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Collaborative Advantages in Education Development

ABSTRACT:
The current globalization of nanotechnology development is qualitatively different from any of the globalization experiences from our past. The implications of these differences have not been addressed by our key decision makers in government, nor industry with regards to the needs of our outdated education structure. As a global organization, we have found through collaboration with many nations that these issues can be addressed in this decade to shift the paradigm from failure to success for our students and teachers. This paper will address some of the solutions that can be initiated in the next few years to prepare our children for a very different future regarding ethics, expanded knowledge, cultural differences and adaptable skill sets necessary for intelligent global participation in the future markets around the world. Systemic changes are necessary from the bottom up as our schools are operating on a structure that was originally designed for the operation of one-room schoolhouses in the 1800's. It is time for the United States to move away from an almost certain futile attempt to maintain dominance in the global market place and move towards an approach in which leadership comes from developing relationships for mutual gains as equal partners.

This collaborative advantage does not come from self-sufficiency or maintaining a monopoly as we have done in the past, but from bringing valued knowledge as a collaborator at all levels in the international system of technology development.[1] It has been proven in our long history that economic competition backed by force is a classic formula for unending war. Wars are always about one nation wanting something that another nation has, and we can only change this cycle by diffusing the poverty that causes these desires through sharing our knowledge base collaboratively with mutual advantages for all nations. This is especially important in the area of education for the converging technologies.

This move to a new environment was accelerated by the development and diffusion of new communication tools, which expanded our borders exponentially creating the information age with new work-sharing technologies over the past decade, that need to be mastered in K-12 classrooms. The No Child Left Behind Act (NCLB), set the goal that all students should be technology literate by the end of eighth grade. This should not be a problem as schools are able to get their technology funding through the federal

[1] New Horizons for a Flat World, Leonard Lynn, Hal Salzman, U.S. Innovation Policy, Winter 2006, pg.77

Enhancing Education Through Technology Funds (EETT). This seems to be more of a challenge for the teachers and administrators than the students as they are happy to operate in multiple digital environments and are not intimidated by technology. Converging technology for the classrooms have recently been more acceptable to educators, who are normally not early adopters, whereas their young students can operate computers, game consoles, cell phones, and MP3 players while keeping up with Instant Messaging from their friends. Multi-tasking is a natural function for young students who are 'digital natives' in their digital environment outside the classroom, which is why so many of the students find institutional learning environments with textbooks and testing so boring.

Many of the IT companies such as Dell are selling complete set-ups to the schools designed as Intelligent Classrooms that include computers, projectors, VCR/DVD devices, speakers and sound systems and the Promethean ACTIVboard interactive whiteboard and ACTIVote student response devices. They come with content geared toward either math and science or language arts and social sciences. The math and science classrooms also include probeware such as sensors and data loggers from Fourier Systems Inc. Since these companies are experts in technology development their knowledge and expertise have provided the missing link that is enabling changes to take place in the classroom environment for the educators. The next step will be to collaborate with the hardware suppliers and provide enhanced nano science content for inclusion in their Intelligent Classrooms.

With the technology solutions shifting the paradigm to visual interactive classrooms, the next aspect that educators will need to focus on are how to teach collaborative competencies rather than just technical knowledge and skills to meet the needs of a new global innovation system. The cross-boundary skills are the most important aspect which must include working across disciplines for teachers and students, while developing organizational skills and cultural knowledge with an understanding of the time/distance boundaries for teamwork to function in different countries. International collaboration as part of the curriculum will also allow students to understand other approaches to science and engineering so they can recognize an organizational order to the cross-cultural management that will be required as the workforce of the future. The education system also needs to understand the new engineering requirements rather than attempt to shore up out-dated approaches from the industrial era.

The multi-national companies that are locating new operations around the world should consider offering support for international education opportunities, along with internships to university students from the U.S., rather than just funding the education at universities in the foreign lands of their locations. This has not been their focus and consequently we have witnessed our large multi-national corporations abandon the U.S., claiming that our failing education system is forcing them to find workers in other nations. China and Korea are more than willing to work with these multi-nationals such as Intel, IBM, and Microsoft who are donating millions of their corporate profits for education in these countries, which have willingly agreed to develop the courses in their education systems to match the corporate demands for technological savvy workers.

Since we have been hampered with systemic issues and unable to easily make the necessary changes, some of our students are taking back the control, choosing to become self-educated as they are motivated to have choices in the corporate world that suit their needs, rather than the established norm in the job market. As noted in the following excerpt from a recent magazine article, they prefer opportunities for life-long learning experiences and challenges, rather than traditional benefits, stock options and long hours of internships. This generation was raised in the digital information age of multi-tasking and they do not respond to boring repetitious work. They have established different values for their preferences in the workplace and are demanding life-long learning opportunities along with flexible time schedules and remote location working environments.

"Managers and their companies are now dealing with the new generation of workers called the millennials, who are the 76 million children of the baby boomers generation, born between 1978 and 2000. With this new influx of workers that are pouring into offices around the country, we now have four generations that need to coexist in our workforce."[2]

First are the traditionalists (born before 1945), then the boomers (1946-1964), next comes generation X (1965-1977) and finally this new crop of millennials, who never stop questioning the status quo. Managers are challenged to minimize the friction and maximize the assets of these four distinct sets of work styles and values simultaneously. The millennials are not interested in the financial success that drove the boomers or the independence that marked the gen-Xers, but in careers that are personalized. They want educational opportunities in China and a chance to work in their companies R&D departments for six months. Their values are different and they are not interested in stock options. They are impatient with anything that doesn't lead to learning and advancement and nothing infuriates them more than busywork. Experts believe that this won't wash away with age, "It's not a case of when they grow up, they'll see the world differently," says Joseph Gibbons, research director at the FutureWork Institute. So if companies want to attract, retain, manage, and motivate the next generation of workers, they are going to have to adapt." [3]

Since 80 million boomers will retire over the next 25 years, and there are only 46 million genXers, the millennials will dominate the workforce for at least the next 70 years.

