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Sustaining an Intellectual Balance of Power between the US and China

Michael CS Trumbo[1], Chris Forsythe[1*]

1. Sandia National Laboratories, MS1188, Albuquerque, NM, USA. *Email: jcforsy@sandia.gov.

Abstract

In part, the US has sustained superpower status as a result of educational systems that are superior to much of the less industrialized world. If the US wishes to remain a dominant economic and political force, rigorous intellectual standards must be a priority. The pendulum of intellectual capital has perhaps begun to tilt in the direction of China, in particular due to the staggering manpower of the country, but also as a product of restructuring spanning decades, in both education and politics. This restructuring has prompted the US to question the level of threat China could pose if they increase their role on the global stage. A position is asserted that through an integrated, systems-level approach that treats intellectual capital as a vital national resource, the US may broaden the gap to amass an indomitable advantage. A target is proposed whereby through a combination of science, technology and practice, there is a shift such that our top 50% are performing at or above the levels of today's top 2%. Such an accomplishment may be achieved partially through US educational policies, but more importantly, there must be commitments to essential science and technology. While investments in different areas of science and technology may impact the global balance of power, this paper, will focus on one facet of science and technology — specifically, cognitive neuroscience and related neurotechnology. The elements essential to achieve such a dramatic shift in the balance of intellectual capital exist — what is lacking is a vision to bring these pieces together, motivated by a desire to build upon our intellectual capital as the means to assure global dominance.

Keywords: education, China, intellectual capital, international policy, strategic investment, human dimension, cognitive systems

Intellectual Capital as a basis for Strategic Policy

The intellectual capital of a country is a significant factor in its capacity to compete globally in the realms of politics and economics (1). It has been asserted that intellectual capital is a combination of both the knowledge and skills of a population and the infrastructure that population is given to utilize its skills (2). Nations in the midst of economic expansion, such as the Peoples' Republic of China (China), whose per capita GDP has experienced an average annual growth rate of 9.3 % during the ten years covered by the Penn World Table (1998-2007) (3), are assumed to experience a parallel rise in the intellectual capital of their citizens, as the resources they gain are turned to support educational advancements (4). Decades ago, Chinese policy makers realized that successful competition in a global market necessitated an overhaul of their educational system. In light of this, the tradition of tight governmental control of higher education and the focus on standardized systems of education has been disbanded out of concern for the crippling effect such a system may pose to intellectual creativity and market demand (5).

While the Chinese are developing an increasingly advanced educational system (5), less than 10% of Chinese workers are desired by multinational corporations (6). China may be upgrading its ability to educate, but the effects of such change are yet to manifest. Therefore, an opportunity exists for the United States to take preemptive measures that would counterbalance the rise of Chinese intellectual capital. To understand the need for such action, as well as the opportunities presented to the US, a deeper examination of the current state of Chinese education is necessary.

Obstacles to Chinese Educational Progress

Since 1949, China has made a concerted effort to decrease the rate of illiteracy in the population, constructing a foundation for later incentives for more specialized education (7). The rapid growth of student populations as government mandates compelled citizens to learn has plunged general illiteracy from 80% in 1949 to 14.5% in 1998 (7). In 1995, China gained admission to the World Trade Organization, illustrating a desire to spread the impact of Chinese policy beyond its borders (5). China developed the minban system of schools in 1998, which are run by the people of China with only limited governmental support. As of 2000, these schools have enrolled one million students (8).

