serve this new educational paradigm and because the

DoD education targets are not centrally located, they bring different cultural backgrounds, are accustomed to widely varying sets of standards, approaches and biases. Most of these can be overcome by a sufficient supply of really good teachers, who do not need simulation to obtain the needed improvements. However, there are clearly not enough of these teachers to go around in civilian life. (Thernstrom and Thernstrom 2004) and many of the best instructors in the DoD are otherwise engaged in non-teaching tasks. The authors posit, and to some degree have observed, that pedagogically sophisticated, interactive simulations can make up for this scarcity by extending the reach of good teaching.

As mentioned above, USC has a very effective Distance Education Network in which live educators provide education for students, worldwide. The need to reach the remotely assigned student was particularly evident in the defense industry. New visualization techniques and interactive computer instruction show promise for opening up education to even wider populations. Researchers at USC (Johnson and Beale 2003) use avatars for teaching.

In an earlier paper, the authors (Davis & Davis 2003) advanced the use of short MPEG clips instead of animated avatars. JFCOM's experience with HPC has shown that it can extend the span and reach of existing simulations. A similar advantage is seen in using expansive arrays of appropriate MPEG clips, all inter-actively initiated as the simulation aided education program calls for them. As the "human component" of teaching and learning is so critical, the use of avatars, even as they become more realistic, can have a negative effect.

The authors hold that experience indicates that the learner becomes more involved if exposed to an interactive environment. There is evidence that true interactivity, both in the interface and in the presentation methodology, will further enhance learning and retention. The key question in this area is the efficacy of the combination of virtual environments and interactive teaching techniques in enhancing focused education. Two other critical issues are the architecture of the computing assets needed to economically serve such a program and the impact such a program might have on students' achievement and attitudes. (Davis and Davis 2006)

Early Experience with HPC-enabled Education

One of the authors, Dan Davis, was a major supporter of an initial attempt to enable education through the use of High Performance Computing. This work was conducted at the California Institute of Technology, under the auspices of Caltech's Center for Advanced Computing Research. The Hrothgar Project, named after the wise king in Beowulf, was an effort started by Thomas D. Gottschalk. Its purpose was to explore the utility of high-end (university research caliber) computers for educational, not research, purposes. It is outlined here, not to show the utility of the application, educating the students in cluster use, but the viability of using HPC in an educational setting.

A Beowulf Class PC cluster was selected as the initial platform. It was originally planned that the 4-processor "start-up" machine to later evolve into a 16-processor, 2 GFlops computer. Setting up the hardware was found to be the easy part. The harder part, by far, was finding the appropriate niche for the technology in an education environment. The exact characterization of this niche was by no means obvious.

The method chosen was for students to use the cluster to simulate subatomic magnetic fields an Ising Model. The students were thus exposed to HPC programming and physics, resulting in output as is shown in FIGURE 1. This was seen as an opportunity to educate them about the "thinking like a physicist" and understanding Monte Carlo simulations.

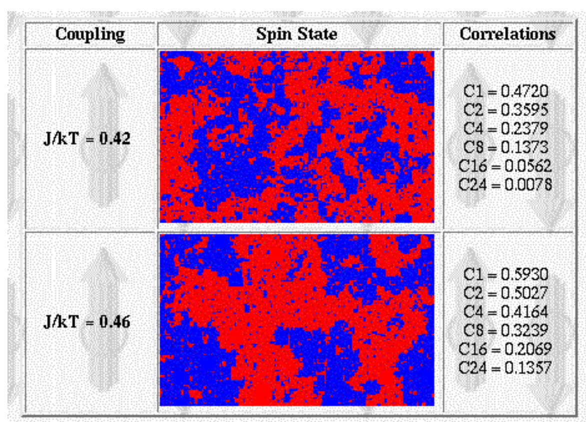

FIGURE 1. STUDENT RESULTS OBTAINED ON ISING MODEL RUN

The project's early activities were "technology insertion experiment" with three basic assumptions:

1. There is utility in large-scale simulations.
2. Simulations must come from "research."

3. Educators must direct curricula designs.

Access to realistic, large-scale simulations was held to be a useful tool for instructors in the sciences, social sciences and other disciplines. This enabled modeling and analysis not feasible in standard learning environments and exposed students and instructors to advanced technology.

In order to demonstrate both technology and re-search, the simulation projects run on the Beowulf machine were adaptations of existing, re-search quality codes. Clearly, this approach cannot easily happen without active participation of the computational scientists who designed and implemented the original code, but shows the general applicability of HPC to the education process.

However, leading edge technology cannot simply be left with the educators with no further support." Educating the educators" on the importance of High Performance Computing is a significant secondary goal. But, the research scientists need "education" as well, since many of them have little experience with educational theory and cognitive processes.