How did we miss preparing management for this phenomenally talented generation? Our experts totally ignored the fact that this generation was immersed in PCs, video games, email, the Internet, and cell phones for most of their lives. They suffered through the boredom of schools that did not understand their abilities to digitally multi-task and they have no fear of learning or achieving their goals. They are truly a generation of self-achievers. If they did not learn it in school, they figured out how to find the information on the Internet and became self-sufficient individuals who can and will change the world.

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[2] "Scenes from the Culture Clash" by Danielle Sacks, Fast Company, Jan/Feb 2006, pg 72.
[3] "Scenes from the Culture Clash" by Danielle Sacks, Fast Company, Jan/Feb 2006, pg.75.

They are the first generation that will continue achieving through "Life Long Learning' that many experts have discussed, but have not moved forward to establish within our educational structure.

How do these young professionals fit into our establishment now?

Young lawyers were once willing to sacrifice the first 10 years of their lives chained to a desk in a law library working 100 hour weeks for the chance to make partner. That is now history. Law school graduates from this generation want work-life balance, flexible schedules and philanthropic work. It is affecting the entire spectrum of the workforce including financial firms such as *Deloitte and Touche USA* who have been testing a program in New York that allows their new employees to work remotely. The old way of camping out on-site at a client's company was not acceptable to the new millennial workers and the test worked out so well, they are rolling the program out nationally over the next 18 months.

Marriott International had to change their style of training to recognize the millennials rapid-fire style of information consumption. They are now developing "bite-size edutainment" training podcasts so workers can download information to their cell phones, laptops and IPods as they need it. Podcasts are also being developed in universities to replace their traditional classroom lectures.

The new workers also insist on relationships with top management and want to be 'heard' when they speak. They value respect and prefer to build relationships in the workplace, not based on titles or hierarchy, but respect for ideas and human interactions. They aren't asking for signing bonuses or stock options. They just want to be heard, and we might just learn something from them if we take the time to listen. It may lead to real ethics and values in the corporate workplace, rather than the current hypocrisy of greed, fear and dishonesty that we have witnessed from our corporate culture.

So how does this fit into collaborative advantage for education?

First, government officials and politicians should invite input from this new generation of workers who are changing the values and setting the rules in the global workplace. Mentoring their development for global diplomacy through invitations to join national 'think tanks' at an early age would prepare them for leadership roles when they are able to run for political offices in the national arena.

Second, we need to enlist these young talented people to collaborate with our 'experts' who are still researching 'how children learn'. Since they recently finished school and have entered the workplace as digitally adept adults, much wisdom could be garnered from their self-adapted learning styles and experiences.

Third, we need those experts and researchers to spend some time in the K-12 classrooms, observing how many of our young students have already mastered digital communication. These students are now helping their teachers learn how to use the technology and also sharing their knowledge as team players with students who have not been exposed to the technology at home. Our organization has even had requests from a head-start program manager that wanted nano education for pre-school children. She stated that many of them learn how to turn on the computer at only 2 years of age and they are not interested in the pre-school packaged learning that is available. She felt that visual elements showing the nano scale would challenge their minds and whet their appetite for science and nature at an early age.

Fourth, we need to encourage teachers to investigate creative ways of sharing knowledge with their students so that they are not just "teaching to the test". Changing our methods of teach/learn knowledge sharing in the classrooms is necessary and the teachers can make the difference if they are encouraged to work as teams and collaborate with their colleagues. Suggestions on how to interweave the subject material from the single focus textbook version into multiple topics through story-telling[4] sessions and real life role-playing situations can bring the difficult concepts of math and science into a perspective that fits their lives. Creative subjects like art and music enter into these story-telling sessions and the teachers enjoy the classes as much as the children. Reading and writing skills are developed when subjects are interwoven naturally in the early grades with young children.

Teaching Nanotechnology in Grades 1-6 in China

A perfect example of this type of teach/learn activity was shown to us by China, who introduced Nano Science and Nanotechnology to grades 1-6 in January 2005. Balestier Hill Primary School introduced a nanotechnology program for all its pupils - from Primary grades 1 to 6, and I believe it to be the first primary school to do so.

The school set up a $25,000 air-conditioned nano lab for 'hands-on' experience lessons. Associate Professor Belal Baaquie, whose daughter Tazkiah, 11, attends the school, came up with the idea. "Nanotechnology is an emerging area in science and technology," he said. "Students should be exposed to it from young - when they are open to new ideas."

In December 2004, the NUS' physics professor gave a talk on it to the school principal, Dr Irene Ho, and her teachers. He even organized a visit for them to the NUS labs. Convinced, Dr Ho swung into action. She submitted a proposal to the Ministry of Education and was given a $15,000 grant from the School Innovation Fund, with another $10,000 from the School Cluster Fund.

A month later, (not years in the decision-making process) the lab was ready. Now, the children go to the lab two or three times a week. Lessons are made fun and simple, especially for the younger ones. "For instance, under the teacher's supervision, the Primary grades 1 and 2 children are allowed to fiddle around with the microscopes," said Dr Ho.

'They are then encouraged to talk or write stories about their experience. So as they familiarize themselves with a science lab and the objects found there, they are also improving their speaking, reading and composition skills," she added. Meanwhile, those

[4] http://www.thenanotechnologygroup.org/index.cfm?Content=88&PressID=961

in Primary grades 3 and 4 learn how to construct models of atomic structures, using golf balls and Lego sets.

Things get a little more in-depth in Primary grades 5 and 6 who are permitted to use the microscopes independently. As they examine a strand of hair, they must first observe, then record their findings on worksheets which gives them an actual research lab experience. The Primary grade 6 pupils also have to do a project on nanotechnology along with the lab research experiences.

"However, there are no exams or tests. Instead, it becomes a part of their syllabus by being integrated with other subjects", said Dr Ho. "For instance, an art teacher can book the lab and ask her pupils to draw what they saw under the microscope."