The minban provides primary, secondary and higher education, and offers opportunities for the rural population to migrate to the cities in search of a higher quality of life. A country housing over one billion people needs to provide sufficient food and water to sustain those pursuing academic endeavors. The Chinese have adopted an overhauling mentality, believing the upper echelon of their intellectual capital will only rise when the proper foundations are in place to sustain such growth. In 1998, the Chinese government also founded the College of Rural Development (CORD), in tandem with the Centre for Integrated Agricultural Development (CIAD) (9). Together, these institutions train farmers to use new technology and efficient farming methods in order to mitigate difficulties associated with the logistics of feeding a country that is shifting from farming to higher intellectual pursuits. While providing schooling to increase the efficiency and output of agriculture, China also began renovating the upper echelon of the educational pyramid, founding 344 second tier schools (the equivalent to an average American college) with enrollment of 540,000 as of 2005 (10). In 1995, China had two overseas programs that enabled students and faculty to pursue higher education in foreign countries. By 2005, such programs had grown to 745 (11). The Chinese government is posturing to both initiate educational reform, and be prepared for a concomitant increase in agricultural education that will initiate an exodus from rural areas to provide cities with human resources of potential intellectual capital. A socio-economic advantage of the proliferation of overseas educational programs is that every Chinese student that relocates for purposes of education is also one less student that must be domestically fed and sheltered. As of 2009, China claimed roughly 20% of its college-age population (i.e., 18 to 24 year olds) to be matriculated in higher education (12), compared to 36.2% in the US (13). However, the actual number of matriculated students in China is greater, as there is a substantially larger base population. Yet the quality of Chinese education has struggled until quite recently, a point which will be subsequently expounded upon.

The aforementioned educational expansion situates China as a formidable competitor to the US on academic S&T markets. However, there are numerous limiting factors that must be taken into account. Due to rapid economic expansion and associated industrialization, China has experienced dramatic urbanization over the past two decades (14), swelling the enrollment of universities (5) but also leading to a great deal of pollution (15). They have recently begun to implement a three "R" system (i.e., reduce, reuse and recycle) to stabilize increased waste production (16). The major industrialization feeds the national movement toward globalization, while proportionately increasing the appetite for economic and international influence, factors also present in the historic rise of Germany, Japan, and Russia during the 1930s (17).

In addition to crowded cities and pollution levels, the quality of the Chinese education system is the target of much criticism. Though the minban schools have enrolled one million students since 2000, only 228 of these schools are authorized to grant a diploma, and only 23 can provide undergraduate degrees (8). While the central government will likely continue their intensive funding of key universities, local and less prestigious universities face the prospect of limited support, leaving the burden of funding (in the form of tuition and fees) on students and their families — a burden that weighs heavily on students from poor areas, given the scarcity of scholarships and loans, which have failed to keep pace with the massification of higher education (5). Several student riots have occurred in the last decade, protesting against high tuition and poor education, and false promises of degree attainment (18). The second tier schools have enhanced the capacity to educate beyond the high school level, but have encouraged unrest among student populations as well. There have been recent allegations that PhD dissertations submitted at many of these schools have contained material copied verbatim (i.e., plagiarized) from the Internet and other sources (19). Perhaps this may reveal oversights that a strained faculty supporting upwards of 40 research degree students at one time have had little choice but to accept (20). In 1998, student enrollment at college level schools totaled roughly eight million, while in 2005 the number nearly tripled to 23 million (18). This influx of students has led to overcrowded classrooms, underprepared faculty and a somewhat poorer quality of education. The rising number of exchange programs (e.g., 745 in 2005) (11) can be seen as an effort to address this educational weakness, but these too bear their own complications.

Trends in Exchange Student Retention

Due to political instability, salary differentials, and quality of research facilities, many foreign students are lured to the US to pursue higher education (20). The Institute of International Education's Open Doors Report has shown a new record of 690,923 foreign students enrolled in US colleges and universities during the 2009/10 academic year (21). Furthermore, the 3% annual growth rate has been driven by a 30% increase in Chinese student enrollment in US educational institutions (i.e., nearly 128,000 new students, which equates to over 18% of the total international student population in the US) making China the leading country sending students to US universities (21). This trend holds for graduate level education as well — in 2003, foreign students accounted for 51% of US PhDs awarded in science and engineering fields, up from 27% in 1973 (22). Despite disparaging interpretations of global standardized test scores, the US has remained the leading destination for international students, especially from China, Korea, and India (23). As global demand for higher education soars, this makes education an attractive export and serves the additional role of attracting a global talent pool to the US The retention of such a talent pool has a two-pronged effect in enhancing intellectual capital nationally by drawing the best and brightest scholars to the US while removing them from competing nations. But, this is only a viable resource if these scholars are retained. This retention is a key strategy, and unfortunately the US may be losing ground.

