Creating an Appropriate 21st Century Education

Robert Sylwester, Editor

David Moursund, Editor

Dedicated to Harry Wolcott
superb author, valued colleague, true friend

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Preface

This book contains a series of Information Age Education Newsletters that explore various elements of the educational issues that will confront our society during the 21st century. The principal focus of the series is on the dramatic developments currently occurring in the cognitive neurosciences and computer technology. These promise to play an especially significant role in reshaping educational policy and practice.

The authors of the articles are all widely known and respected for their work in the area in which they write. They were asked to select a general issue that they consider important to 21st century education and to discuss the elements of it that they consider especially significant to educators. Some authors focus on simply exploring the issue itself and others also suggest educational applications.

We've incorporated the articles and selected reader responses that the newsletter articles engendered into this online book. We hope this preliminary discussion will help lead to the eventual development of a comprehensive 21st century theory of education.

This book certainly isn't the only current search for the elements of what 21st century education could and should become. For example, *Edutopia* has published a series of articles (http://www.edutopia.org/blog/21st-century-leadership-overview-ken-kay). The new Learning Resource Network (http://www.l-rn.com/welcome_video.htm) at Johns Hopkins University provides a clearinghouse of educationally significant developments from several disciplines. What will occur over time as the literature expands is that an increasing number of educators become involved, and a bottom-up consensus will eventually emerge. Nothing new. Bits and pieces merging into a complex entity describe how biology, technology, cities, and democracy develop and function.

About the Editors

Robert Sylwester

Robert Sylwester is an Emeritus Professor of Education at the University of Oregon. He has traveled widely, presenting more than a thousand talks and workshops. He was the major professor or co-major professor for more than 60 doctoral students.

His most recent books are *A Child's Brain: The Need for Nurture* (2010, Corwin Press; see an excerpt at http://www.sharpbrains.com/tags/robert-sylwester/) and *The Adolescent Brain: Reaching for Autonomy* (2007, Corwin Press). He wrote a monthly column for the Internet journal *Brain Connection* during its entire 2000-2009 run (archived: http://brainconnection.positscience.com/library/?main=talkhome/columnists). He is a regular contributor to the IAE Newsletter.

For more information about Robert Sylwester, see http://en.wikipedia.org/wiki/Robert_Sylwester and http://www.sharpbrains.com/blog/2008/01/06/learning-the-brain-interview-with-robert-sylwester/.

David Moursund

David Moursund earned his doctorate in mathematics from the University of Wisconsin-Madison. He taught in the Mathematics Department and Computing Center at Michigan State University for four years before joining the faculty at the University of Oregon.

At the University of Oregon he taught in the Mathematics Department, served six years as the first Head of the Computer Science Department, and taught in the College of Education for more than 20 years.

His professional career includes founding the International Society for Technology in Education (ISTE) in 1979, serving as ISTE's executive officer for 19 years, and establishing ISTE's flagship publication, *Learning and Leading with Technology*. He was a major professor or co-major professor of 82 doctoral students. He has presented hundreds of professional talks and workshops. He has authored or coauthored more than 60 academic books and hundreds of articles. Many of these books are available free online. See http://iae-pedia.org/David_Moursund_Legacy_Fund.

In 2007, Moursund founded Information Age Education (IAE), a non-profit company dedicated to improving teaching and learning by people of all ages throughout the world. See http://iae-pedia.org/Main_Page#IAE_in_a_Nutshell.

Information Age Education

Information Age Education is a non-profit company in the state of Oregon that was established in 2007 by David Moursund. Its goal is to help improve worldwide informal and formal education at all levels. Its current list of free resources and activities includes:

- Free books published by IAE. See http://i-a-e.org/free-iae-books.html.
- Free IAE Newsletter published twice a month. See http://iae-pedia.org/IAE_Newsletter.
- IAE Blog. See http://iae-pedia.org/IAE_Blog.
- IAE-pedia. See http://iae-pedia.org/index.php?title=Special:PopularPages&limit=250&offset=0 for a list of pages ordered by popularity.
- Other IAE documents. See http://i-a-e.org/downloads.html.
- A major IAE initiative on math tutoring. See http://iae-pedia.org/Math_Tutoring_Project.

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Article 1

[IAE Newsletter #75. See http://i-a-e.org/newsletters/IAE-Newsletter-2011-75.html.]

The Roles of Cognitive Neuroscience and Computer Technology

Robert Sylwester
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University of Oregon

> Don't be trapped by dogma, which is living with the results of other people's thinking. Don't let the noise of others' opinions drown out your own voice. And most important, have the courage to follow your heart and intuition. They somehow already know what you truly want to become. Everything else is secondary. (Steve Jobs, talking to the Stanford graduating class in 2005.)

About 100 years ago, events (some of which helped to precipitate World War I) led John Dewey to argue that the development of democratic values and skills in school would become at least as important to 20th century education as the mastery of the 3Rs. Further, the classroom itself could serve as an excellent laboratory for developing them, since it provides a dozen year-long opportunities for students to interact with a couple dozen non-kin in the solution to group management problems. He argued in his early 20th century publications that the existing authoritarian classroom management and instruction model should thus be replaced with a democratic model that he called Progressive Education (http://en.wikipedia.org/wiki/John_Dewey).

Many educational leaders embraced Progressive Education, but the authoritarian model was so deeply ingrained in American culture that it took well over 50 years for elements of Dewey's model to emerge and demonstrate how it could work. A.S. Neill's Summerhill School (http://en.wikipedia.org/wiki/Summerhill_School) was one important early example of what came to be called the Free School Movement in mid-century (http://www.pathsoflearning.net/books_Free_Schools_Free_People.php).

The current high-stakes standards and assessment programs suggest that the authoritarian model of education didn't die, but rather has come back with a vengeance. Our educational system continues to resist change even when it is much needed, as it is today because of rapid culturally and educationally significant advances in science and technology. These new advances, alas, can be used to empower students or misused to maintain existing political and cultural constraints.

Towards the end of the 20th century, many educators and researchers sought to free our educational system from the shackles of Behaviorism, which viewed our brain as a *black box* that would never be understood. An initially small group of educators were excited by the emerging field of cognitive neuroscience. They began to explore how we might teach students about the human brain and adapt instruction to this new knowledge. Some of the early speculations look foolish now, but false starts are a part of any innovation. As more educators became interested, the field matured and the level of professional knowledge about our brain and cognition increased.

At the same time, computers were beginning to increase in capability, decrease in price and size, and demonstrate their potential as aids to learning and problem solving. The cost of computers and the amount of staff development they initially required slowed their assimilation into schools, but computers began to emerge as a powerful change agent outside the world of education.

And now it's the 21st century and WOW! The pace of change has certainly quickened.

Since the turn of the century, neuroimaging technology has discovered credible answers to many cognitive mysteries, and new discoveries are occurring at a previously unimaginable rate. Renowned cognitive neuroscientists, such as Michael Posner and Mary Rothbart (2006), John Ratey (2008), and Stanislas Dehaene (2010) are writing books that directly address the educational applications of their research. Other scientists are contributing chapters to books directed to educators. Graduate programs are introducing educators to the biological base of our profession. Professional organizations, such as the International Mind Brain and Education Society (http://www.imbes.org/) are shaping the emerging field of Educational Neuroscience. Commercial educational programs that purport to be based on cognitive neuroscience research are expected to provide convincing independent research evidence to support their claims. The future of Educational Neuroscience looks promising!

Moreover, students are growing up with routine access to the Internet and Web, computerized social networking and texting, a wide range of computer-based entertainment venues, and steadily improved computerized aids to learning. Who could have imagined the key role that cell phones would play in the emerging democratization of the Middle East?

The next article focuses on the manner in which computer technology is currently impacting educational policy and practice, and what we might expect in the coming years.

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Robert Sylwester

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For more information about Robert Sylwester, see http://en.wikipedia.org/wiki/Robert_Sylwester and http://www.sharpbrains.com/blog/2008/01/06/learning-the-brain-interview-with-robert-sylwester/.

Comment by David Moursund

Science fiction provided my early introduction to brain science. The E.E. Smith *Lensman* series of books featured protagonists with super mental powers. The first book of the series was published in 1948, which was before the first commercially produced computers came on the market. Needless to say, the electronic computers in the books were truly feeble relative to today's computers.

Brain science became something real to me when I read Howard Gardner's 1983 book *Frames of Mind: The Theory of Multiple Intelligences*. This eventually led me to seek out Bob Sylwester in order to learn more about brain science. For about a year we met regularly for lunch and "deep" conversation. Bob taught me brain science and I taught Bob about computers. We eventually presented a couple of workshops together.

Over the ensuing years, it has been fun to watch the ups and downs of brain science and computers as they have struggled to make useful and lasting contributions to education. In both cases there has been considerable hype. In both cases there has been the challenge of translating theory (or, the ideas of the leading researchers and practitioners) into widespread practice. In both cases there has been a very rapid pace of change in the disciplines. Each discipline has contributed considerably to the other. In some cases early adopters fell behind to new people entering the fields.

And, the excitement continues. The combination of modern Cognitive Neuroscience and Information and Communication Technology is now making significant contributions to the improvement of education.

Article 2

[IAE Newsletter #76. See http://i-a-e.org/newsletters/IAE-Newsletter-2011-76.html.]

Information and Communication Technology (ICT)

David Moursund
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> Computers are incredibly fast, accurate, and stupid. Human beings are incredibly slow, inaccurate, and brilliant. Together they are powerful beyond imagination. (This quote is often mistakenly attributed to Albert Einstein; most likely the correct attribution is Leo Cherne at the Discover America Meeting, Brussels, June 27, 1968.)
>
> Humans now routinely use three types of brains: their 'meat' brain; paper and pencil brain; and computer brain. Three brains are better than one. (David Moursund, 2012.) See http://iae-pedia.org/Two_Brains_Are_Better_Than_One.

Since long before recorded history, humans have used their capabilities to discover and invent tools that enhanced their physical and mental capabilities. Comprehensive oral communication is one of those capabilities.

More than 10,000 years ago, some groups of humans started the Agricultural Age. This was a game changer—agriculture has facilitated huge changes in our lives and world.

About 5,000 years ago, humans developed reading and writing. The accumulation of information and the use of reading/writing to access and process the information greatly augmented the capabilities of a human brain.

About 240 years ago, the Industrial Revolution was just getting started. Quoting from the Wikipedia:

> The Industrial Revolution marks a major turning point in human history; almost every aspect of daily life was influenced in some way. Most notably, average income and population began to exhibit unprecedented sustained growth. In the two centuries following 1800, the world's average per capita income increased over 10-fold, while the world's population increased over 6-fold. In the words of Nobel Prize winner Robert E. Lucas, Jr., "For the first time in history, the living standards of the masses of ordinary people have begun to undergo sustained growth.... Nothing remotely like this economic behavior has happened before."

About 60 years ago, the first electronic digital computers became commercially available. Information and Communication Technology (ICT) can be thought of as a way of combining the power of reading and writing with the power of ICT. Now our routine use of automated mental and physical tools in research, development, and implementation are greatly increasing the pace of change in our world.