The lab looks like a creative, high-tech play room. For example, in one corner stand two eye-catching rectangular floor lamps. One features huge polka dots, the other has black-and-white motifs - the kind more commonly found on jersey cows. Principal Dr Irene Ho stated, "We want to make the entire experience fun and non-threatening for our children." The walls of the lab - both inside and out - are also covered with bright, bold wall paper, featuring graphics of atoms and molecules.

Taking pride of place are the eight electron microscopes - which are X1600 resolution models. This means the students can see objects the size of a micron - which is about the size of a dust particle. Each microscope costs about $3,000. There is also an interactive corner with Lego sets and golf balls for model-making, as well as display cabinets featuring the works of some pupils.

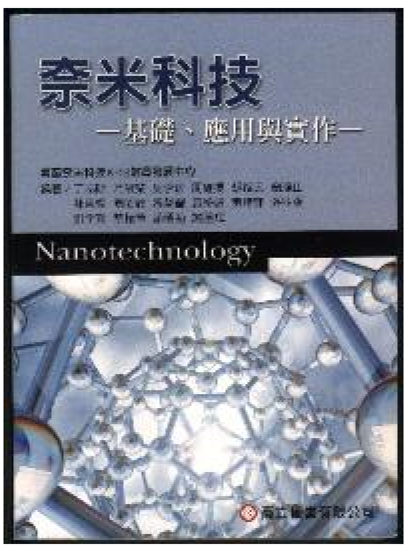
What can we learn from this example of teaching in China?
Building labs in our elementary schools is probably too expensive, but we can expand the many outreach programs around the country that have traveling vans with scanning tunneling microscopes and atomic force microscopes by transferring samples from their work to DVD and filming the children's lab experiences for distribution to a wider audience as virtual classroom laboratory experiences.

The teachers can then use the visual elements from the microscopes to introduce nano scale teachings in their classrooms with examples of how to share the lessons with associates in art and language programs to develop the same type of experiences that were successful in China. This would also introduce team teaching to elementary teachers along with story-telling based on the artwork and writings produced by the students. Integrated subject teaching introduced in the primary grades can advance education to new levels of comprehension very quickly.

Microscopy shows students that size does matter in science, which then involves mathematics and biology as they are looking at a strand of hair or a skin sample at the atomic level, bringing their cells to life, not just graphics on a page in a textbook. This enables teachers to show them real-time images of how nature works in their bodies and when they can actually see the visual of the cells, physics, chemistry and biology become natural subjects to explore as they mature to learn how their world actually works.

Taiwan teachers also take the initiative to develop nano science education for K-12
Launched in 2002, the Taiwan program was developed to undertake the task of education and teacher professional development in cooperation with the Ministry of Education. From the beginning their program has included K-12 education development along with the needs of higher education at the university level. In comparison the United States National Nanotechnology Initiative (NNI) which launched in 2000, has still not addressed primary grades education funding, except as outreach component programs by centers funded for research. The first NNI Nano Center for Teaching and Learning funded to address modules for middle school was announced in 2005, while Taiwan considers K-12 education to be a primary part of the project from the inception stages of their programs.

In just two years of operation, engineering faculty from 17 universities and 193 teachers from 169 K-12 schools participated in programs at the regional centers. Even though the teachers knew very little about the science or technology when they entered the program, they were able to develop 224 lesson plans, write one set of textbooks, a comic book, and create one animated film for K-12 students.



A large textbook with instructions for experiments was developed by the teachers from the many lectures they attended. Even though the textbook (451 pgs.) was printed in Chinese the diagrams and photos included with the text clearly showed the quality of the teachers understanding. As they explained their program to U.S. professors during their 1st International Collaboration for Education[5] in November 2005, it was apparent that this method of training elementary teachers by sending them to lectures at the universities was quite successful and less expensive than dedicated summer workshops. The possibility of translating the textbook from Chinese to English was discussed for future cooperation between our countries.

Along with these early training sessions in the first two years, they also established five regional Atomic Force Microscope (AFM) Labs for the teachers and students along with a touring van outfitted with scientific instruments for school visits. The program also included lectures and workshops, on-line courses, websites and newsletters.

The next step was the development of teacher workshops as the primary method of knowledge transfer where experts, professors and experienced "seed" teachers gave talks and led hands-on activities. Topics included carbon nanocapsules, carbon nanotube models, and making nano solar cells. Laboratory tours were arranged for all the teachers with visits to the National Science Council Northern Region Micro-Electro-Mechanical

[5] http://www.thenanotechnologygroup.org/index.cfm?content=129&Menu=27

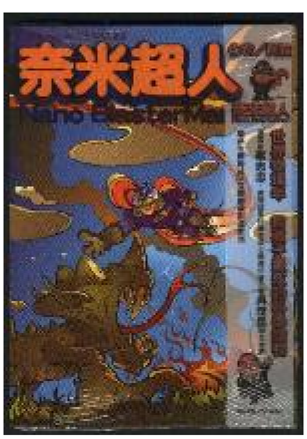
Systems (MEMS) Research Center and the Industrial Technology Research Institute (ITRI).

Development of Lesson Plans and Instructional Materials was the next phase of the project based on the lectures and workshops they had attended. Most of the teachers preferred to work with colleagues in the same schools and the new teaching materials were discussed during regular meetings to make sure they were suitable for the various grade levels of students. Materials were then evaluated in terms of the national curriculum at elementary and junior high schools, tested in trial classrooms, re-evaluated to be sure they were successful, and then presented at the second annual conference.

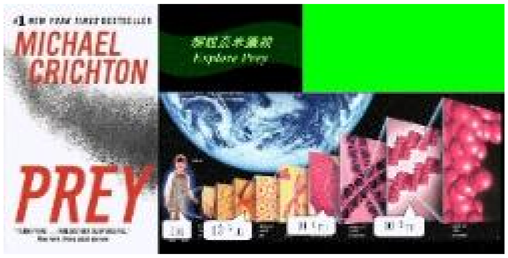
To assemble the instructional materials, the lessons, pictures, and text created by the teachers were collected and published as a three-part book titled: ***Nanotechnology Symphony: Physics, Chemistry and Biology,*** which encouraged the early integration of these three important subjects in the primary grades**.** As introductory material about nanotechnology, the book contains concepts such as nano-size, nano-material, nano-catalyst, photonic crystal, and various applications, along with 6 experiments designed to give students hands-on experiences in a regular high-school laboratory. The experiments also included various topics such as synthesis of aqueous ferrofluid, and diffraction of laser beams with ferrofluid.