Between 1978 and 2006, nearly one million Chinese students and scholars opted for overseas education; only 300,000 returned to China (20). The majority of these were comprised of government-sponsored visiting scholars with little opportunity for obtaining a permanent position abroad (24). Fearing a "brain drain" situation, China has proactively instituted policies designed to encourage students that travel abroad to return to China to disseminate their knowledge and skills (20). As early as 1992, China's returnee policy emphasized the need to increase the homecoming rate by offering returning scholars the freedom to come and go, manifested in 2000 as the issuance of multiple-entry visas to students and scholars (20). Return policies rapidly expanded to include financial support for short-term visits (including offers to academics to spend their summers in China at a rate of pay up to five times that of their overseas salaries), implementation of the Changjiang Plan that afforded leading Chinese scientists living abroad the opportunity to return to China for a year in a strategic research role, and large monetary awards (as high as 500,000 RMB) to exemplary young overseas researchers – with the stipulation that the money be spent in China (20). The average growth rate of returnees to China in the late 1990s was 13%, but as a result of the aforementioned policies, between 2001 and 2002 the number of returnees increased by 45% (20).

Chinese policy makers are cognizant of the fact that foreign-acquired expertise may make employment of skilled workers an expensive endeavor, especially given the technical infrastructure required for such individuals to remain productive (20). However, if these trained, skilled individuals remain overseas and retain contact with Chinese officials and institutions, China could to reap significant benefits from these individuals without much of an investment. For Chinese nationals with no plans to return to their country of origin, China offers several encouragement plans that enable continued national service including holding concurrent positions in China and overseas; acceptance of commissions to engage in collaborative research between China and their current overseas affiliation; and returning to China periodically for academic and technical exchanges, consulting, and assisting Chinese firms to locate viable export markets (25).

These cautionary flags should galvanize US policy makers if they wish to maintain the intellectual gap between China and the US. Clearly, China is in the process of amassing its intellectual capital, but at present may lack the educational infrastructure of the US (and other western nations). However, this intellectual — and educational — gap is closing, and this is important to US educational, and science and technology policies and activities. To remain internationally competitive, the US must recalibrate its educational methods, as well as related science and technology policies, to recognize the critical influence of intellectual capital to national prosperity and national security.

Growing the US Intellectual Capital Gap

Several proposals have been offered to address perceived deficiencies associated with US K-12 education, and the threats posed by the growth and investment in science and technology by emerging nations. We propose here that the policy objectives of the US should seek to grow the intellectual capital gap between the US and other emerging nations, as opposed to merely maintaining the status quo. Around the world, nations are continually amassing intellectual capital through education of their populations, advancements of their scientific communities and intellectual property development within their technology sectors. The key to expanding the US's intellectual capital gap lies in accelerating the rate at which the US is gaining intellectual capital relative to other nations. This may be accomplished in two ways:

First, is the need for substantial activity on the frontiers. This is work generally associated with those on the forefront of their respective disciplines and requires resource investment and formation and sustenance of an economic and administrative climate that fosters creative, high-impact achievements.