ICT and Education

It is amusing to look back at the first commercially produced electronic digital computers. In retrospect, they were more like glorified calculators than what we now think of as being a computer. In the past 60 years, the cost-effectiveness of computers has improved by a factor of well over one billion! Many of today's smart phones have more computing power than the multimillion-dollar super computers of 30 years ago. Moreover, these cell phones not only provide us with person-to-person communication, they also tie in with the Web. They provide users with easy access to the world's largest library of print and multimedia materials, to the computing power and capabilities of the Internet, and to interactive games.

So how has ICT affected education, and how might it affect future education? As with all research and development efforts that might have a significant impact on education, there is the issue of "theory into practice." Our formal educational systems are very resistant to change.

Way back in 1980, Bob Taylor wrote a book titled *The Computer in the School: Tutor, Tool, Tutee*. The book was a collection of papers on the use of a computer as a teaching tool (tutor), use of a computer as an aid to solving problems (tool), and use of a computer as a device that people could instruct, i.e., write programs for (tutee). He also thought about adding a fourth section with the title of *Toy*. Although the role of computers in entertainment was already well established and was beginning to affect education, this was not yet a "scholarly, academic" topic for a scholarly book to be published by Columbia University's Teachers College Press.

Here is a more modern list of key aspects of computers in education currently affecting education and/or likely to strongly affect education later in the 21st century:

1. **Intelligent Computer-assisted Learning (ICAL) systems**. ICAL systems are better than human teachers in certain components of instruction and assessment, and they are steadily growing in capabilities. When integrated as a component of distance learning, we have a game changer. The vision is that of high quality, Highly Interactive Intelligent Computer-assisted Learning (HIICAL) being made available to all students throughout the world.
2. **Access to information and aids in processing/using the information**. The Web is not only the world's largest library, it is also a steadily growing set of tools that can solve or help solve problems. Perhaps the single best example of this is Wolfram Alpha (n.d.). Ask this system a question and it uses a combination of artificial intelligence, immense amounts of stored information and access to information, and huge computing power in an attempt to answer the question. The system steadily gets better through analysis of successes and failures, research in artificial intelligence, and more powerful computers.
3. **Automation of mental and physical jobs being done by people**. The Industrial Revolution substantially increased productivity of humans doing physical work. ICT is doing the same thing for mental jobs, as well as helping in continuing efforts to automate physical jobs. You have repeatedly heard the statement that we must educate students for the "jobs of the future that have not yet been created." A variation of this is

that education should not focus on educating students for the current jobs that will eventually be done by computers and computerized machines.

4. **Steady improvement in attention-grabbing and attention-holding multimedia entertainment**. One way to think about such forms of entertainment is its addiction capabilities. The carefully crafted instant gratification and longer-term addiction characteristics of such entertainment have already greatly changed how younger people (and indeed, many not-so-young people) spend their time. When we add in texting, social networking, and other computerized aids to communication and entertainment, we see that schools are fighting an uphill battle for students' time and minds.
5. **Working in partnership with ICT systems**. ICT is making it easier and easier for humans to collaborate with each other and with computers. We need an educational system in which students learn to work in such collaborative efforts to deal with the problems and tasks in our everyday world. See the IAE-pedia articles *Two brains are better than one* and *Computational thinking.*
6. **Improving human-machine interfaces**. Voice input to computers is now relatively common. Indeed, it is now possible for a person's brainwaves to control a computer. Many popular commercially available games now use gestures as input to a computer system.
7. **A steadily increasing pace of change**. Progress in the various technologies feeds on itself. In the past, the pace of technological "progress" was very slow. A hunter-gatherer might have to adjust to a better spear or stone hammer. An early farmer might have to adjust to a new type of crop being farmed or a new type of domesticated animal being raised. The pace of change increased rapidly with the Industrial Revolution and has increased still more rapidly since the beginnings of the Information Age in the mid-1950s. To a large extent, our educational system is backward looking rather than forward looking. Unfortunately, it is not well designed to prepare students for a lifetime of continued rapid change.

Final Remarks

In brief summary, we need an educational system with the following characteristics:

1. It prepares students to be independent, intrinsically motivated, lifelong learners.
2. It prepares students to deal with a rapid pace of change both in technology-related areas and in the world as a whole. Students face a life in which issues of sustainability, global warming, over population, and huge inequities among people within various countries and between countries are continuing and growing problems. Computer technology plays a major role in contributing to these problems and as a possible aid in dealing with them.

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David Moursund

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Afterword by David Moursund

It seems easy to look back and make suggestions about what students should have been doing and learning in the past. It is much harder to look into the future and forecast what will constitute a good education for this future.

Over thousands of years educators have learned that there are some parts of an education that well serve students for their lifetimes. The communication skills provide an excellent example. Being a decent, caring human being who is respectful of others and contributes to society provides another excellent example. These components of informal and formal education have endured and will very likely continue to serve us well in the future.

As the totality of accumulated human knowledge, skills, and tools has grown, informal and formal education have faced the challenges of deciding what students should learn. The development of reading and writing contributed to this challenge, but also contributed to meeting the challenge. We need to help students learn to read and write, and to effectively use libraries that contain the accumulated knowledge of humankind. We need to place increased emphasis on learning to be an effective and efficient learner.

Now we have nearly ubiquitous access to the information that can be stored in electronic digital libraries, aids to communication, and tools that can help solve many cognitive problems. We have barely scratched the surface of fully integrating these capabilities into everyday curriculum content, teaching processes, and assessment in our schools.

I try to imagine what it will be like when the assessment and student performance components of schooling are "open computer access." We have made great progress toward achieving this for everyday life outside of school settings. Formal schooling has yet to seriously take on this challenge.

Article 3

[IAE Newsletter #87. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-87.html.]

How Educational Neuroscience Will Contribute to 21st Century Education

Ron Brandt
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Educational Leadership

I have been encouraged by the editors of this series to offer my perspective on the striking change in how educators view the brain. For about 20 years I was executive editor of *Educational Leadership* and other publications at the former Association for Supervision and Curriculum Development (now simply ASCD).

Just a few decades ago, educators considered brain functioning as mostly a mystery and irrelevant to their work. Some still do, but most now recognize that knowledge about the brain is an essential part of understanding learning. References to brain research are found regularly not only in professional publications but almost daily in the mass media.

Praising Effort, Not Ability

For example, a recent article in *The Washington Post* reported that teachers in Montgomery County, Maryland outside Washington, D.C. are being asked to stop giving undeserved praise. The article noted that some experts have warned for years that, compared with their peers in other countries, American students tend to overestimate their capabilities and that the cause was a mistaken effort to build students' "self esteem." These authorities say that when teachers tell students how "smart" they are, it gives children an unrealistic view of their abilities. Teachers are advised to praise effort rather than ability.

The article is an interesting example of how brain research has come to be accepted as providing a basis for particular practices. It says teachers at Rocky Hill Middle School in Montgomery County talk about neuroplasticity and dentritic branching. They tell students, "You have a whole different set of neurons popping up there!" Neuroscientists might question the apparent oversimplification involved, but the project is based squarely on the work of psychologist Carol Dweck of Stanford University, author of the book *Mindset* and an online curriculum called *Brainology*. Dweck's publications do cite brain research, although her recommendations are derived from numerous other sources as well.

A Long Search

Educators have long sought to base our professional practice on scientific knowledge. Calls for valid research findings that would support dependable recommendations were sounded throughout the 20th century. The Elementary and Secondary Education Act of 1965, which provided for creation of federally-funded research centers and regional laboratories, was justified as a means of "putting research into practice." At that time, however, few people would have considered this goal as including references to dendrites or neurons. And most editors of education publications would have rejected manuscripts on the subject. So what happened?

The editors of this series believe that in the years I spent as editor and publisher at ASCD I played a role in this transition. If I was unusually receptive to manuscripts on the subject, it may have been because I had developed a deep interest in thinking and learning during the eight years I spent as associate superintendent of the Lincoln, Nebraska Public Schools. A related reason was that early in my career as an educator I reached the conclusion that traditional methods of education were outmoded and that we should experiment with a variety of innovative approaches.

Early Books About Brain Research

I first became interested in the brain when I read *How the Brain Works* by a free-lance writer, Leslie Hart. His descriptions of brain functioning were not always accurate compared with the knowledge available now, but his work was interesting because he was an accomplished writer. It was also groundbreaking. Hart strongly condemned behaviorism, then the prevailing theory of learning, on the grounds that it was contrary to what medical researchers and cognitive psychologists were beginning to understand about the brain. Although behaviorism still has its place, most current cognitive psychologists would undoubtedly agree.

I don't know exactly when I read Hart's book, but it was published in 1975, three years before I moved to ASCD. About that time I had begun sponsoring a pair of capable entrepreneurs, Sydelle and Lyle Ehrenberg, who had developed a teacher in-service program based on the works of Irving Sigel, a child development psychologist at Princeton, and Hilda Taba, a respected professor of education at the University of San Francisco. The course was quite different from what most teachers had encountered in education classes. It emphasized concept formation and what a few years later would be called "thinking skills." In Lincoln the Ehrenbergs taught the course to the central office subject-matter consultants I supervised, and the consultants then taught the course to teachers of their subjects.

Another pioneering book, a copy of which is still on my shelves, was Richard Restak's *The Brain: The Last Frontier*, published in 1979. When I glance through my copies of the books by Hart and Restak, I note that both authors emphasized the work of neuroscientist Paul MacLean and his concept of the "triune" brain (reptilian, old mammalian, and new mammalian).

My Role as an Editor

These and probably other books published at the time suggest that it was only reasonable that someone in my position—sort of a "traffic cop" for ideas—should want to provide readers with information about the brain. Although I surely did not realize it then, the explosion of knowledge about the brain that has characterized the last three decades was just beginning. It was my responsibility to be aware of it and encourage it if I could.

ASCD Publications

A 1981 article by Robert Sylwester was probably the first article about the brain ever published in *Educational Leadership*. In the years that followed, *Educational Leadership* published more of his articles, as well as articles and books by other capable interpreters of brain research such as Renate and Geoffrey Caine. When I heard that Sylwester was retiring and might have some time available, I urged him to write a book. He was reluctant, but finally agreed—and the result was one of the most popular books ever published by ASCD: *A Celebration of Neurons*.

Other Exciting Ideas

I published books and articles about the brain for the same reason that I chose to publish on other topics that I saw as potential ingredients in a growing base of knowledge about teaching and learning. I was excited by developments such as teaching thinking skills, cooperative learning, effective teaching, multiple intelligences, differentiated instruction, performance assessment, and outcome-based education. Each of these terms, and numerous others, represent portions of the valuable heritage that I believe future educators should be able to draw upon. Unfortunately, these topics are considered by some people—including some educators—as little more than fads that have distracted our profession from the common-sense task of running schools.

I believed otherwise. I was personally excited as I learned about each of these topics. They were thoroughly explored by thoughtful, committed advocates. Proposed practices were tried and tested, and while some proved unworkable, others were highly productive. Unfortunately many of the ideas that I thought held great promise have been abandoned through the years as schools tended to regress to conventional "tried and true" patterns.

Fads?