The animated films and comic books projects took a special effort of design and development with a first testing in flash animation created by the teachers in elementary schools, and then reworked with professional help provided by the main program office.

The animated film titled: **A Fantastic Journey for Nana and Nono** was released in July 2004, (after only one year into the project) introducing the basic theory of nanotechnology and applications for daily life from a child's perspective. The 15-minute film was developed in Chinese language with English subtitles and in August 2004, Thailand signed an international contract to use this animated film in their schools, as an example of collaboration between countries for education.



The Comic book titled: **Nano BlasterMan** was created for middle school students and depicted the adventures of a superhero named Nano BlasterMan who could use the power of nanotechnology to fight evil. The comic book was suggested by teachers as students of all ages love this media and they felt it would be a successful introduction to middle school students of some fairly difficult concepts. After the teachers developed the story, it was drawn by a professional illustrator, and then assessed and confirmed by the engineering faculty for accuracy of the technical details.



A high school lesson was also developed from the best-selling science fiction book **PREY** by Michael Crichton, where the teachers took advantage of the story line to show the real science of bionanotechnology and to discuss the social implications.

During discussions at University of Wisconsin, Professor Wendy Crone asked the presenter from Taiwan about that course of action. As she stated, “In the United States, science fiction books are ignored basically due to the bad science within the storyline, therefore, would never be included in instructional materials.” However, it was then explained that the results from the lessons created from the book in Taiwan were determined as positive for the students, who would read the book anyway and wonder if it could really happen. By addressing the story in class, it gave the teachers an opportunity to teach discernment between real science and science fiction and created a more informed student.

In order to give teachers and students experience with advanced nanotechnology equipment, the regional centers also set up AFM labs at the participating universities. Starting in September 2004, the equipment was purchased and the AFM manuals were developed for the K-12 teachers and students.

To reach schools in remote areas, the main program office worked with the National Taiwan Science Education Center in Taipei to build a demonstration van in 2004. Domestic products such as cloth, tiles and tennis racket nets, which used nano materials were displayed along with the animated films, AFM microscopes and hands-on activities such as light penetration and reflections of buckyballs. The van was staffed by volunteer teachers who would then visit the schools.

The Higher Education Nanotechnology Program was also in development at the same time as the K-12 was being established. Five regional centers were also established to coordinate resources and develop the interdisciplinary Nano curriculum, along with a web platform that was set up for researchers and academics to share curriculums and teaching materials.

In just two years, engineering faculty at thirteen colleges and universities worked together to develop a number of nano programs including courses in fields such as Mechanics, Electricity, Optics, Materials, Chemical engineering, Environmental Engineering, Manufacture, Measurement, Biomedical Engineering, MEMS, Physics, and Chemistry. The all inclusive programs introduced nanotechnology techniques while providing teaching materials and establishing research environments that aimed at conducting cross-department education and study of the theories and techniques. They also developed human resources from these courses for the emerging nanotechnology industries.

Cooperation is the key to their success by inclusion of all levels of students into their NHRD program at the very beginning of the initiative. The final segment of the program was the operation training for equipment. In cooperation with the Core Facilities Program of the National Science and Technology Program for Nanoscience and Nanotechnology, the Higher Education Regional Programs carried out experiments and Nanotechnology related training and operation courses for both pre-service and in-service training for engineers. Through this program, engineering students are able to have hands-on experiences in operating important equipment in the field of Nanotechnology and to increase their comprehension of practical applications in the various fields.

Collaborative Advantage for Nanoscience and technology with Thailand

Since the 1st International Nanoscience Education Conference on Human Resources in 2003 the Asian Institute of Technology (AIT) has developed courses online for students in developing nations while also continuing to offer excellent workshops on location for students to attend. Their government and education officials were very impressed with our organization's suggestions on inclusion of K-12 education for nano science and initiated programs to work towards education in Thailand of the younger students, which will enable them to have a head start for their future.

The NanoTechnology Group Inc. is also supporting their intent to establish a Nanotechnology Center of Excellence for Developing Nations and have offered our full support to AIT and the United Nations for this effort. This proposal to UNESCO in April 2006 to establish a UNITWIN Chair in 'Nanotechnology for the Developing World' at AIT would be very progressive towards developing nano science education globally.

Our working group will focus on the following areas for this project:

- Develop multidisciplinary training in "Nanotechnology" that can be beneficial to developing nations
- Provide technological education to prepare a competent workforce for nanotechnology
- Dissemination of scientific knowledge and technical expertise
- Open education that may be available to masses to reduce "Nano-Divide"
- Concentrate on niche nanotechnology research relevant to the region like advanced sensors, pollution reduction etc.
- Cooperate with S&T organizations in other developing regions to disseminate information
- Act as a bridge between the developed and developing Countries

The establishment of the center will be at the Asian Institute of Technology in Bangkok, Thailand, which was founded in 1959 as an autonomous, international institution empowered to award post-graduate degrees and diplomas. With its international team of faculty and staff drawn from Asia, Europe and North America, AIT tutors more than 1000 students every year, from across the world. AIT is well placed to contribute to the development of trained engineers to take up the challenges in the commercial use of nanotechnology for further development of the region and other developing countries at large.

Partnerships for Global Collaboration Confirmed

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Vietnam is another example of a successful Collaborative Advantage
Collaborations for this center started at the Conference for Human Resources at the Asian Institute of Technology in Thailand in 2003. Consultations the following year advanced the project through the discussion phases concerning the type of courses necessary for the Vietnam universities to develop that would benefit their country as a first step. They decided on building a laboratory for microelectronics and nanotechnology research as their first expansion of the education project.