Second, and perhaps more importantly, is the need to enable greater contributions to growth in US intellectual capital. As illustrated in Figure 1, given a measure of each individual's contribution to the intellectual capital of a nation, one might imagine a statistically normal distribution where the contributions of most individuals appear around the average, with there being comparatively few individuals who make substantial contributions and appear in the upper tail of the distribution. One might speak of enabling those between the 15th and 50th percentiles to contribute at an equivalent or greater level than the current 50th percentile, or enabling those at the 50th percentile to contribute similarly to those currently at the 98th percentile. The objective is to implement measures so that

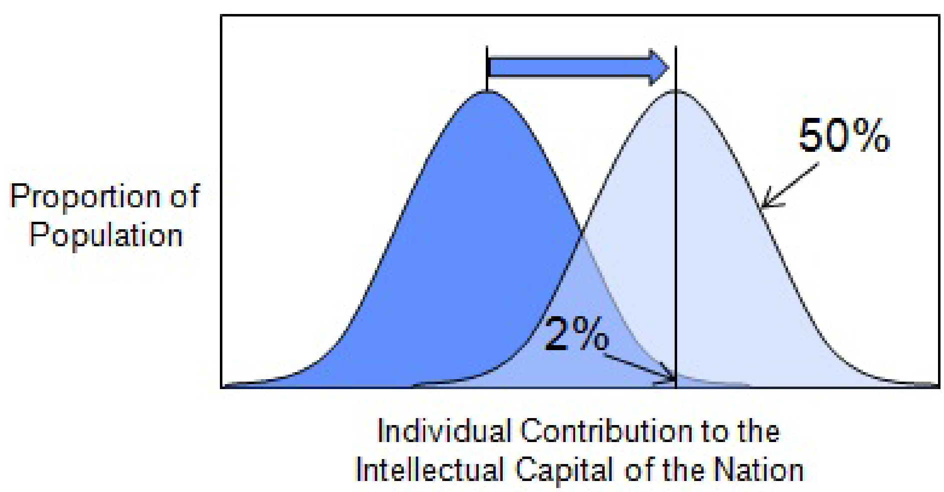

Figure 1. It is assumed that the contribution of each individual to the intellectual capital of the nation may be measured and the population forms a statistically normal distribution. An objective may be proposed whereby those at or above the current 50th percentile are provided the means to contribute at a level that equals or exceeds the current contributions of the top 2%.

at every level, there are increases in individual contributions to US intellectual capital.

To achieve across-the-board gains of this magnitude, a multi-faceted approach will be required. There is no magic bullet. A systems approach that simultaneously leverages numerous opportunities to achieve gains in intellectual capital is believed to be necessary to achieve anything more than minor incremental improvement.

It is improbable that substantial gains will be achieved through initiatives focused solely on more schools, more teachers, or more of a particular type of school, or type of education. These initiatives are seen to be political "hot potatoes" that allow ideological and political agendas to be advanced, but result in mostly non-productive debates and successive policy give-and-takes. If there is a philosophical stance to be taken, that stance must be that progress will come through the integration of science, technology and practices to achieve a broad systems solution. It is the outcome that matters, not the ideologies served by the various mechanisms.

We believe the key lies in policies toward science and technology, and particularly, those facets of science and technology that directly address human performance. In the following sections, we will examine a specific area of science and technology, cognitive neuroscience and related neurotechnology. These areas represent the author's fields of expertise, but are also important in that they have direct bearing on human cognitive performance and the mechanisms by which gains in human performance may be realized. Certainly, investments in other fields of science and technology may impact the global balance of power (e.g., nanotechnology, microelectronics, genetics). However, cognitive neuroscience and neurotechnology present a direct path, as well as a path for which the US possesses a strong scientific and technology foundation.

Our intent is to explicate that cognitive neuroscience and neurotechnology are direct paths to enhance human intellectual capital and specifically, human cognitive performance (i.e., as the basis for intellectual capital). These are areas where China is quite weak and their efforts to catch-up are not very impressive, yet, there is growing interest in these discplines and their effects. so, while China's efforts in neuroscience and technology may, at least at present, not pose any direct leverage upon or threat to the intellectual and economic capital afforded by these fields, the growing momentum of Chinese investment in S/T writ-large, and an increasing interest — and investment — in neurocognitive sciences and technologies will be important to the calculus of scientific, economic and perhaps even socio-political power upon the world stage (26). In light of this, we argue that these are areas where the US is already strong and thus, further US (and western) investment represents an opportunity to build upon existing strengths.