I continue to wonder whether attention to such potential improvements is in fact "faddish," although I acknowledge that it would be a huge challenge for any group of practicing educators to implement simultaneously ALL the good ideas advocated by outside "experts." In fact, I wonder whether the structure of our profession may be a contributing factor in what I see as our inability to sustain complex changes. The field of education is characterized by a huge chasm between "experts" (consultants and professors) who promote various ideas and "practitioners" who may pay lip service to these ideas but actually are often hostile, or at least indifferent, to such "unrealistic" notions. I don't know whether this is true of other professions as well, but it seems unusually exaggerated in education.

In recent years this unfortunate pattern has been overridden to some extent by politicians at state and federal levels who have imposed their own versions of "reforms." These requirements have often prevented schools from even considering more radical innovations.

A Sound Body of Knowledge

Although this development has been profoundly discouraging to me, I continue to believe that, over time, educators will accumulate a sound body of knowledge that is the basis for reliable practices. Findings from brain research will routinely be part of this knowledge base—although not independently, as though neuroscience can by itself dictate classroom practice. For that reason, as Robert Sylwester has observed, terms such as "brain-based education" are no longer appropriate. That kind of language may have been useful a few years ago to get educators' attention, but it has quickly become outmoded. Discoveries that certain mental functions are associated with particular areas of the brain, or that certain behaviors reflect particular neuronal patterns, are extremely valuable—but only when combined with findings from psychological studies and from applied research in school settings. Our profession does not yet have the body of valid knowledge that many of us want, but I continue to believe we will have it eventually—and that brain research will play an important part in its development.

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Ronald S. Brandt

Ron Brandt was editor of publications for the Association for Supervision and Curriculum Development (now ASCD), Alexandria, Virginia, from 1978 until his retirement in 1997. In that capacity he was also executive editor of *Educational Leadership* magazine. He is author or editor of 7 books and 38 articles, not including numerous pieces he wrote as editor of *Educational Leadership*.

Before joining the staff of ASCD, he was associate superintendent of the Lincoln, Nebraska Public Schools. He had also been a teacher and principal in Racine, Wisconsin; teacher-consultant with a University of Wisconsin project in Nigeria; program coordinator for the Upper Midwest Regional Laboratory; and director of staff development of the Minneapolis, Minnesota Public Schools. He lives at 1104 Woodcliff Drive, Alexandria, VA 22308-1058. brandtron@verizon.net

Comment by David Moursund

This article by Ronald Brandt fills in an important part of the history of brain science in education. Ron was the "right person" at the "right time" to make very important and continuing contributions to our changing world of education. I also enjoyed Ron's article because it helped me learn more about some of the early contributions of my colleague Bob Sylwester.

In his leadership role at ASCD, Ronald Brandt faced a steady stream of challenges of trying to separate the wheat from the chaff. In helping to review a very wide range of articles and their ideas, how does one differentiate what is unsupported claims or fads from what will prove to make lasting and valuable contributions to our educational system? How did Ron figure out that the emerging field of cognitive neuroscience was going to be an educational game changer?

Quoting from http://en.wikipedia.org/wiki/Cognitive_neuroscience#Emergence_of_a_new_discipline here is a little bit of the earlier history of cognitive neuroscience:

> Before the 1980s, interaction between neuroscience and cognitive science was scarce. The term *cognitive neuroscience* was coined by George Miller and Michael Gazzaniga "in the back seat of a New York City taxi" toward the end of the 1970s. Cognitive neuroscience began to integrate the newly laid theoretical ground in cognitive science that emerged between the 1950s and 1960s, with approaches in experimental psychology, neuropsychology, and neuroscience. (Neuroscience was not established as a unified discipline until 1971.) In the very late 20th century new technologies evolved that are now the mainstay of the methodology of cognitive neuroscience, including TMS (1985) and fMRI (1991). Earlier methods used in cognitive neuroscience include EEG (human EEG 1920) and MEG (1968). Occasionally cognitive neuroscientists utilize other brain imaging methods such as PET and SPECT.

It helps to be good at forecasting the future. Brain science has a long history. What was there about the last quarter of the 20th century that suggested we were going to eventually have a wave of new ideas, new research tools, and rapid progress in something that eventually came to be called cognitive neuroscience? Ron's background allowed him to learn with this new wave of progress and to help facilitate dissemination of the sound and useful results.

Article 4

[IAE Newsletter #77. See http://i-a-e.org/newsletters/IAE-Newsletter-2011-77.html.]

Educating Tomorrow's Students

Eric Jensen
Consultant

In the early 1980's I was introduced to the new emerging interface between education and the brain. My first curiosity was to find out IF we could use our rudimentary knowledge about the brain to change it and to better serve school age kids. With two partners, we co-developed an experimental residential academic enrichment program to test the possibilities. This program (SuperCamp) became a proving ground for "extreme student makeovers." See http://www.supercamp.com/.

Over 55,000 graduates later we became confident that brains can and do change if you do things right. When educators do things that work in alignment with how our brain works, we usually see better results. This program had a large enough group of participants to provide encouraging support for the possibility of brains changing.

Meanwhile, research scientists who used computerized instructional technologies were discovering changes in the brains of children who were delayed in language and reading mastery (Temple, 2003). In school settings, when solid scientific-based reading programs were used, educators and parents have seen positive changes in student performance (Tallal, 2000). Other behavioral changes were discovered with skill-based programs that used similar scientific principles. Recent successes with special needs students are encouraging educators everywhere (Russo, 2010).

My second question was, "Could we scale this up so that we could transform education?" Creating miracles with kids as an independent business was easy compared to influencing change in America's K-12 schools. After 30 years, the widespread effects of the staff development effort on public and private schools remain elusive. Right now, we have the knowledge and capacity to routinely make massive and widespread dramatic boosts in student capacity to learn, behave, and contribute to society. We know how to make miracles happen with kids from poverty, with those who have special needs, and with second language learners.

So, if having good ideas and strategies is not enough to change education, what is? What lessons have I learned about the potential to transform education with a more thoughtful "brain and mind" approach? What can we expect will actually change schools in the next 25 years?

What will ultimately change education?

A Proposal

I have learned that there are five forces, each of them extraordinarily strong, that have already, and will be, shaping the 21st century educational landscape. I also believe these forces are unstoppable. The only question is, "How will we manage them in ways that are more visionary and less destructive than our failures of the last 100 years?" Let's introduce the five forces, in no particular order.

1. Mind and brain research will continue to reveal more and more about how we learn, behave, and achieve. This force will grow in influence and will remain the benchmark for how we understand and measure our learning. There are at least a dozen significant new understandings from the last 25 years. The most important may be the discovery of boundaries and properties of plasticity and malleability in the human brain. Knowing THAT the brain can change is very exciting, but knowing HOW to reliably change a student's brain is truly revolutionary. Having the "will" to do it, the knowledge, and culture is still key and it is missing from most schools.
2. The Internet has dramatically changed the role of teacher (and textbook companies) as a provider of content. This means we have to thoughtfully reassess the role of a teacher. While some schools are still recruiting and hiring content experts, the number of public high school students who are taking online classes (for credit), with the Internet as the content provider, has skyrocketed from zero in the year 2000 to over 25% of secondary students today. I expect that number to exceed 10 million within 5 years. At the International ASCD Conference, one of the larger conferences for educational leaders, the percentage of exhibitors who are pushing technology has gone from 5% just ten years ago, to over 40% of all conference exhibit booth space. This mega trend will reshape the entire school experience for kids. Countless teachers will lose their jobs.
3. Our social brain just loves connecting and any technology that taps into our brain's natural tendencies will have incomprehensibly huge effects. Social networking has changed the way students conceptualize their world. Schools were always social worlds for kids, from cliques, gangs, clubs, and teams to collaborative class work, testing, or homework. But those opportunities were often "managed" by the school. Today, kids can be anywhere and still socialize endlessly. If a classroom is still set up with ugly desks in linear rows, students now feel isolated and even suppressed. The mobile social networks are the revenge of every student against an antiquated educational construct that often embarrasses even those who work within it. Slowly, students are empowered to make school more social by their own choice.
4. The new global economy will significantly change education. Depending on which numbers you believe, long-term U.S. debt may be between 55 and 210 trillion. We currently don't have the economy to repay our debts. This debt thus cannot be paid off, and so will have to be monetized (money printed to pay for it), which will devalue the dollar further. It will result in massive inflation, unprecedented cuts in services, losses of jobs and slashed programs. Policy makers, legislators, and administrators will continue to be looking for ways to cut costs. Soon we'll see more massive increases in class size, reductions in student services, increased cuts in arts, PE, and vocational programs. Human brains get stressed easily and anxiety can make for poor decision-making. We'll see dramatic cuts at the secondary level as fewer teachers are servicing more students and online learning becomes the new norm. In short, a significant change in education will be driven by dramatic new budget cuts of the next decade.
5. Accountability is the last of the mega changes. Years ago, there was no way to determine if one teacher was more or less effective than another. There were no metrics

to compare two teachers or even two schools. That's all changed. Today, the taxpayers and legislators demand greater results for the money. Recent test-score altering and cheating scandals highlight the stress of teachers who crack under the pressure of accountability in a culture of test scores. This trend is towards expecting more and more accountability from educators, with fewer resources and in less time. Teachers will have less job security and greater scrutiny of their work than ever.

Conclusion

This is a sobering new reality. All of us must "wrap our brains around" this new paradigm. What you just read is not a doomsday scenario or pessimist's dire prophecy; it is already happening. This altered reality requires us to be smarter, more agile, and to move quickly. When decisions are made out of fear, ignorance, or short-term "stock-market" mentality, students lose out. This is why all of us must be vigilant about supporting what's good for kids. I'm hoping you're on board with this path. The future will be bumpy, tough to predict, and unsettling. But if we are ready, it'll be a bit easier to manage.

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Eric Jensen

Eric Jensen is a former secondary teacher who synthesizes brain research and its applications for educators. Jensen, a member of the invitation-only Society for Neuroscience and New York Academy of Sciences, is currently completing his Ph.D. in Human Development. Jensen has published over 26 books including *Teaching with Poverty in Mind, Different Brains, Different Learners, Teaching with the Brain in Mind,* and *Enriching the Brain.* Eric Jensen's blog: http://www.jensenlearning.com/news.

Comment by David Moursund

I am reminded of the quote, "When you are up to your neck in alligators, it's hard to remember the original objective was to drain the swamp." (Adage, unattributed.) Jensen describes some of the alligators and then presents us with five components of a scenario of the future of education. In his conclusion he says: "This is a sobering new reality. All of us must 'wrap our brains around' this new paradigm."

Frankly, some of the future Jensen forecasts has me worried. I can wrap my head around some of the scenarios, such as the three based on increased progress in cognitive neuroscience and online learning, and increased demands for accountability. Our increasing understanding of cognitive neuroscience can be built into Highly Interactive Intelligent Computer-assisted Learning (HIICAL) that is delivered online at modest cost. (See, for example, *Supersized* *online courses* at http://i-a-e.org/iae-blog/supersized-online-courses.html.) Student accountability, along with much better formative and summative assessment, can be built into such HIICAL systems. This will lead to major changes in the roles of teachers and has a good chance of improving the quality of education that students receive.

I believe that the social interaction needs to be examined more closely. Sherry Turkle's (4/3/2012) 20-minute video *TED: Connected, but alone* argues that the type of connectivity students are engaging in is socially destructive—not a good substitute for face-to-face communication. She sees it as disruptive to our entire society. See http://www.ted.com/talks/sherry_turkle_alone_together.html.