The training courses on microelectronics and nanotechnology, were organized by the Nanotechnology Laboratory of the Ho Chi Minh City National University, which has welcomed lecturers from the French Atomic Energy Commission's Electronics & Information Technology Laboratory (CEA/LETI) and about 100 participants from research institutes, universities and companies.

The Nanotechnology Laboratory of the Ho Chi Minh City National University was one of the first nanotechnology labs in the country. Established at a cost of 4.3 million USD a year ago, the laboratory is aimed at training people in microelectronics and nanotechnology, as well as applying its research in industries.

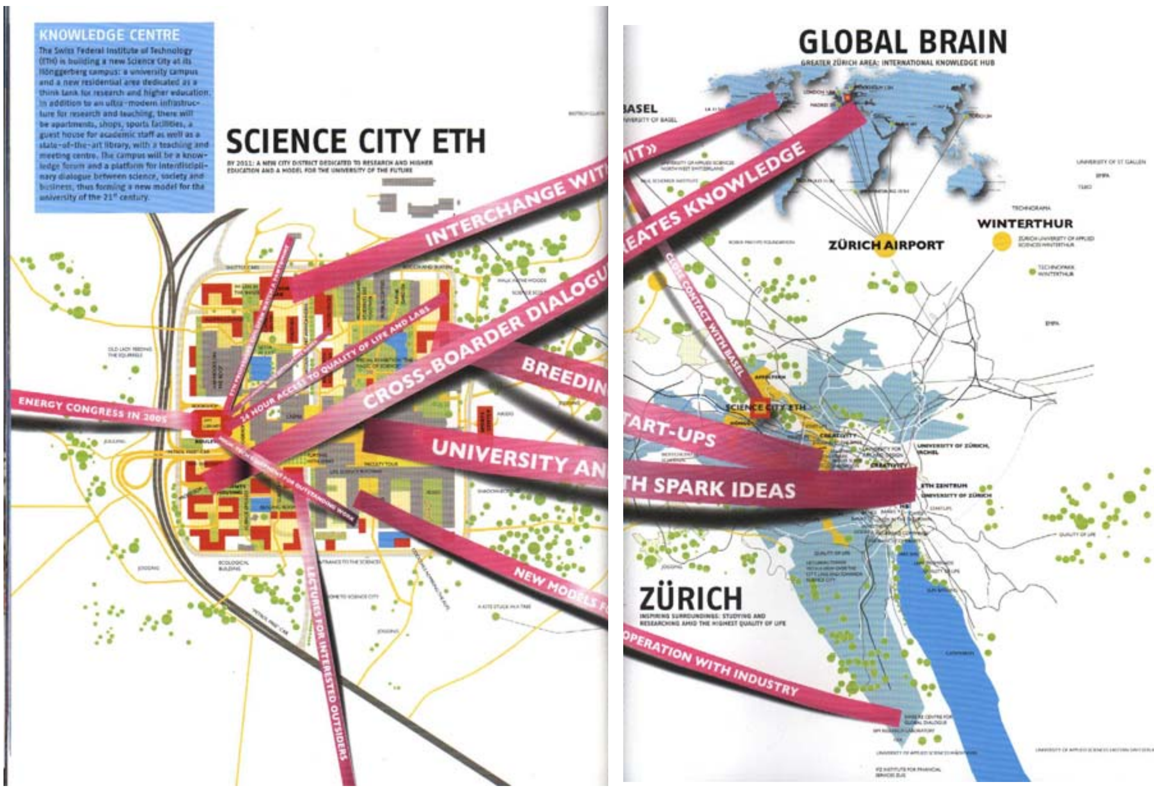
To date, the laboratory has set up relations with CEA/LETI and many other organizations in the Netherlands, the Republic of Korea, Belgium and Switzerland.-Enditem

Collaboration efforts will be scheduled later this year for the next phase of their ongoing project.

Switzerland develops Science City ETH as a Knowledge Centre for the Future
Our Location Switzerland associates have invited me to review technology development in their country and the education system many times since 2002. They excel in their

collaborative efforts with many partners and the following project is an excellent example of their abilities to prepare for the future.

The Greater Zurich Area will become an International Knowledge Hub as the Swiss Federal Institute of Technology (ETH) announced their plans to build Science City ETH by 2011, featuring a new city district dedicated to research, higher education and a model for the University of the Future. MIT is already collaborating on this project and it is a good example of International Collaboration and Integration of cross-disciplinary organization at all levels.



Our current complex system for education in the U.S.
Over the past few years, many documents have been developed by the National Science Foundation (NSF) based on the converging technologies identified as nano, bio, info, cogno. In the 2003 publication of the ***Converging Technologies for Improving Human Enhancement*** [6], a section titled **Visionary Projects** included a K-12 Education Vision by James G. Batterson and Alan T. Pope, NASA Langley Research Center, discusses some of the complexities and how we might address them.

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Delivery of learning experiences will be designed to enhance student attention and mental engagement. This goal will be supported in the classroom and at home by digital

[6] http://wtec.org/ConvergingTechnologies/

game-based learning (DGBL) experiences that provide (1) meaningful game context, (2) effective interactive learning processes including feedback from failure, and (3) the seamless integration of context and learning (Prensky 2001). Entertaining interactive lessons are available (Lightspan Adventures™) that run on a PC or a PlayStation game console so that they can be used both in school and after school in the students' homes.

The educational game platforms have been researched and are a proven method of interactive learning but are not on the funding horizon for another 5 years, nor will they be accepted in the classrooms for another decade or more. Our organization will be addressing this issue through development of edutainment games for informal education introduction of nano science and technology within the next few years.

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Virtual reality technologies, another tool set, will provide the opportunity for immersive, experiential learning in subjects such as history and geography. Coupled with interactive simulations, VR environments will expand the opportunities for experiences such as tending of ecosystems and exploring careers. A NASA invention called "VISCEREAL" uses skin-surface pulse and temperature measurements to create a computer-generated VR image of what is actually happening to blood vessels under the skin (Severence and Pope 1999). Just as pilots use artificial vision to "see" into bad weather, students can use virtual reality to see beneath the skin. Health education experiences will incorporate realtime physiological monitoring integrated with VR to enable students to observe the functioning of their own bodies.