Science of Human Performance

For many decades, there has been extensive research to uncover the principles that underlie human performance, as well as research to elucidate factors contributing to the relative success of educational and training initiatives (27). Much of this knowledge has been embodied within established guidelines and methodologies for the design, development and testing of products, services and organizations. However, the science to date has generally focused on normative behavior. Despite some notable exceptions (28), psychology research concerning human performance and related cognitive processes has focused on characterizing the typical individual.

In the same way ideology clouds policy considerations, dogma shrouds our thinking concerning human performance. Ericsson and colleagues (29) have made this point effectively in recent publications challenging the conventional wisdom regarding exceptional performance. It has been deeply engrained in most of us that there are certain individuals who are "gifted" implying that they possess inborn traits that predispose them to excellence for a given activity. Through an exhaustive review, it has been shown that with the exception of the advantages conveyed by height and size in sports performance, there is virtually no evidence that there exist innate factors that would limit excellence to a small minority of uniquely endowed individuals. Furthermore, popular dogma emphasizes the importance of extensive, dedicated practice to achieving the highest levels of performance. A commitment of time and effort certainly seems to be necessary, yet is not sufficient. Instead, there is growing recognition that those who excel tend to practice differently, and in particular, practice in a way that has them routinely operating at the boundaries of their capabilities. This is in stark contrast to the rote repetition that permeates much current thinking regarding the achievement of mastery in sports, academics, trades or most any other domain for which individuals may be distinguished with respect to their relative performance capabilities.

The science of human performance is considered an essential ingredient to the proposals being advanced here, however there must be increased emphasis on understanding the traits and practices that distinguish those who excel. This must be combined with research to uncover mechanisms by which the attainment of expertise may be accelerated through education and training practices, and technology-based augmentation.

Personalization

Industrialization brought the prevalent belief that cost-effective productivity was achieved through economies of scale. This has fostered a "one size fits all" doctrine that has driven educational systems, the functional make-up of technologies, and organizational and institutional processes. Routinely, responsibility is placed on each individual to learn the processes and expectations of systems and technologies such that each individual must bear the cost of adapting in whatever way is required to assure uniformity and compliance. Advances in technology now begin to undermine these economies. Particularly, the cost of adaptation can now be off-loaded to computing systems that are capable of learning the peculiarities of each individual and adjusting to each individual in a manner that provides for the greatest efficiency and productivity, both individually and overall. An age of personalization is upon us enabled by advances in technology and motivated by the desire to reclaim the individual time and effort lost as individuals constantly seek to adapt to the inefficiencies inherent to technologies, and organizational and institutional systems.

Automated performance assessment provides the basis for targeting education and training to the individual needs of each student (30). With proper foresight, there is hardly any activity or system that cannot be instrumented to provide key data regarding individual, as well as team, performance. This is particularly true given the growing availability of lost-cost, highly adaptable devices for sensing and collecting data (e.g., game controllers, mobile communications). Given the availability of performance data, diagnostics may be developed that provide detailed feedback concerning the knowledge and skills of each individual. Consequently, instruction may be tailored so each individual receives a program of instruction targeted to their specific needs and structured to promote their progress, and eventual mastery. Today, the benefits of technology-enabled individualized instruction have been well documented (31), yet the trade-off between the cost of system development and the resulting return on investment has often been questionable. However, advances in computational approaches that streamline the system development costs stand to radically tip the balance in favor of this method (32).