DoD Experience with Distributed HPC

There is a common misconception about the use of HPC in that it is usually envisioned as a process too expensive, too difficult and too fragile to be of use. The authors hear daily from those who could well use the additional power of HPC, but are intimidated by:

- Imagined costs
- Feared complexity
- Anticipated loss of control

While these issues may have been hurdles in the past, now they are less forbidding (Lucas & Davis 2004). Additionally, there is an easy access to HPC for DoD personnel via the High Performance Computing Modernization Program, (HPCMP 2008).

Another break-through area is the new concept, developed at Caltech, of the parallel computer made up of inexpensive, easily maintained and rationally programmable Linux clusters (Sterling *et al.* 1999). These clusters can provide significant increases in computing power on the order of as low as $1,000 per node. These clusters use GigE communications and can be administered by any reasonably competent Unix sys-admin personnel. That means, for a few tens of thousands of dollars, any shop can have their own HPC assets locally available.

Note that this is increasingly the only way that more power will be available, for it seems that Moore's Law may be finally hitting the limit that Gordon Moore suggested it would hit two decades ago. (Moore 1965). This means that the increases in computing power experienced in the past will now be more dependent on practicable parallel computing (Fox *et al.* 1994).

As discussed at length in earlier papers, (Messina *et al.*1997, Brunett *et al.* 1988, Lucas & Davis 2003, Davis *et al*. 2005), there is support for the case for the utility of distributed HPC in the DoD. The Joint Forces Command (JFCOM) and its experimental directorate, J9 have been utilizing HPC for the last several years to achieve the high entity count needed on their battlefield simulations which are used for evaluation and training. As shown in Figure 2 below, they have sought out and benefited from the HPC capabilities, which were developed earlier in the science communities on the campuses of major research universalities. These capabilities have grown up around researchers in all of the sciences, but have been most applied by the physical sciences.

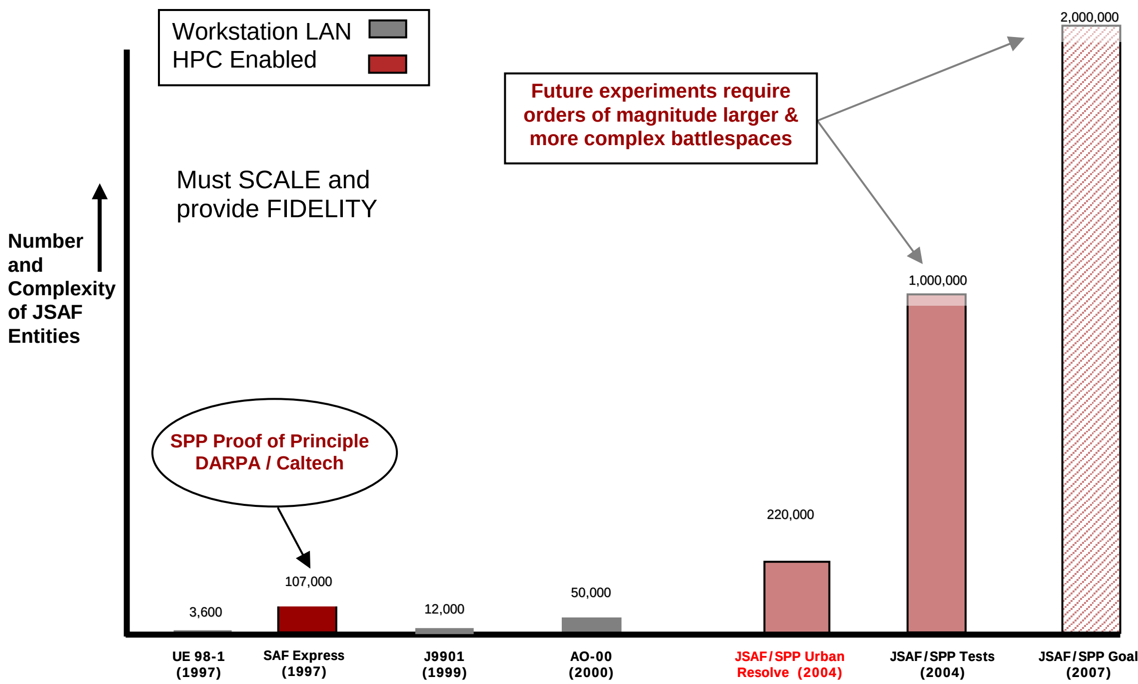

FIGURE 1. CAPABILITIES GROWTH IN BATTLEFIELD SIMULATION ENTITIES

One of the great strengths of the JFCOM experimental design is its use of distributed assets and its service to dispersed users. The experiments themselves are housed and controlled by the JFCOM out of its experimental bay near Suffolk, Virginia. Environments and data are managed remotely out of Fort Belvoir in Northern Virginia. The civilian “culture” entities are laid down and managed by a team a continent away in San Diego, at the SPAWAR center on Point Loma. The two 128 node, 256 processor Linux clusters that are provided by the HPCMP, are located in Maui at the Maui High Performance Computing Center (MHPCC) and at Wright Patterson Air Force Base at the Aeronautical Systems Center Major Shared Resource Center (ASC-MSRC) in Ohio. This system has supported up to 1,500 participants, but still using less than T1 bandwidth, with individuals logging in at <500kbps. Communications between the sites are provided by the Defense Research and Engineering Network (DREN). The Linux operating system is common across the net (usually Fedora, but also Red Hat Enterprise) and most of the programs are written in C++, with a smattering of Java.