Virtual reality technologies are available and could very easily be developed for all subjects by filming the experiences and sharing the content over the Internet for K-12 students globally as an introduction to the future possibilities for this technology. Once developed, the curriculum would be easily maintained as real-time learning experiences with technology updates for multi-cultural exploration and understanding between countries. This would be a first step in the technology growth patterns towards fully Immersive Learning Environments in the next decade.

Transforming strategy
The major technical barrier for instituting CT into the K-12 curriculum is the political complexity of the curriculum development process. Curriculum is the result of the influence of a number of communities, both internal and external to the school district, as shown in Fig F.3.

There are many excellent resources available on the internet but they are scattered so widely that teachers do not have time to find them. Private companies[7] are now creating their own content for schools through administrative classrooms of the future software, while government supported instructional materials are only accepted through textbook publishers after reviews by local school boards.

[7] www.prometheanworld.com

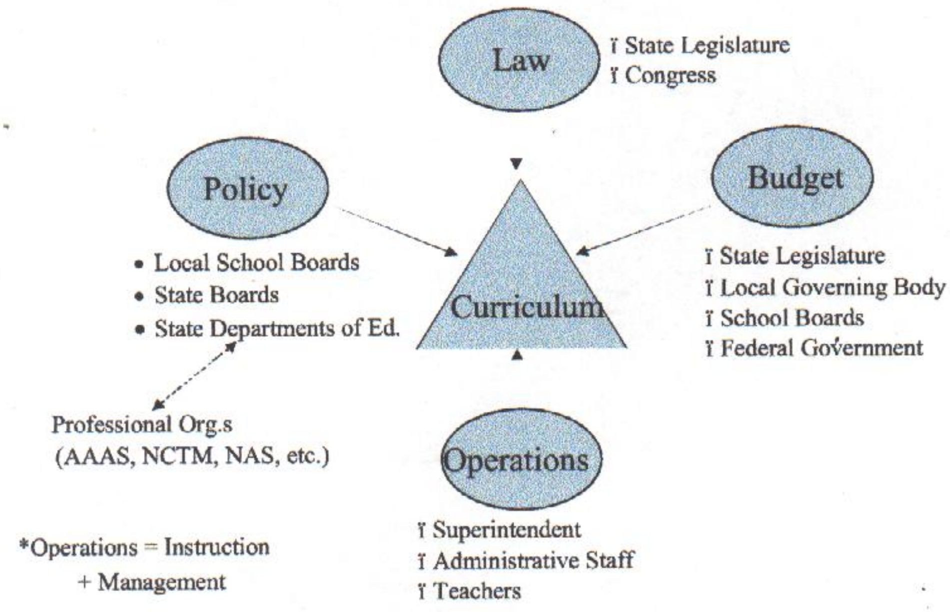

Figure F.3. The curriculum communities.

Courses can be created, but for curriculum development, the courses must be institutionalized or put into the context of the other courses in the school district. Since there are approximately 50 million K-12 students in 15,000 school districts in the United States, its territories, and the District of Columbia, a major strategy needs to be developed.

Since there is no U.S. national curriculum, having national CT standards serves only as an advisory function. For these standards to be used in curriculum development, they need to be accepted by state boards of education in development of their separate state standards (Fig. F.3 and F.4). Each state must then have courses available that meet the standards it adopts. Many states have developed statewide assessments or tests for various subjects. A major step toward implementation of CT curricula would be positioning CT questions on statewide science assessment tests.

A solution: Invite State and National School Board administrators to government and university conferences and lectures concerning the converging technologies. Stress communication with all levels of the curriculum committees including teachers. Set aside admission passes for them to attend these important sessions where they can be exposed to the new technologies and how they will affect students in the future. Also, send government and university education administrators to the National and State School Board Conferences to demonstrate the K-12 education outreach projects that are available for their classrooms, along with nano science instructional materials and experiments, already developed for classroom ease- of –use by teachers.

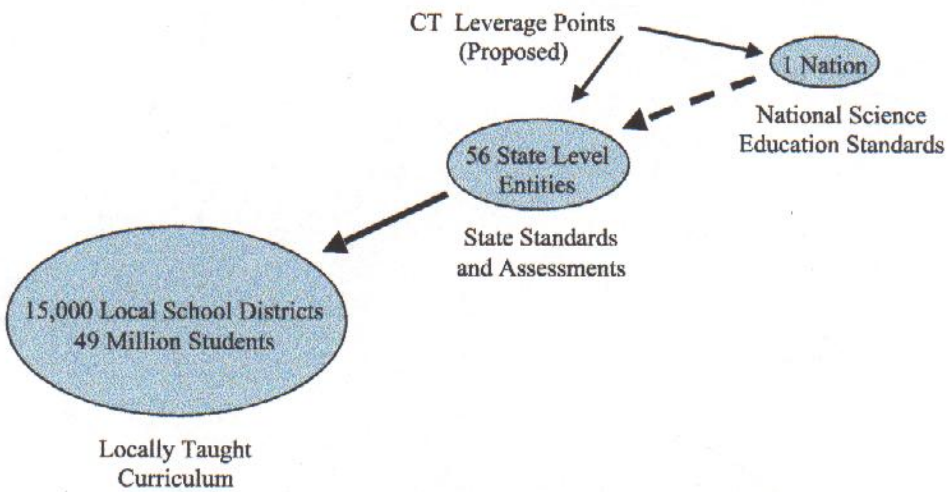

Figure F.4. Relationships between national and state standards and local school districts.

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Revisions in curriculum standards seem to take about five to ten years to develop, absent a major sea change in what is being taught. CT is a major change and it further moves curriculum to stay current with scientific and technological advances. This will require regularly occurring curriculum reviews at the state level and the ability to adjust content and assessment with a factor of ten more efficiency than is done today. As a guide to the states, a national curriculum must also be reviewed and updated in a similarly regular way.