Much in the same way that instrumentation allows individuals to be monitored, and education and training adapted to each individual, operational systems may monitor the performance of users to adapt to their ongoing needs (33). This is something that humans readily do on a regular basis during interactions with one another, usually without even thinking about it. For instance, when you walk up to someone's office door and see they are on the phone, you know not to interrupt them. Likewise, you come to appreciate when others are least able to cope with added demands, and time major inconveniences to avoid those periods. In contrast, many of our technologies operate like a child that has not matured beyond seeing themselves as the center of the universe. For example, operating system updates often come at the most inconvenient times, taking over your computer and daring you to resort to a hard shutdown. Capabilities are becoming readily available for technologies to observe and learn about their users and appropriately adapt to ongoing levels of demand, situational factors and cognitive readiness. Operationally, over the course of a typical day, there may be marginal gains in productivity, yet these gains become substantial when considering the cost of recovering lost work, undoing hastily made decisions, etc.

The previous ideas may be extended to encompass the capability for technologies to engage users on the basis of what they do and do not know. Again, this is something that people readily do during day-to-day interactions. When you have had shared experiences with a given individual, you use your shared recollection of those experiences to place current events within context (e.g., "this is the same thing that happened when doing the job for xyz"). Similarly, we have an understanding of what we each know and the vocabulary that is going to allow us to have a productive discourse. For instance, the language you would use in conversation with an individual well-versed in your own field may be completely different than that used to talk to someone with little or no background. In contrast, consider the help utilities provided with your computer operating system and many software applications. You have a specific problem or question, and the response you receive is often either too basic or too sophisticated, and certainly not tailored to your own knowledge and experience.

A "Cognitive System" has been defined as one that observes a user and interacts with the user on a knowing basis (34). This implies a capability to watch and learn what a given user knows and does not know, and then engage users at a level appropriate to each individual. This is not a proposal for artificial intelligence that seeks to automate the functions of humans, but instead, a call for systems that are able to engage humans in a more knowing manner, keeping the human in the loop, while minimizing inefficiencies, lost time and effort, and periods of artificially constrained productivity.

Leveraging Advances in Technology

The technology landscape is rapidly evolving. With the growth in information workers and the spread of information technology to permeate ever-broadening areas, there is a parallel transformation in the nature of work and the qualifications required of many occupations. Technology acquisitions will be made on the basis of a perceived need to keep up, with there being a continual onward march driven by increasing demands for computational processing, memory, etc. This must happen, and will happen across industry and government.

There are also those technologies that go beyond the incremental gains in productivity that drive continuous technology renewal and change the way things are done. Inevitably, discussion focused on specific examples is outdated given that the next big thing is likely sitting out there now unrecognized and indistinguishable from counterpart ideas that will languish and eventually be forgotten. Yet, in general, there are a few general classes of technology that will be keys to advancing intellectual capital.

While simulation-based training is often associated with the high-dollar military simulators that have been broadly adopted and have fuelled the growth of a substantial industry to supply the associated equipment and services, its application stretches into almost any domain where individuals must be trained to make complex decisions within dynamically changing conditions. With increasing capabilities for collecting data during everyday operations, it is now feasible to use recreations of real-life events as a basis for training future decision makers. Furthermore, game-based approaches open opportunities to embed education and training within engaging, contextually-rich environments. However, it will be important to move beyond the fascination of elaborate technologies, and instead focus upon using simulation-based approaches to teach fundamental skills and nurturing an individual's abilities to cope with ambiguous, unpredictable situations.

As mentioned previously, data collection and instrumentation are core to many of the approaches being advanced. A related key technology enabler will be mobile computing. With the adoption of networked, portable computing devices, instrumentation can follow an individual wherever they may go. This not only feeds data collection, but additionally provides continuous access to utilities to enhance performance and provide training.

The impact of mobile computing is amplified by growth in social media applications. It is envisioned that the combination of these technologies will alter the ways in which people learn and work. Often, it may not be necessary to have an instructor present and one may instead rely upon their peers for the type of feedback that would typically be received from an instructor. Consequently, education and training opportunities will not be limited by the availability of instructors. Furthermore, within work settings, social media technologies have the potential to increase each individual's awareness of the available knowledge and expertise of different individuals and provide the mechanisms for leveraging that knowledge and expertise.