Jensen's comments about the U.S. and global economy might well be expanded to include issues of global warming, sustainability, increasing population, and so on. The world faces very complex and very challenging problems. Education is often suggested as part of the key to effectively dealing with these problems. At the same time, the problems may seriously disrupt education. We are faced by the need to improve education, decrease its cost, and make it readily available to everybody.

Article 5

[IAE Newsletter #78. See http://i-a-e.org/newsletters/IAE-Newsletter-2011-78.html.]

Have Schools Become Historical Museums?

Kathie F. Nunley
EdDBrains.org

My son takes trombone lessons from a man who lives 20 miles away. It's a bit far to trek every Monday afternoon, but I do it because my son very much enjoys playing trombone in his high school jazz band and Mr. Bailey was the closest trombone teacher we could find.

Mr. Bailey has been teaching trombone and trumpet for many years, but most of his income comes from his musical instrument repair business. If you need your clarinet re-corked, or an ultrasonic cleaning of your flugelhorn, he's your guy. The area band teachers refer their students to Mr. Bailey and he has had a steady business for decades.

On our drive home last Monday, I pondered whether Mr. Bailey would still have a viable business if schools disappeared off the planet tomorrow. Were it not for school bands, how many clarinets, trumpets, flutes and flugelhorns would there be in our section of southern New Hampshire? A hundred years ago, when town bands were quite popular, perhaps Mr. Bailey could have survived without the school band programs. But today, I highly doubt there would be enough to support Mr. Bailey's instrument repair business.

How many other industries today would be nearly extinct if not for our school system? Our schools have now become museums of sorts for many things once commonplace in our daily lives. Sadly, the world inside school has become so far removed today from the world outside of school, that it has become a foreign land that young people find increasingly difficult to participant in successfully and enthusiastically.

A Contemporary Classroom

To get a sense of this, we need only look at this year's school supply list for a local elementary school:

30 number two pencils
pencil cap erasers
one box of Kleenex
one package assorted colored construction paper
one package: manila drawing paper
one Mead cursive writing tablet
one black-and-white composition book for science
one package of lined 3 x 5 index cards
five pocket folders with brads
three packages wide ruled notebook paper
small bottle of Elmer's glue
one packet of Post-it notes
one box of colored pencils
one ruler
one pencil case
three spiral notebooks
one red pen
a pair of safety scissors
loose leaf 3- ring notebook
2 boxes of 24 crayons

It amazes me to note that with the exception of the Post-it notes and maybe the missing Big Chief tablet, the list is almost identical to the one I had when I attended elementary school, way back in the 1960s.

When I walk into an elementary school today, I also recognize the physical environment of the classroom. There is a large analog clock on the wall, colorful bulletin boards constructed out of butcher paper and cut-out construction paper, individual laminated student desks with work storage areas in them, wooden chairs, sitting on a linoleum floor, a whiteboard with the alphabet written in cursive running across the top, a wooden teacher desk in the corner with a computer on it, bookshelves lining one wall filled with a variety of children's books, a large basket in the corner with playground equipment such as rubber balls and ropes.

Other than the fact that the chalkboard has been replaced by the whiteboard and the teacher's desk now has a computer, the classroom looks very much like it did when I was in elementary school all those many decades ago.

How is it that schools have managed to remain somewhat fixed-in-time, while the rest of society kept moving? Possibly because schools have always been centered around literature and the printed word, while society has moved on to the use of alternate narrative forms.

The written word was valuable for hundreds of years because it was the most stable and durable format we had available for recording ideas and information. Today though, we have alternate narrative forms that equal, if not surpass, the advantages of printed literature. Unfortunately, the concept of integrating alternative literary devices has instilled fear rather than excitement in many educators. Thus we cling to our old dogma.

The Chasm Between School and Home

If I reminisce back to my early grade-school years, I recall that anticipating the first day of school was an exciting time. I would eagerly gather my school supplies together. I would carefully arrange my pencils in my pencil case, insert it along with the lined notebook paper into my 3-ring binder, and it all made me feel part of the grown-up, real world.

For I saw all these objects used by the adults in my world. My father used a pencil and slide-rule to calculate loan rates and noted them in a spiral notebook. My mother wrote lists and letters on lined paper using a ballpoint pen. Our house was full of often-used hard cover books such as encyclopedias, cookbooks, science books and an assortment of reference books. The teller at the bank would carefully write my small deposits into the paper passbook I carried in and out with me. I would often accompany my father to the main Chicago public library where he would peruse the stacks while doing research for one of his projects. In other words, the tools used inside my school matched the tools I saw used outside my school.

My choices for amusement back then were simple too, and what little disparity existed between school and home favored school. Our house had one color television set which sat in the living room on a TV cart. We had our choice of three channels to watch -- game shows in the morning, soap operas in the afternoon, the nightly news at 6 PM, and a variety of different programs in the evening. Once a year, a channel ran *The Wizard of Oz,* which was always a much-anticipated event. If I wanted to talk to a friend in town, I could call her on the corded telephone attached to the kitchen wall. If I wanted to visit with a friend who had moved away, I wrote a letter.

Obviously our lives and homes today are very, very different. Nearly all of our students have their own personal laptop, iPad, or at least share a family computer. The majority of them stay in touch with their friends either through social networking sites or by texting on their personal cell phones. The idea of going to the library to do research would seem ludicrous. In fact, it is the opinion of most students that if it cannot be found on the Internet, it is not worth looking for. Most of us rarely pick up a pencil and paper and the idea of using them to write a letter is a distant memory.

Television networks now run programs 24 hours a day with seemingly thousands of channels. Visual and auditory entertainment is available within seconds with the touch of a button. Access to information and entertainment is almost unlimited and instantaneous.

Close the Chasm

Forty years ago schools were an exciting place to be. It was the place that we could go to meet and chat with our friends. Books filled with information were stored in a library just down the hall. Technology meant that if you were lucky, there would be a filmstrip to watch during social studies class. And if you were really lucky, you got to be the chosen student who would sit beside the projector and flip the filmstrip to the next frame when the record player sounded the tone.

Teachers were a wonderful and appreciated source of information. The pictures in the textbooks provided us with a way to see our world, and even a brand-new box of 64-count crayons was an exciting possession.

It doesn't take a genius to figure out that a box of 64-count crayons or a teacher’s lecture can no longer compete with the excitement of video gaming, graphic-arts software, and media technology.

And yet somehow we feel justified in expecting students to be excited about signing off of their computer games, leaving their media-filled home, taking the music ear-buds out, pocket their cell phone for the next hour, and sit at the same laminated desk used by their grandparents. Then pick up a pencil, get out a piece of lined notebook paper and listen to a teacher talk in front of the room while the big analog clock stares down to remind them how long it will be until they can leave and go back home, where the amusements and information are now kept.

Conclusion

Our challenge as educators is to embrace our shifting role from sage-on-the-stage to coach-on-the-sidelines. We need to accept the value of alternative ways of communication and the fact that we are no longer the sole, nor perhaps even the best source, of information. We need to rethink how to utilize the variety of media available today, which equal or exceed traditional ways to communicate the ideas of a culture and the knowledge of a society.

We must let go of the old dogma, lest we go the way of the dinosaurs.

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Kathie F. Nunley

Kathie F Nunley is an educational psychologist who delights teachers from around the world with her practical and inspirational solutions to the challenges of today's diverse classrooms. Her popular seminars and workshops combine classroom experience with her current research. A noted speaker at state, national, and international conferences, Dr. Nunley is the author of many books and articles on teaching in mixed-ability classrooms including *Differentiating the High School Classroom* (Corwin Press). Her work has been used by institutions and publications around the globe, including *Family Circle* magazine, ABC's *Extreme Makeover: Home Edition, Canada Living,* and the *Washington Post.* She is the developer of the Layered Curriculum® method of instruction (http://help4teachers.com) and the founder of Brains.org. She has spent over 15 years as a classroom teacher in both urban and suburban schools. Her Website: http://brains.org.

Comment by David Moursund

I find Kathie Nunley to be a delightful and insightful author. I was immediately led to viewing her Website at http://brains.org, and I recommend it to you. The menu on the left side of the first page of this Website contains links to 14 of her articles.

For many years I have felt that our schools are much more backward-looking than forward-looking. Kathie's description reinforces that belief. A backward-looking educational system helps to preserve and pass on the culture and traditions of the past. These are important components of our society and will remain important throughout a student's life.

However, the pace of change has been steadily increasing. An education that was good enough for your grandparents and parents is not good enough for today's children. It does not prepare them for a world that is steadily growing smaller, a world that is growing more crowded, a world of Information and Communication Technology with its superfast pace of change, and a world with problems such as huge inequities, global warming, and sustainability challenges.

Kathie's article captures the spirit of the problem of a growing schism between a student's life in school and the student's life outside of school. It is clear to me that school life and outside-of-school life march to the beat of two different drummers. This situation reminds me of Seymour Sarason's 1993 book, *The Predictable Failure of Educational Reform: Can We Change Course Before It's Too Late?* In this book he argues that our school reform efforts will fail unless we concentrate on empowering students and their teachers. I am still impressed by his foresight!

Article 6

[IAE Newsletter #79. See http://i-a-e.org/newsletters/IAE-Newsletter-2011-79.html.]

Neurodiversity: More than Just a Good Notion

Thomas Armstrong
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Two recent articles highlight the positive dimensions of mental health conditions such as autism, schizophrenia, and bipolar disorder. In the journal *Nature,* an article by Canadian neuroscientist Laurent Mottron emphasizes the advantages of autism (Mottron, 2011). Mottron suggests that, in addition to the well-known savant abilities of a small sub-section of autistic individuals, there are also assets in a broader segment of that population, including their ability to process large pieces of perceptual information. This results in among other things, an often-superior performance on non-verbal, highly visual assessments such as the Raven's Progressive Matrices.

In *New Scientist,* science writer Kate Ravilious reports how the genes for schizophrenia, bipolar disorder, and other psychiatric conditions may have given our ancestors an evolutionary advantage by providing unusual ways of thinking that helped spark the development of culture (Ravilious, 2011).

These two articles hint at a theoretical concept—neurodiversity—that has been emerging over the past decade, one that promises to revolutionize the way we think about mental illness and developmental disabilities. This new theory suggests that we should celebrate differences in brains just as we honor differences in flowers (biodiversity) and societies (cultural diversity). We don't say that a calla lily has "petal deficit disorder," but value it for its own intrinsic worth. Similarly, we don't say of people from Holland that they have "altitude deprivation syndrome," but rather we appreciate the country's unique geographic features.

Neurodiversity similarly suggests that we honor differences in brains, even when those brains initially appear to be defective. Interestingly, the term neurodiversity did not originate within the scientific community as a "top down" phenomenon, but rather came from the disability community, and in particular, the autistic community. It thus represents a "bottom up" grassroots movement (Solomon, 2008).