The complexity of our system of education has hampered the efforts to develop new instructional materials. While we wrestle with the politics of an outdated system, other countries are rapidly passing us with new curriculum that is used in their classrooms within a year or two of development, leaving our students behind in the global knowledge society.

Education structure is a complex system:
While the current policy of education reform is using a uniform measure of accomplishment and development through standardized testing, it is clear that more effective measures must be based on a better understanding of cognitive development and individual differences. The importance of gaining such knowledge is high because evaluation of the effectiveness of new approaches to education typically requires a generation to see the impact of large-scale educational changes on society. The positive or negative effects of finer-scale changes appear to be largely inaccessible to current research. Thus, we see the direct connection between complex systems approaches to cognitive science and societal policy in addressing the key challenge of the education system. This in turn is linked to the solution of many other complex societal problems, including poverty, drugs, and crime, and also to effective functioning of our complex economic system requiring individuals with diverse and highly specialized capabilities. Pg.399

This is the general consensus on our lack of good education. Each generation that we do not educate properly will fall into the complex society problems of poverty, drugs and crime. It reminds me of a puppy chasing his tail and never catching it. It is just not acceptable in the 21^{st} Century.

Transform Education

The importance of education in complex systems concepts for all areas of science, technology, and society at large has been mentioned above but should be re-emphasized. There is need for educational materials and programs that convey complex systems concepts and methods and are accessible to a wide range of individuals, as well as more specific materials and courses that explain their application in particular contexts.
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Integration of subjects requires collaboration and team teaching

In the current era of converging technologies, students are being faced with decisions concerning integration of courses that were once single focus fields of study. Unfortunately, our present educational system does not foster the type of individual who works well in collaborations.

Courses in communication and collaboration need to be offered to teachers and professors of K-20. The art of listening and understanding technical languages between disciplines has not been taught, nor encouraged.

To achieve the training of good scientists and teachers who have the capacity to work well in multidisciplinary groups, there are several new kinds of traits necessary.

The first and perhaps most difficult is to learn to communicate across the disciplines. We learn the technical language of our respective disciplines and use it to convey our thoughts as clearly and precisely as possible. However, researchers in other disciplines are unfamiliar with the most technical language we prefer to use.

When talking across the bridges we seek to build, we must learn to translate accurately but clearly to an audience who will not be familiar with our respective languages. We must begin to train our students to learn the skill of communicating across the disciplinary divides.

This will require the development of programs in which students are systematically called upon to explain their work or the work of others to their peers in other areas. It would also be helpful for them to explain their work to K-12 teachers so that they can develop new courses for their students without difficulty.

Thus, the best programs will be those that throw the students from diverse disciplines together. The next generation of researcher will need to successfully form collaborative efforts to use the new converging technologies.

In order to accomplish these efforts, we need to pose challenges to our students to work in teams of mixed skills, teams of engineers, mathematicians, biologists, chemists, and cognitive scientists. Since we cannot train our students to be experts in this broad range of fields, we must encourage them to communicate across the complete range and to seek out experts who offer this expertise. Funding agencies must continue to enlarge the mechanisms that support this type of work if they want to have a unique position in fostering the development and optimal utilization of the new technologies as applied to other fields.

Among biologists, there is beginning to be curiosity and enthusiasm for engineering, robotics, and the new emerging technologies. The field of nanobiotechnology is growing much faster among engineers than among biologists. We must work harder to improve our outreach to biologists. It is likely that the full potential for nanodevices will only be reached by uniting engineers with biologists. Biologists presently have little exposure to information about nanotechnology. Comparatively, the engineers know relatively little about the real neuronal substrate with which they seek to interface. It will not be a trivial task to actually understand what will emerge when nanotubes are directly contacting neurons, stimulating them, and recording from them. It will require considerable multi-focus team expertise and imagination. Exposing biologists to the potential power and usefulness of the technology, and exposing engineers to the complexity of the biological substrate, can only come about through intense interactions; it cannot come about through groups operating alone. The journal Science has done a great deal to bring nanotechnology to the attention of the general scientist. However, no true understanding can come without hard work. Development of novel bioengineering programs will be another approach to development of nanotechnology.

Training biologists and engineers in the same educational program will go a long way to overcoming some of the present difficulty. Nanotechnology is difficult. The underlying chemistry and physics will not come easily to everyone. It is most likely that the best method of developing it is through explicit programmatic efforts to build collaborative teams of engineers and biologists. Summer workshops can provide incentives by exposing individuals to the potentials of the union, but only through full-fledged educational programs can the efforts move forward effectively.

Collaborative versus competitive projects in education

A collaborative effort among nations would initiate team learning and integrated courses while introducing real-time multi-cultural experiences. All courses would be offered in multiple languages increasing the desire of U.S. students to become multi-lingual at an earlier age. Global access to learning materials 24/7 will stimulate the desire to excel while continuously challenging the mind with new information.

Effective Collaboration Skills are Necessary for all Global Citizens

As educators struggle with integrated subject material, the communities, states and countries are also facing new cross-border collaborative situations in economic development which involve universities in most cases. SSTI.org had two examples that were excellent in describing some of the issues that face our current leaders.

Two Examples at Improving Cross-Border Collaboration for economic development
Whether it's a boundary between two communities, two states or two countries imaginary lines define real rules of commerce (e.g. by the taxes levied, property values, etc.) as well as intangible concerns and perceptions. In many places, intercommunity rivalries seem to almost spill over from the high school football fields and incapacitate the ability to achieve real change throughout a region. The spillovers of significant economic development investments often pay little attention to political boundaries.

The ritual of states chasing large automotive plants is demonstrative. The latest example is provided by Kia with Georgia shelling out $160,000 per job (one-third of which are expected to go to Alabama residents because the plant will be located within five miles of the border.) Both states were competing for the plant; some analysts argue Alabama won since it ponied up nothing to get up to 800 jobs. A collaborative approach between the two states for wooing Kia might have yielded the same choice in locations, with lower public incentive costs. Perhaps, that in turn would have freed up more funds to support education and economic development projects to sustain economic growth.