Biometric Measures

The instrumentation and behavioral data collection discussed in previous sections may be supplemented with biometric data to gain insight into the physiological and cognitive state of individuals. Here, "biometric" refers to any signals that reflect physiological functions, whether based on central nervous system (e.g., EEG), or any of the other systems of the body that support and interact with the central nervous system (e.g., heart rate, respiration). With the advent of readily available commercial biometric measurement devices, there is a growing familiarity and comfort with the prospect of tracking one's physiological functions. A progression is anticipated in which monitoring becomes the basis for enhancement, with decisions made regarding when to study, practice or work based on data and projections regarding when an individual's capacities are at optimal or suitable levels. For example, a simple software application has recently been made available for tracking caffeine intake, and projecting blood concentration of caffeine into the future to time the intake and adjust quantities to achieve the optimal benefits (35). While the use of these capabilities may center around the individual and the decisions that they make to promote their effectiveness and productivity, the same data may also be fed into the technological systems with which individuals interact to allow adaptation of systems to each individual and their ongoing readiness and capacities for cognitive work.

Enhancement

The final area addressed here concerns enhancement, and specifically measures taken to promote an individual's capacities for cognitive performance. The previous sections have mentioned scheduling, perhaps on the basis of biometric data, as one means to achieve enhanced performance. Other methods more directly seek to alter the performance capacities of the brain. This already occurs with many through their consumption of caffeine or their use of light exercise as a means to stimulate the brain. A variety of nutrient supplements claim to enhance mental function, and the use of pharmaceuticals such as Ritalin for cognitive performance enhancement has been the subject of many reports (36). A market is emerging, particularly among the elderly and the parents of children with learning disabilities for games and exercises that are purported to enhance mental functioning and sustain mental functioning into later life. Finally, brain stimulation is being explored by many groups as a means to produce gross enhancement, as well as enhancement of specific cognitive functions.

Conclusion

It remains to be seen how the US will choose to cope with the ascendance of China as a global economic and political force. Will the US emphasize science and technology investments as a mechanism to sustain its competitiveness? If so, which facets of science and technology will the US focus upon, and will initiatives be undertaken from a systems perspectives or as a series of isolated efforts to address limited objectives?

While the economic fates of the US and China may be intricately interwoven, the stage is set for conflict, with China seeing itself as an ascending power and the US committed to sustaining its global prominence. Over the next several decades, there may never be armed conflict between the US and China. However, as occurred during the Cold War, in the absence of direct armed conflict, skirmishes may occur on many other fronts. To the extent that these skirmishes are economic, technological and political, they will draw upon the intellectual capital of the respective nations. Thus, as the US appraises the balance of military power between itself and China, it would be wise to also assess the balance of intellectual capital.

Only a couple of decades ago, the educational system within China was insufficient to supply the intellectual talent essential to pose a substantial threat to the US and other major economic powers. However, in the interim, China has instituted fundamental changes with the objective to transform their nation by constructing the infrastructure and invoking policies for amassing intellectual capital. Several decades may pass before the capacity to supply a high-quality education to the masses attains a level equivalent to the US However, there is a numbers game at work such that the intellectual capital of China may catch up and surpass the US long before they attain an equivalent educational system.

Based upon these concerns, a call is issued for US policy makers to recognize intellectual capital as a resource vital to our national security and prioritize programs that have the effect of fostering the accumulation of intellectual capital. It is emphasized that we do not have the luxury of focusing on those with the greatest potential for success, but that an across-the-board approach is required that addresses all segments of our society. Consequently, educational initiatives alone are not sufficient. Instead, a systems level approach is required that addresses the contributions of all ages and combines innovation in education and training with technological advances geared to enhance human cognitive potential and productivity. This will require a program at the broadest level of government that has the capacity to coordinate efforts across federal agencies toward an over-arching objective. We remain focused upon informing such possible policy decisions, and are committed to their development.

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Competing interests

The authors declare that they have no competing interests.

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