In a seminal article for the neurodiversity movement, "Don't Mourn for Us," autism rights activist Jim Sinclair suggested that autism is not a disease or a life sentence, but rather, something positive and worthy of exploration and development (Sinclair, 1993). The actual use of the word "neurodiversity" first occurred in a 1998 *Atlantic Monthly* article in which journalist Harvey Blume wrote: "Neurodiversity may be every bit as crucial for the human race as biodiversity is for life in general" (Blume, 1998). Since that time, neurodiversity has been the subject of, among others, bloggers (Seidel, 2004-2011), journalists (Harmon, 2004), essayists (Antonetta, 2007), public policy experts (Baker, 2010), educators in higher education (Pollock, 2009), and educators in special education (Hendrickx, 2010).

Neurodiversity As a 21st Century Challenge

This new approach to human differences strikes at the heart of the medical model, which has been the primary 20th century discourse used to talk about people with mental health labels. Instead of focusing purely on defects and deficits, the field of neurodiversity proposes that equal attention be given to the assets, advantages, and abilities of individuals who are wired differently from those who are “neuro-typical” (Armstrong, 2011).

While the rapid growth of knowledge about the human brain in the past two decades has given us more information about the regions of the brain that are damaged or diseased in individuals with psychiatric conditions, this research also promises to reveal something about the positive dimensions of those with mental and developmental disabilities. Mottron (2011), for example, includes fMRI images depicting the perceptual regions of the brain activating more among autistics than non-autistics during a non-verbal intelligence test. Similarly, research suggests that individuals with dyslexia utilize more of their right hemisphere when reading than non-dyslexic readers (Eide, 2011). In the field of genetics, a “novelty-seeking” gene has been identified and associated with individuals diagnosed with ADHD (Hartmann, 2003).

This new look at the positive side of what have traditionally been seen as negative conditions does not mean that we should glorify what are in many cases very challenging disorders. But it suggests that we should complement what we already know about the difficulties and problems associated with mental health diagnoses, with a look at the strengths and capabilities of these individuals. Such a project is perfectly in line with the new field of “positive psychology” championed by Martin Seligman (2002), the “capability approach” of Amartya Sen and Martha Nussbaum (1993), and the “strength-based approach” utilized increasingly in the fields of social work, counseling, and psychotherapy (Rudolph and Epstein, 2000).

Practical Applications

The practical implications of neurodiversity are considerable, in that a positive approach to mental health provides an opportunity for researching the optimal conditions for growth that can promote the well being of individuals with autism, dyslexia, ADHD, schizophrenia, and other conditions. Since neurodiversity is basically an ecological conception, I’ve used the evolutionary term “niche construction” (e.g., a spider spinning a web, a beaver building a dam etc.) to designate the process of building environmental supports to help negatively labeled individuals lead full lives (including the use of key learning strategies, assistive technologies, environmental modifications, and human resources).

One excellent example of niche construction can be found in Denmark at a computer software firm called Specialisterne, which hires 75% of its employees from individuals on the autistic spectrum (Austin, 2008). These individuals are particularly adept at computer programming, enjoy detailed work, get to work alone, and are being rewarded according to their strengths rather than penalized or patronized because of their disabilities.

Educators who wish to help individuals flourish who are beset with mental health labels would do well to investigate this emerging field of neurodiversity, and work to design programs and environments in schools that will assist such students in reaching their fullest potential. The use of iPads for children with autism, rubber ball chairs for students with ADHD, speech to text software for students with dyslexia, and self-monitoring devices for students with emotional and behavioral disorders, are just a few of the many strategies that can be used to build positive and nurturing environments for those whose brains are "differently wired" (Armstrong, forthcoming).

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Thomas Armstrong, Ph.D., is a keynote speaker and workshop leader who has written 14 books that have been translated into 25 languages. These include: *The Power of Neurodiversity: Unleashing the Advantages of Your Differently Wired Brain*, *The Human Odyssey*, *Multiple Intelligences in the Classroom*, *7 Kinds of Smart*, *The Myth of the A.D.D. Child*, and *In Their Own Way*. He can be reached at: thomas@thomasarmstrong.com. His Website www.thomasarmstrong.com contains additional articles on his work with neurodiversity and other issues related to learning and human development.

Comment by David Moursund

Over the many years of my life I have learned to cope with minor inconveniences such as very poor spatial sense, poor manual dexterity, very poor eyesight, mild Asperger's syndrome, prosopagnosia (face blindness), cataracts, glaucoma, and now an aging mind and body.

Fortunately, none of these have kept me from what I wanted to do in terms of marriage, family, professional career, and retirement. What they have done is to provide me with a glimmer of insight into the diversity of physical and cognitive capabilities of people.

My work as an educator and my studies in cognitive neuroscience have helped me to understand the huge range of individual differences that exist among people. I have learned that no two human brains are the same—even those of identical twins raised in the same household—and that brains have great plasticity. Education is a brain changer.

Armstrong's article introduced me to the term neurodiversity. I was especially taken by his statement:

> But it suggests that we should complement what we already know about the difficulties and problems associated with mental health diagnoses, with a look at the strengths and capabilities of these individuals. Such a project is perfectly in line with the new field of "positive psychology" championed by Martin Seligman (2002), the "capability approach" of Amartya Sen and Martha Nussbaum (1993), and the "strength-based approach" utilized increasingly in the fields of social work, counseling, and psychotherapy (Rudolph and Epstein, 2000).

A classroom teacher works with students having a huge range of neurodiversity. Research in cognitive neuroscience helps us to better understand individual differences and ourselves. It also helps us to understand the need for individualization in education.

Information and Communication Technology is making possible considerably more individualization of education than has existed in the past. Highly Interactive Intelligent Computer-assisted Learning (HIICAL) has made considerable progress toward providing a level of individualization and convenience that in the past was only available through having individual tutors. HIICAL still has a long way to go, but I believe it is poised to make major changes to our current educational system.

One change in education that I look forward to is an increased focus on each student gaining better insight into his or her capabilities, relative strengths and weaknesses, interests, and drives. I believe education needs to place increased emphasis on students learning to take more responsibility for their own learning and being empowered to make use of this self-responsibility. See my 2009 book *Becoming more responsible for your education a*vailable at http://i-a-e.org/downloads/doc_download/39-becoming-more-responsbile-for-your-education.html.

Article 7

[IAE Newsletter #80. Seehttp://i-a-e.org/newsletters/IAE-Newsletter-2011-80.html.]

Movement as Primary in Learning Processes

Rebecca R. Burrill
Educational Therapist and Movement Director

Primacy of Movement

Movement as the foundation for our brain's organization, development, and learning has been a part of educational approaches since the late 60's. The work of Jean Ayres was and still is in the forefront of this approach (Ayres et al., 2008). Ayres' work as an occupational therapist and developmental psychologist underscored the function of the vestibular system—triggered by physical movement in the gravitational field—as the foundation for motor-sensory-perceptual integration, more commonly known as sensory integration (Robbins, 1977).

The vestibular is a part of the body's proprioceptive system, which informs us about body movement in space, weight (gravity), and time. The first cranial nerve to myelinate in utero is the vestibular/cochlear, which registers movement, vibration, and tone in muscles and sound. In the beginning the fetus' perceptual system is bathed and stimulated by the motion and sound resonance of the mother's body and voice. This in turn triggers reflexive and spontaneous movement, which stimulates the whole motor-sensory-perceptual feedback loop of brain organization, development, and learning. In the beginning, to move is to perceive. All of our other senses are organized on this fundamental movement-sound neuronal base.

As a dancer with training in theory and practice in dance/movement therapy, I orient my educational approach to child development and learning through a psychobiology lens. We must move first to perceive our three-dimensional world in the forces of space, weight, and time (Bainbridge-Cohen, 2008). Through this movement we build inner precepts or images that match the outer world. These are prototypes of experience, sometimes called cognitive universals (Dissanayake, 1995). This movement-sound based precept building is the biological part of psychobiological process (Burrill, 2010).

This fundamental movement-sound unity is exemplified in the nonverbal communication between mother and infant, such as when baby makes high-pitched sounds and mother raises her eyebrows and shoulders in matching movements (Dissanayake, 2001). This is a mirroring process. Mirroring has been a fundamental technique in dance/movement therapy, and more recently a focus in neuroscience (Berrol, 2006). This 'mirroring' between mother and infant is a subjective, emotionally imbued meaningful process that happens through the movements of facial expression, body gesture, muscle tone, and voice intonation. This emotionally imbued meaning making is the psychological part of psychobiological process.

Emotionally imbued biological precepts drive the engine that builds subjective images of memory, dream, analogy, and metaphor of the inner personal world (Hannaford, 2005). The communication of the infant mother dyad is also cross-modal—translations of feeling experience from one sense to another, known as synesthesia. Cross-modal integration and association become a basis for aesthetic perception and intelligence. Cognitive universals become proto-aesthetic elements that naturally and spontaneously amplify, frame, and evoke emotional-feeling-imaginative meaning (Dissanayake, 1995). This perspective points to the earliest brain organization of the motor-sensory-perceptual process as the basis for language and the aesthetic expression of movement and sound—dance and music (Burrill, 2001).

The refinement of focus specifically on the primacy of movement and sound and their aesthetic counterparts—dance and music—is corroborated by a recent doctoral study on emotional intelligence and the arts by Susan Clark, an associate of Xan Johnson. The study measured emotional intelligence scores in relationship to arts programs provided to fifth graders. Dance and music were the art forms with the highest positive correlation effecting scores for emotional intelligence (http://contentdm.lib.byu.edu/ETD/image/etd1489.pdf).

A Movement Based Research Study

I conducted qualitative emergent-design doctoral research in which I introduced dance and art-making as activity choices two times a week in a public preschool (Burrill, 2001). These activities were improvisational and spontaneous—child centered—providing a high degree of freedom of movement and expression. They were compared with morning circle time, an activity where movement was highly controlled and teacher directed.

The comparison was done though a dance/movement therapy assessment tool—The Kestenberg Movement Profile (KMP). The KMP (http://www.kestenbergmovementprofile.org) is psychobiological, recognizing that a biological pattern of muscular behavior generates a corresponding psychological meaning. For example, the biological-muscular experience of lightness-of-weight ordinarily generates psychological meanings associated with happiness, ease, humor, inspiration, fickleness, giddiness, and so forth.

The KMP developmentally delineates biological needs and drives for survival, emotional-feeling dispositions, and the sense of self in relationship to the environment, others, and learning (Kestenberg Amighi et al., 1999). I used the KMP to give insight into the nonverbal, subjective experience of the children. I asked the question: Did the educational environment foster or hinder the creative process of learning?

I used the KMP innovatively to assess group movement of the children in the three activities—dance, art, and circle time (Burrill 2001, 2011). My final interpretation of results hinged on scores for the following:

- **Biological age.** The biological age being expressed in both the dance and art activities was age appropriate. For circle time the biological age was regressed, mostly expressing needs and drives for the first and second years of life. This indicates behaviors resembling developmental delays.
- **Animated vs. deanimated emotion.** Full animation of emotion was being expressed in dance and art, whereas in circle time there was an above normal amount of deanimated emotion—an indication of inner emotional conflict and feelings of unsafety and distrust of the environment.

- **Self-esteem.** The dance and art activities expressed balance of self-feelings, while circle time expressed an imbalance of closed, isolated, and defensive feelings, an indication of feelings of low self-esteem.
- **Ego-conscious control of behavior.** Lastly the KMP delineates the maturation of ego-conscious control of behavior. The scores for dance and art indicated that these activities allowed the children to express themselves with the more unconscious and instinctual spontaneity that is appropriate for their age (Blomberg & Dempsey, 2007). Circle time scores indicated the opposite.