Two recent projects on opposite sides of the country are exploring ways to foster cross-border collaboration, an increasingly important requirement for competing in a global economy. We look first at the efforts of e-NC in North Carolina, then jump to San Diego and its work across international borders.

Crossing Counties and State Lines
By leveraging assets on both sides of the state line, border counties in North Carolina can become more attractive and competitive locations in technology-driven, knowledge-based economies, says a new report from e-NC Authority.

The study identifies best practices and outlines recommendations to promote collaboration and create additional wealth among neighboring regions in three rural North Carolina counties. Some of the problems facing these counties are, in part, caused by economic barriers intensified by political boundaries, the report states. This may include the historical culture and practice of states directly competing for business locations, R&D facilities and federal funding. Such challenges faced by border counties are not unique to North Carolina, the report adds.

Through a series of interviews and facilitated meetings with leaders in business, government, economic development, and higher education throughout North Carolina, South Carolina and Virginia, the authors identified hurdles and developed a set of recommendations. Over the course of the interviews, three categories of initiatives that focus on technology access and innovation emerged. These include information and communication technology access, training and education, and innovation development. Existing cross-border activities on technology access and training in other states and countries were surveyed as well.

For many participants, funding was reported as a major hurdle for cross-border programs. Having a pilot phase was essential to securing an initial round of funding for several of the programs the authors reviewed. This also gave the program time to garner political support while refining program activities and goals. Participants also recommended securing funding from a variety of sources, including state, local and federal government, foundations, the private sector, and universities.

A key issue for the design of cross-border programs is the inclusion of various stakeholders, according to the study. Other lessons learned include effective leadership over a coordinated team, having formal legal entities to confront tax and infrastructure challenges, and multi-year project commitments.

The study is part of e-NC's Cross-Borders Initiative to address barriers to economic development specific to border counties. The goal is "to help facilitate and encourage the emergence of knowledgeable cross-border stakeholders, including policymakers, who can help translate new ideas for collaboration into operational pilot programs and initiatives."

The report, Creating Wealth: Regional Development Through Cross-Border Collaboration, is available at:
http://www.e-nc.org/pdf/Creating_Wealth_Cross_Border_Report.pdf

When Boundaries are Between Nations
Borderless Innovation outlines 10 recommendations designed to enable the San Diego-Baja California region to spur local growth and prosperity. The bottom line requires a broad coalition of interests to overcome previously fragmented efforts and take the steps necessary to collaborate in creating a new Innovation Corridor of the Californias. Borderless Innovation is part of a larger effort called the Crossborder Innovation and Competitive Initiative, the current focus of the San Diego Dialogue. The Dialaogue is a program of University of California-San Diego (UCSD) Extended Studies and Public Programs.

The report analyzes parallel growth trends in specific industries on both sides of the border and seeks to explain the minimal efforts to collaborate and jointly market significant competitive clusters in high technology, science and other sectors. Borderless Innovation identifies a number of untapped capabilities and opportunities on both sides of the border, including biomedical devices, software, marine biotechnology, and aerospace and defense. The report describes the complementary institutions, organizations, technology clusters, and other elements that, when properly coordinated and leveraged, could be the impetus for even greater economic growth.

Three major findings emerged from the nearly two years of research involved in the report:

- *There is a need for strong collaborative marketing efforts related to the high-value technology and innovation clusters in the region;*

- *Leadership from both sides of the border must collaborate on expanding research, technical assistance, professional and workforce education to assure sustainable growth and competitiveness; and,*
- *The crossborder region needs new social and institutional mechanisms with shared leadership, co-investment and well-orchestrated programs to build competitive capacity for this innovation corridor.*

San Diego-Baja collaboration faces some challenges that are unique to international boundaries but others that can be quite common: security at the border and the cost of delays due to wait times; expansion of the global economy; infrastructure, including ports; the need to increase the number of science and engineering degrees in the region; and, perhaps most important, the challenge of trust.

"Were the region to develop a strategy to support an Innovation Corridor of the Californias, it would require a significant amount of collegiality and trust among civic leaders, policy makers, educational institutions and the private sector," the report notes. "This means sharing timely and relevant information, frequent interactions and a commitment to one another's future and quality of life … only with this level of trust can the region achieve its deepest integration and most promising competitive opportunities."

To address these challenges, the report closes with 10 recommendations for redefining the crossborder region as one with the potential for borderless innovation and catalyzing a new vision for "transforming clusters of opportunity into clusters of prosperity, which improves the quality of life for all." The recommendations are:

- *Create a crossborder innovation and competitiveness center as the catalytic agent;*
- *Launch a crossborder program to foster scientific and technology relationships and communication;*
- *Provide ongoing research and analytical reports on crossborder clusters;*
- *Work with Baja California to establish crossborder clinical research as a precursor to growing a transregional biopharmaceutical industry;*
- *Promote private investor networks in the region;*
- *Promote "smart border" technologies and infrastructure;*
- *Expanding existing crossborder education and research linkages, create new ones;*
- *Harmonize economic, health and educational data to provide consistent reports;*
- *Convene a high-level working group to assess the feasibility of a California model based on the Costa Rican INBio model for balancing conservation and development; and,*
- *Explore broader, non-technological economic linkages.*

A copy of the 53-page report is available from the Dialogue's website, www.sandiegodialogue.org . It was made possible by funding from the State of Baja California; CENTRIS, an economic development collaborative in Tijuana; CICESE, a federally funded science and technology research center in Ensenada; the City of Chula

Vista; Wells Fargo Bank; and program and development funds from UCSD's Division of Extended Studies and Public Programs.

The comprehensive issues that all countries will face in the future as we struggle to understand this new era of globalization will affect everyone from the local school district to the multi-national corporation. If we are open to new ideas and keep our focus on the advantages of collaborative efforts, our country will remain successful in a global atmosphere.

Nothing improves until we collectively decide to strengthen our education system and learn to communicate effectively across international borders.