Note that there are geographical separation issues, Maui being on the order of five thousand miles from Suffolk. Fortunately, these speed-of-light latencies alone are not readily detected by humans and they are easily tolerated by both operators and participants. HPC distributed education may also rely more heavily upon the distributed game experience, where an ongoing action may be joined or left at the participant’s discretion. Additionally, maintenance and help-desk per-sonnel could rotate around the world, *a la* “The World is Flat” (Friedman, 2003)

Analysis

The foregoing recitation and explication of needs, pedagogy and technology lead the authors to consider the feasibility of a system that is capable of proffering the requisite collaborative, interactive and risk-reduced environment in which to educate the DoD leaders of the next decade. Considering the modest bandwidths needed for supporting even large groups of simulation participants, it seem patently evident that a synthesis of the new and the proven will likely bear entire successive generations of leadership fruit when the nation needs it the most.

The authors maintain that they have shown sufficient new technology and ample new pedagogical insights to justify the consideration of a major new initiative by the community on which to develop, experiment with, and evaluate a series of interactive educational capabilities that are to a very large extent self sustaining, self correcting and self evaluating. Such a system could, using technology already under development at many institutions, mine the information on world events, construct probable scenarios, generate ranges of probable outcomes using environmental computing, and apply educational templates to the input data. This would produce an up-to-date set of simulation environments with topical scenarios. The automaticity and relative anonymity of the activity would further reassure the students of the safety to take risks, test boundaries and assess approaches. This will be best accomplished with a pedagogical foundation for engagement with the simulation that:

1) involves the participants and others currently in combat in the design of learning objectives and authentic simulation features;
2) provides for multiple experiences with the same scenario using different risk-taking lenses (*e.g*. political, interpersonal, physical, tactical);
3) focuses on the ways in which participants acquire the knowledge that impacts the decision-making process, not just their ultimate actions and explicit outcomes;
4) provides opportunities for learning about how soldiers learn, so that leaders can better structure learning opportunities for those in their commands;
5) immerses participants in a community of learners with whom they can process the simulation experience;
6) requires participants to engage in reflection in every exercise, identifying salient insights and extending their application to transferred contexts or scenarios.

The authors maintain that only High Performance Computing can support all of these roles**:** data input, scenario generation, data mining, interactive computing at real time latencies and data management sufficient to collect and evaluate student reactions. The collection power to amass and process real-world data must be unsurpassed in order to convey reality to the student. The interactivity must be sophisticated enough to pass a sort of a "Turing Test" (Turing 1950) for simulation, *i.e*. the user can not readily differentiate the real world from the presented environment. The scenarios must be both believable and focused on learning objectives, all the while conveying the sense of challenge without driving the participant into defensiveness. Finally, the distribution of data, all automatically tailored to the pedagogical optima, and the management of activities and input, all stored in ways making it easy to retrieve and order, can only be supported by the massive compute power of parallel computing. This research effort would necessarily be distributed across the country and across disciplinary boundaries.

CONCLUSIONS

It has been the purpose of this paper to convey the following facts:

- To keep up with modern demands, DoD education' needs newly developed capabilities
- High Performance Computing has benefited evaluation and training
- DoD operations force geographical dispersion of users, educational assets, and computing systems
- DoD educational systems can use HPC power to meet these needs

The authors continue to champion open-source, public licensed software, *e.g*. that from the Linux community, which is active and involved. Source code is available for scrutiny, modification, and implementation. Recognizing the value added by major commercial vendors and their support staffs, the authors feel that experience indicates that open source software should be seriously considered. (Graham et al. 2004)

One last insight: while the great bulk of the code to be developed is easily within the capabilities of journeymen programmers, the overall design can be fatally crippled if it is not optimized for parallel processing. It is the authors' experience that, at this time, there is no substitute for absolutely world-class parallel architects working with world-class educators. Finding creative and experienced parallel programming and pedagogical professionals is a *sine qua non.* It is a variant of the facts earlier articulated by Fred Brooks, (Brooks 1995) who emphasized the value of extraordinary programmers. He thought any one "hero programmer" (and "hero teacher," Professor Brooks?) was worth as much as ten others. A prudent implementer of a distributed educational system would be ill advised to proceed without an experienced and successful parallel architect and a battery of effective instructional personnel, those with proven track-records of innovation in their fields.

High Performance Computing brought the research community new capabilities, which then yielded incredible amounts of new information, leading to the need for large scale and sophisticated data analysis, for which HPC was also optimized. Education is in dire need of all of these attributes, especially considering the needs of and constraints on the DoD service members. The combination of careful planning and openness to others' skills are required for success in the enhancement of DoD Education.

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