Movement, Homeostasis, and Learning

As an educator I see these results in terms of the role of homeostasis in early learning and development. Homeostasis is the maintained balance, or matching between self and world. This is understood to be a biological, perceptual, emotional, and rational process (Damasio, 1999).

In order for children to learn creatively, they must feel safe and accepted for their own natural learning processes (Perry, 2009). Children need learning environments that are age-appropriate so that homeostasis can stabilize and creative learning be fostered.

The above results indicate that the high control of movement and expression in morning circle time was disruptive to homeostasis. It seems that the children were being required to use a level of motor-sensory-perceptual organization and ego conscious control that was not age-appropriate. This caused biological confusion (regression), and anxiety and distrust of themselves and their environment. It seems that internally the children's energy and focus were struggling to maintain homeostasis rather then being channeled for creative learning (Perry & Pollard, 1998).

Results also indicate that freedom of movement and expression, in their aesthetic forms of dance and art-making, allowed the developing children to feel safe and accepted in their own natural leaning processes. This stabilized homeostasis and therefore fostered the creative process of learning.

Results also point to the highly influential and delicately balanced relationship between the educational environment and the children's inner learning processes. Children are especially venerable to their environmental influences because they are building a neuronal template for homoeostasis, which needs to be patterned to encourage later learning and development (Perry & Pollard, 1998).

Conclusion

Freedom of movement and expression are old themes in the democratic and child centered project of progressive education. That aesthetic intelligence is intrinsically entwined with the biology of movement—most fundamentally through dance and music—is rarely understood or acknowledged. Dance is the least represented of the arts in public schools. Arts in general are considered an expendable frill, and if not, they are commonly thought to be items to be integrated into the 3 R's. Rather, the arts are developmentally precursors and fertile ground for the integration of the three R's and literacy skills based learning. Arts are the fundamental in which movement and dance are primary.

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Rebecca R. Burrill

Rebecca R. Burrill is an educational therapist, movement educator, dancer, and visual artist. She received her doctorate in studies focusing on the relationships between movement, brain evolution, child development, art making, and learning. She is trained in a dance-movement therapy assessment tool—The Kestenberg Movement Profile, and in occupational therapy related systems such as Brain Gym, Rhythmic Movement Training, and Body-Mind Centering. She works in private practice as an educational therapist and movement educator with all ages. She is a certified elementary educator and is artistic director of improvisationally based dance programs in schools, K-12. She recently performed a solo dance piece—Dancing the Dunes—linking languages of nature with languages of art, exemplifying her work of linking human intelligence with primal human relationship with Nature as instrumental in the development of language and art. Through this understanding she seeks to renew human engagement with the primary creative intelligences of movement, sound, feeling, imagination, and ecological consciousness and their natural, organic, empowering, and integrative capacities. Contact information: rburrill@verizon.net.

Comment by David Moursund

Rebecca Burrill's article talks about human movement—to produce art, music and dance—in a way that I found fascinating and deeply insightful. The article also made me think about some of the computer-based art, music, and dance that have become a routine part of our world.

Consider, for example, young children "playing" by moving mathematics manipulatives, such as units, rods, flats, geoboards, dice, spinners, and so on. Contrast these with computer simulations that exist for each of these. What does a child learn and experience when moving physical (concrete) manipulatives versus when moving computerized (virtual) manipulatives? Doug Clement's seminar article on these types of questions provides a start for exploration.

> Clements, D.H. (1999). 'Concrete' manipulatives, concrete ideas. *Contemporary Issues in Early Childhood.* 1(1), 45-60. Retrieved 4/22/2012 from http://www.didax.com/articles/concrete-manipulatives-concrete-ideas.cfm.

Similar questions can be posed for art. Young children can draw and animate in a computer environment, making use of both pre-drawn objects and objects they create. Computerized tools allow grade school students to create, edit, and perform (using a computer to perform) music. Computer devices used in game controllers can capture physical movement and integrate it into a game. This might be thought of as a new form of dance.

Computer technology is impinging heavily on "traditional" art, music, dance, and movement. We do not have adequate research to understand potential positive and negative effects of these changes in the everyday lives of children and adults. What we do know is that many children enjoy the creative freedom that this new technology is bringing them.

Article 8

[IAE Newsletter #81. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-81.html.]

The Positive Roles that the Arts, Arts Education, and Creative Obsession Will Play

Susan Stauter
Artistic Director
San Francisco Unified School District

Arts Education

An overwhelming number of K-12 Arts Education programs faded or disappeared in the United States during the last part of the 20th century. At the same time, the cultural role of the arts in society increased. This article argues that the disconnect occurred in part because K-12 arts education got untracked by standards and assessment programs that misunderstood the role of arts in education and society.

The Arts

Our brain's basic task is to plan, regulate, and predict our movements, and to predict the movements of others and of objects. Humans often add aesthetics to various movements and call it the Arts, a phenomenon deeply imbedded in human psyche and history. The artist articulates the culture—defining and challenging in ways that reflect personal truth but also become aesthetic cultural hallmarks. Those who wish to understand the history of a culture need to listen to its music, observe its clothing and architecture, and read its plays, poetry, and literature—all of which describe humans who are moving physically, emotionally, and intellectually.

That the images of the caves of Lascaux focus only on live moving animals tells us much about the tribesmen/artists who cared enough to record the images and the value system that drove the imagery. Through music we communicate across languages, value systems, and space. We are able to “speak” through the arts in ways that are emotionally engaging and intellectually stimulating. Questions are raised, deepening levels of inquiry are pursued, new ideas introduced, and challenging ways of viewing the ordinary are posed so that life takes on a newer, extraordinary meaning. It has been said that the arts make the strange familiar and the familiar strange.

The arts are supremely engaging. That they're processed in so many of our brain systems demonstrates their centrality to our personal life. But they also surround us and are thus integral to the breadth of our cultural life—and this causes a sort of cognitive dissonance when they're reduced or cut from the K-12 curriculum to save money. They've come to be viewed as an "extra" or sort of dessert to be served, perhaps, after the real academic meat and potatoes have been prepared and put on the curricular table.

With disengaged students struggling to understand the disconnected facts that schools so energetically teach and test, we should value the cultural breadth and integration the arts could provide as a part of the daily education of students—to engage and help them move aesthetically.

Aesthetic movements can be somewhat predictable, such as those of a pianist playing a well-practiced piece, or they can be improvisational, such as a pianist who elevates common keyboard skills and a simple melody into a unique artistic expression. The ability to improvise, to be flexible and make changes on the spot, to take risks and work both independently and as part of a larger ensemble, translates to the workplace and will be considered an important 21st century workplace skill.

Assessing the Arts

Many such skills, while directly related to the arts education experience, are not easily translated into the current right/wrong fill-in-the-blank mentality of testing, and are easily marginalized, if taught at all. Assessment of the arts becomes tremendously challenging in this "Age of Assessment." It's chilling to look at the ways in which an artist like Vincent Van Gogh was "assessed" by his contemporaries and potential purchasers. Imagine the world without those sunflowers and that starry, starry night—the fruit of his artistic capabilities and obsession. When his brother Theo told him the paintings weren't selling, Van Gogh persisted and created something new. Now we assess this work in an entirely new way, with billionaires competing for the privilege of having one of these images on their wall, and major museums vying for them so that we may stand in front of them in wonder.

And yet, when we assess student art we too often fall into a coloring book mentality; staying within the lines and drawing up grocery lists of rubrics and standards and mandates, the very things real artists abhor once they get beyond mere technique. Picasso famously stated that he had to work his whole life in order to once again make art like a child. The combination of technique and style make art, and while technique may be registered more easily, style is personal by nature and harder to quantify, qualify, and assess. This is the conundrum.

Art is unique. If the results of aesthetic movements are predictable and practical, we call it craft. The prototype of a manufactured vase can thus be art, but the reproductions are craft. We consider multiple performances of a stage production to be art, even though the script, technical elements, and set are constant. Subtle to important differences will occur during a series of performances, however, so each performance is art, as it happens in the moment and is changing constantly along with the factors surrounding it—many of them driven by the direct response of the live audience in the room. The actor changes metabolically during the performance, weeping, sweating, laughing, and crying. The body literally mirrors the emotions being channeled by the character being played. It happens in real time and the bodies of those watching from the audience change as well, as inspiration and emotion cause us to change metabolically.

The arts are experienced directly. We cannot read a book on painting and be a painter any more than we can memorize Hamlet and step on the stage to play it. We have to do things. We have to experience the arts on all sides, as creators and as perceiver/audience members, and what drives us to make art is primal and might be labeled obsessive.

Obsession

The word obsession carries a negative connotation for most of us. Issues around control and the lack of it and possibly being consumed by something out of our control connect with the word itself. The feelings of a person who is in the grip of obsession may be strongly driven by an image, an idea, an unanswered question or an overwhelming desire.

Artists in the grip of the creative process often feel a level of obsession, with all of their energies going towards the solving of a creative riddle or the realization of an image, musical score, or choreographed movement pattern. The creative artist works around, over, and through sometimes seemingly impossible obstacles. The drive to create is often fueled by an intense, obsessive energy that reaches its conclusion when the creative act is complete and the 'problem' seemingly solved, at least for the moment. Artists talk about feeling as if they are gestating and then giving birth to their creative products, sometimes carrying the unfinished design with them, or perseverating about a role or movement pattern as part of their own unique creative process.

While some creative artists need to have long gestation periods before arriving at their creative product, others work quickly and actually thrive with pressure and difficult, short deadlines. One unifying driving force is the fact that the goal for the creator is high stakes; that is to say it matters a great deal. The resolution of the problem, the creation of the new work, is of greatest importance to the creative artist and acts as a driving force. Some playwrights seem to continue to write the same play over and over again, consumed with certain issues and concepts. Perhaps what we call “style” in visual art is a coded response of artists to make visible that which consumes and is of great interest to them.

When we stand amazed before Michelangelo's David or sit listening to the music of Stravinsky, we are in the presence of work that was created by a human being who was driven to create it with a tremendous need and energy. We marvel at what possessed the artist to create the masterwork, and we puzzle over the sometimes-tremendous obstacles that the artist faced and overcame. Does it take a level of obsession to create art, and how do we find a new way to view creative obsession, perhaps through the lens of creativity and the creative process?

The word obsession also carries with it notions of a lack of balance, both emotional and intellectual, a giving over of the self to that which obsesses. Artists take risks when they choose to confront great truths and unanswerable questions by delving into areas of life that are sometimes difficult, dark, and dangerous. They symbolically take us with them as fellow travelers, without the actual danger of real life experiences. With the artist as guide, works of visual and performing art provide a way for all of us to both lose and find ourselves—to deal with emotional questions and find ways to speak unspeakable truths.

As children we drew and sang and played out our fears and interests, sometimes with tremendous intensity. I watch my four-year-old grandson “become” a “scary monster” one minute and a “train” the next. Fearlessly and with great physical, emotional, and intellectual energy, he works out what interests and obsesses him, and he doesn't want to stop until he gets it right. This is the seed from which art grows; the need is to articulate and give form to what is of greatest interest. Far from the binary “right and wrong” answers called for in our current test driven education systems, the passionate creative act has more than one “right” answer, is subjective, and exceedingly difficult to assess.

Our culture is replete with the stories of struggling artists whose success came after they left conventional society, and when our children tell us they want to be artists, who among us is not initially taken aback with the image of the obsessed, failed artist. And yet, it is this drive, this passionate need to create, to solve the problem and to give it form that is ultimately of highest value in a creative society.

The recent death of Steve Jobs (a creative genius although not an artist in the strict sense of the word), sparked praise and mourning for a man whose obsessive drive to create resulted in dramatic aesthetic changes in technology that affect all of us. While in the throes of his creative journey, Jobs persisted in seeing his ideas take shape and form, and his standards were notoriously obsessively high. He was, as all artists are, persistent in his pursuits, driven by something other than money and fame, both of which he had in excess. We say we are inspired by Jobs and people like him, and we revere the work of great artists not only for the persistence of vision that formed the crucible for their creations, but also for the way they change our lives and add to our experience of being human. We honor the fruits of their obsession, though we may be afraid of this quality in ourselves. And yet, to tackle the daunting problems that face us will take extraordinary creativity, perseverance, and vision. And it will involve the same sort of risky out of the box thinking that artists understand and embrace in their work.

21st Century Arts Education Challenges

When we allow students to experience deep and authentic arts education, we afford them a place to put the tremendous energy that fuels them, and to go to levels of engagement that encourage a love of learning that transfers to subjects other than the arts. When students are taught technique, both in the visual and performing arts classes, they are given a palette and a lexicon with which to paint, dance, sing, and act out their feelings and individual creative voice. The parts of our brain that process emotion are integral to processing the creation and appreciation of the arts—connecting us not only to our own feelings but also to empathic feelings for others. While certainly not all students will grow up to be artists, many will become educated consumers of art and their lives and communities will be richer for it. And some will be artists, and they will take their place in the long line of creators who go back to the caves and who define the cultural history of our species.

At any age, when we are disengaged we cannot learn, and are not motivated to solve problems or to create. While obsession may be dangerous at some levels, a little bit of it may be what drives us as human beings to fearlessly tackle the big ticket issues and problems that face us. Obsession and the obsessive drive to create may be qualities we need to redefine and value as we search for ways to re-engage and create new solutions to sometimes seemingly insolvable problems. Creative artists have never been afraid to go to the limits. Those who will take us to the next level will no doubt think as artists do, taking risks, pushing past obstacles, and doing what has previously been labeled impossible to save what we value and move us forward.

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Susan Stauter

Susan Stauter is the Artistic Director of the San Francisco Unified School District, the former Conservatory Director of the American Conservatory Theater, and the founding chair of the Los Angeles County High School for the Arts Theatre Department. Among the organizations she has consulted for are Disney Entertainment, the Grammy Foundation, and The New World Symphony Orchestra. Ms. Stauter is a lead trainer for the Leonard Bernstein Artful Learning School Reform Model and a frequent keynote speaker and advocate for arts education.

Comment by David Burrowes

I very much like what this says. And I think the early point, about the disconnect between the importance of arts in our society versus what we teach in school is one that I think deserves much more attention!

David Burrowes, computer programmer and computer consultant.

Comment by Rebecca R. Burrill

I like the idea about obsession combined with "the need to articulate and give form to what is of greatest interest" to the creating artist.

Rebecca R. Burrill, educational therapist, movement educator, dancer, and visual artist.

Comment by Ann Lathrop

This is a passionate and persuasive plea to return strong support for arts education to our K-12 schools. Cuts in the past ten years have been draconian and both out students and our culture are the losers. I only wish the "powers that be" in education would read this article!

Ann Lathrop, Emeritus Professor, California State University, Long Beach, CA.

Comment by David Moursund

I fully agree with Susan Stauter's assertions that we are doing students, our educational system, and our society a major disservice through down playing and/or dropping the fine and performing arts from the school curriculum. Such changes in our educational system reduce the opportunities for students to "do" and to experience success, pleasure, and flow in the doing.

You probably remember the quote: "All work and no play makes Jack a dull boy." As I read Susan Stauter's article I attempted to draw a parallel between what she is saying and the "dull boy" statement. Throughout my life I have focused strongly on personal growth in the science, technology, engineering, and mathematics areas. Although I have enjoyed my exposures to the fine and performing arts, I have not spent much time cultivating my knowledge and appreciation of these areas.

Susan Stauter's article made me think about areas in which I developed compulsive, creative talents. The "flow and creativity" that Mihaly Csikszentmihalyi researches and writes about have been important parts of my life.

Csikszentmihalyi, Mihaly (1997). *Finding flow: The psychology of engagement with everyday life.* New York: Basic Books.

For me they have come through research, computer programming, working with spreadsheets, computer games, writing, teaching, and giving professional talks.

At the current time, our educational system is being driven by competitive forces that have the flavor of a military industrial complex. This is not pleasing to me. See Dwight D. Eisenhower's 1960 speech on the military industrial complex at http://coursesa.matrix.msu.edu/~hst306/documents/indust.html.

Article 9

[IAE Newsletter #82. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-82.html.]

Creating an Appropriate 21st Century Education: Taking Cognitive Neuroscience Beyond Education

Bob Sitze
Religious Program Consultant/Author

This article invites you to participate in the ever-expanding influence of cognitive neuroscience into every nook and cranny of civilization. I believe this is "what's next" for applied neuroscience. My thesis is simple: we brain-savvy educators have the responsibility to take what we know and make it useful within our additional societal roles.

Some Necessary Background

I write from a personal history of over thirty-five years of observing the expansion of neuroscience into our society and its cultures.

During the 20th century, I was an elementary school teacher and principal, looking for answers to questions that my educational psychology professors had wisely left unanswered. The first glimmers of brain science—stress, endorphins, right/left brains—were compelling and useful in my work. I kept reading and trying to make sense of this developing science. As my career morphed into other arenas in which "learning" was an essential element (or at least a guiding metaphor) I increasingly discovered the value of neurobiology for understanding how the people I served could best achieve their most-desired yearnings for purposed lives.

Self-disclosure: I'm a church guy. Except for the years I worked as a meat cutter and job-trainer, I have been employed by religious enterprises. I've worked in parochial schools, served as a church musician and youth worker, written and edited religious curricula, and developed large-scale programs for a large-scale denomination. I've conducted countless workshops all over the country (and stayed awake during most of my presentations).

All this work was oriented towards the well-being of congregations as purposed social systems. Throughout several decades of leadership at the denominational level, I tried to find ways to integrate neurobiology into "organized religion." When I finally gathered enough experience and insights, I wrote a 21st century book about the subject, *Your Brain Goes to Church: Neuroscience and Congregational Life* (2005). I started calling myself a "neuro-ecclesiologist," at first just a way to tickle folks' curiosity, but later as a fairly accurate description of my lifework. I fortunately found a quiet (but growing) cohort of other church leaders who were also searching for appropriate and necessary applications of the brain sciences to our work.

We were helped by the emergence of the intriguing field of neurotheology (http://en.wikipedia.org/wiki/Neurotheology) and its explorations of the neurobiological underpinnings of such theologically relevant phenomena as prayer, mediation, glossolalia (speaking in tongues), consciousness, and free will. The IAE Newsletter has recently published articles on this type of research (see *Resources* below), and several recent acclaimed books by such renowned cognitive neuroscientists as Michael Gazzaniga (2011), David Eagleman (2011), and Daniel Kahneman (2011) are expanding the societal knowledge base and interest level.

What I Learned Along the Way

Cognitive neuroscience sadly still holds only a precarious perch in churchly enterprises. Because neurobiology easily trends towards metaphysical matters—part of the imagined province of institutional religion—some religious leaders are reluctant to absorb neuroscience discoveries into their thinking and integrate them into their behavior. Others even seem purposely clueless about any kind of science—and neurobiology may especially threaten the doctrinal card-houses they build around themselves. The result? The organized church has a very limited understanding of even the most basic neurobiological knowledge. Few religious leaders routinely seek the wisdom that the cognitive neurosciences could provide to help them answer some of their more vexing questions.

For example, when fear embeds itself into the identity and life of a parish, understanding the biology of fear won't solve the specific problem. But realizing that an underlying (amygdala, cortisol, fight/flight/freeze, etc.) biology exists can lead the congregation to explore ways in which it can avoid becoming a hatchery that breeds fearful people instead of a group committed to the theological/scientific truth, "Perfect love casts out fear."

Over the years I have thus been insistent about the neurobiological foundations of what we do in churches. (Brains *do* go to church!) But I have also encountered pushback. With so many other fish to fry, most religious leaders seem to prefer to behave as they have always behaved, believe what they have always believed, and ignore what they have always ignored. Even though the cognitive neurosciences could easily be applied to the workings of churches, it still hasn't happened in any significant way.

Where This Leads

This has brought me to wonder about other large-scale enterprises within society that we encounter. Although forward-thinking business and political leaders regularly apply neuroscience discoveries to their work, is it possible, for example, that most philanthropists, non-profit and volunteer organization leaders, civil servants, and parents are (like religious leaders) unaware of the utility of brain science to their work? Could they also feel threatened by the implications of neurobiological research? Might they also increasingly discover better questions and answers in the brain sciences that would enrich their leadership?

We educators have been among the first cohorts of societal leaders to put neurobiology to good use. Even though we have disagreed about particulars, we haven't for several decades doubted the educational usefulness of neurobiology. Educational leaders who now ignore the brain sciences do it at their professional peril.

So here we are—you and I—deeply embedded with the extraordinarily helpful findings of cognitive neuroscience. We know how it helps learners of any age.

And what we know about cognitive neuroscience could be useful beyond narrow notions of "education." If we see "learning" as a metaphor for something larger within human consciousness, we also know a lot about how people change. If we can discern how language is formed, we can also determine how to improve communications. If we have discovered how children use brain-savvy strategies to encounter their world, we also know how to help leaders understand the minds of their followers. If we have seen what engenders teens' self-esteem, we also know what might constitute a rich and rewarding workplace environment. If we can demonstrate how continuing stress physically diminishes brains, then we also know how toxic relationships diminish organizations. We probably know more than what we think we do.

The Challenge

If my experiences as a neuro-ecclesiologist are any clue—and if I'm correct about what you already know—then I think this challenge is worth your consideration: It's time that you take what you know about the workings of the human brain and apply those insights to other arenas of human enterprise.

Think of all the places where you have personal influence and all the ways in which you can affect change beyond your primary role as an educator. What organizations are you part of? Toward which larger societal movements—e.g., justice—do you contribute? In what informal groups is your voice important? Where do you volunteer? In addition to other educators, who reads what you write? In what other arenas of life are you an acknowledged leader?

In any of those roles, you have the opportunity to apply fundamental neurobiological truths to the greater good. Where do fear and anger need to be diminished? How can organizations work smarter and actually consider the brains of those they claim to serve? How can you help counteract the machinations and manipulations of people who use cognitive neuroscience discoveries for less-than-admirable purposes? Which thinking and decision-making processes could you teach to others?

Finally

Given the recent progress (or devolution) of our society, I don't think it's defensible for us to keep to ourselves what we know to be true and practical. Although more than enough challenge exists within the educational enterprise, we have a responsibility to the greater society to infuse the increasingly wonderful discoveries of the brain sciences into every human enterprise.

I'll be working at this from a church guy perch. I hope you find your own place and work your own neuro-wisdom into that situation.

For the good of the people you serve.

Resources

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Bob Sitze

Bob Sitze works as a congregational consultant and writer. His books have been published by The Alban Institute (http://www.alban.org). He blogs about simple living at www.thelutheran.org/blogs/simpleenough. He lives in Wheaton, Illinois, with his first-grade teacher spouse Chris and a very smart dog.

Comment by David Moursund

Many years ago I was browsing in a used book store and came across a book by Everett M. Rogers that was selling for one dollar. Here is a citation for a more recent edition of the book:

Rogers, E.M. (2003). *Diffusion of innovations.* 5th ed. Simon and Schuster.

This was probably the single best buy of my lifetime in terms of improving my education! In brief summary, the book explores the pattern of adoptions for new products and ideas.

A new idea and/or process is introduced to a society or more limited group of people. In this article by Bob Sitze, the innovation is cognitive neuroscience. The innovation might be a cell phone, a laptop computer, or doctors using sterile conditions when doing operations on patients.

Early adopters jump on the bandwagon. They might be about 10 percent of the people who are introduced to the innovation at a level where they have some understanding of it. If the innovation catches on, over a period of time the middle adopters—perhaps up to 80 percept of potential adopters—come on board. The remainder of potential adopters may never become adopters.

There are some situations in which the widespread acceptance of an innovation occurs rapidly. As television became commercially available, potential buyers could easily "see" the benefits of owning the product. TV was an at-home extension of the movies they had previously viewed in theaters.

Operating under sterile conditions is a more complex innovation and targets a much smaller potential set of adopters. Adoption takes reasonable insight into how disease-causing pathogens do their nasty things. The idea of germs eventually spread from physicians to the whole population—"Wash your hands before eating."

Cognitive neuroscience has been adopted as a legitimate and highly productive area of research among those who are interested in brain science research. We are well past the early adopter stage for this new discipline. What Sitze is focusing on is the potentials for widespread understanding and adoption of cognitive neuroscience ideas by a larger section of the general public.

The idea of washing your hands before meals and covering a sneeze with a tissue certainly spread beyond the medical profession. It takes relatively little understanding to appreciate that disease-causing pathogens are easily spread. However, compare this with our growing understating of cognitive neuroscience. What level of knowledge and understanding do people need to have in order to apply progress in this discipline to their own lives and their interactions with others?

When this question is asked in the realm of educational curriculum content, teaching practices, and assessment we can easily see the challenges. What do we want individual teachers and our overall educational system to be doing in translating the cognitive neuroscience research into effective educational practices? Sitze's article provides good advice on this question.

Article 10

[IAE Newsletter #83. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-83.html.]

The Top Ten Reasons Why Humor Is FUNdamental to Education

Mary Kay Morrison
Humor Quest

> Today's mighty oak is just yesterday's nut that held its ground.
> (David Icke; English writer and public speaker; 1952–.)

Humor is just the fertilizer needed to nurture stressed kids and anxious educators as they cope with the cognitive and technological revolution that is shaping 21st century education. Humor is rarely looked at as an essential part of student growth or as a credible teaching technique. However, a review of neuroscience research indicates that healthy and positive humor can have a significant impact on student learning. The purposeful cultivation of humor practice nourishes both effective teaching and learning!

Here are ten reasons that flourishing educators purposefully choose humor as an essential teaching strategy:

10. **Humor plants memories**. Powerful emotions are at the root of long-term memory. Ask your students what their strongest memory of school has been so far. Have them categorize how they felt about this experience by charting these memories as either joyful or anxiety producing. Encourage students to think about why they remember this incident. Discuss how they can use humor (a strong emotion) as a device to help them remember information. When The Memory Goes–Forget It!

9. **Humor grows coping skills**. Humor has often been used as a survival technique for prisoners of war. Educators need to survive constant change with new mandates and testing requirements coming frequently from policy makers and legislators. There are numerous "survival" issues in education today! Some research indicates that laughter increases adrenaline, oxygen flow, and pulse rate. After laughter, most people report feeling relaxed and calm. No Sense Being Pessimistic, It Wouldn't Work Anyway!

8. **Humor cultivates energy and engagement**. The traditional auditory lecture is one of the least effective ways to facilitate learning. Purposeful games, directed play, and physical activity all promote humor and learning. The research on the benefits of movement and learning supports the idea that play and laughter increase the oxygen levels and energy that are critical for learning. Energizer Bunny Arrested; Charged With Battery!

7. **Humor captures and retains attention**. Laughter and surprise can hook even the most reluctant student. "Emotion drives attention and attention drives memory, learning, problem solving, and behavior" (Sylwester, 2003). The brain cannot learn if it is not

attending. Humor generates something unexpected, which alerts the attentional center of the brain and increases the likelihood of information recall. It can be integrated into all aspects of the learning process as described in the *Educators Tackle Box in Using Humor to Maximize Learning* (Morrison, 2008). The purposeful use of humor is a skill that can be practiced and enhanced. A favorite follow-up strategy is to invite the students to read a section of the lesson and create a joke or riddle about that segment. Some of these can be used in the actual test for the chapter. Lost In Thought–It's Unfamiliar Territory!

6. **Humor neutralizes stress**. Humor will decrease depression, loneliness, and anger. The contagious nature of laughter is caused by mirror neurons—brain cells that become active when an organism is watching an expression or goal-directed behavior that they themselves can perform. If you see someone laughing, even if you don't know the reason for the laughter, you will probably laugh anyway. The imitative behavior is due to mirror neurons being stimulated. Stress levels have been increasing for both students and teacher. Laughter is contagious. Catch it! Spread it! He Who Laughs–Lasts!

5. **Humor is the #1 Characteristic Students Value in a Teacher**. They may not remember what you taught, but they will remember your sense of humor and the relationships produced in the classroom. Build a Humor Haven in your classroom filled with joke, riddle, and humorous storybooks. Depending on the age of your students, you can add clown noses, squish balls, games, and puzzles. Make Their Day—every single day with laughter and fun. It will make your day too! What Would Scooby Do?

4. **Humor enhances creativity**. The employment market has transitioned from agriculture and manufacturing jobs to positions requiring ingenuity and inventiveness. Humor promotes creativity and critical thinking skills. Often humor comes from unconnected, random thoughts. Grow creativity through laughter yoga, telling funny stories, or playing games. Do Not Disturb, I Am Disturbed Enough Already!

3. **Humor facilitates communication**. Humor is a great way to build relationships with students, colleagues, and parents. Understanding your humor style will assist your humor practice. Humor is a social lubricant. It has the power to generate a culture of trust in your organization. If you understand and nurture a constructive humor style, it will positively impact your ability to communicate. Humorous interaction between coworkers encourages a healthy, productive work environment. A Closed Mouth Gathers No Foot!

2. **Humor supports the change process**. Educators are faced with change on a daily basis. When you can laugh about new mandates or disruptive behavior issues, you know you are able to cope with these challenges. Plan for how you and your colleagues will use humor to cope with new standards, testing, or stressed kids. A great strategy is to create a top ten list of "What's So Funny" about the upcoming change. Change is Good–You Go First!

And now for the number one reason to laugh frequently and often….

1. **Humor Is FREE and FUN**. Teaching is a joyful experience. The current focus on accountability and data-driven instruction can bury our sense of humor—driving it underground. Dig around for humor resources to share with your students and

colleagues. Do not let anything rob you of your passion for bringing joy to your students. Remember, a sense of humor is free and fun! I Want to Live Forever–So Far So Good!

Hold your ground when it comes to your beliefs about how to plant the seeds of learning in your workplace. Weed out the humordoomers and their negative comments. Do not give them the time or energy required to creep into the culture of learning in your environment.

Nurture the nuts in your care. Nurture your own sense of humor, by spending time in developing and growing your humor practice. Consider keeping a humor journal, spending time with colleagues who make you laugh, and purposefully including humor in every lesson every day. Carefully cultivate your humor being to fully share the abundance of joyful teaching. Remember humor is a fundamental factor in the cognitive/technological revolution that needs to shape 21st century education.

Never Take Life Too Seriously–You Won't Get Out Alive!

Resources

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Mary Kay Morrison

Mary Kay Morrison is an independent consultant who works in the field of humor in education. Ideas for improving your humor practice can be found in Mary Kay's book, *Using Humor to Maximize Learning; The Links between the Positive Emotions and Education.* For links to the research supporting the use of humor in learning, please go to Mary Kay's links page on her web site http://www.questforhumor.com/. Check out her blog *Choosing To Teach With Good Humor*. Mary Kay serves on the board of AATH (Association for Applied and Therapeutic Humor) http://www.aath.org/ and was the *Humor: No Laughing Matter Conference* co-chair. Contact Mary Kay at marykay@questforhumor.com.

Comment by Irene Chaya Shapiro Doniger

Wonderfully written article. Information with a chuckle and a smile. The best way to learn and retain something. Thanks Mary Kay.

Comment by James R. Gilbert

As an instructor for an educational graduate course "Wellness: Creating Health and Balance in Today's Classroom," for the Regional Training Center, we often talk about how important humor is. In fact, I talk about it in "Cooperative Discipline" as well.

Comment by Jim Winter

Terrific article! And just in time. Educators need to be reminded this humor stuff is serious business. These are the ideas people can use to "convince their committees" that humor training is a big plus for a professional learning community of any sort. Thanks for your constant advocacy for this dear humor profession!

Comment by David Moursund

Over the years I have been so delighted by Mary Kay Morrison's work on humor that I created a Web page on humor in the iae-pedia. See http://iae-pedia.org/Using_Humor_to_Maximize_Learning. Besides featuring Mary Kay's work, the page includes the following riddle:

> Riddle: What is the longest word in the English language?
>
> Answer: Smiles, according to an old riddle, may be considered the longest word in English, as there is a mile between the first and last letter. A retort asserts that beleaguered is longer still, since it contains a league. The riddle and both jocular answers date from the 19th century. See http://en.wikipedia.org/wiki/Longest_word_in_English.

Many people have developed computer programs that generate jokes. Some of the jokes are even funny—at least to some people. Here are three examples of computer-generated jokes.

> "What do you get when you cross a frog with a street? Answer: A main toad."
>
> "What kind of tree is nauseated? Answer: A sick-amore."
>
> "What do you get when you cross a degree Celsius with a water? Answer: A high c." See http://www.abdn.ac.uk/jokingcomputer/home.shtml.

The first of these three jokes seems funny to me, but I don't "get" the other two. The quality of this humor suggests some of the difficulties of developing artificially intelligent computer systems that can communicate effectively with people. What makes a joke funny to some people and not to others? Can one develop a computer program that can determine how funny a (supposed) joke is, or what types of people will think it is funny?

Learn more about computer programs that can carry on a conversation—with the human providing input via computer keyboard and the computer displaying responses on a computer output device at http://en.wikipedia.org/wiki/Chatterbot.

Article 11

[IAE Newsletter #84. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-84.html.]

Using Computers to Translate Educational Theory into Practice

David Moursund
Emeritus Professor of Education
University of Oregon

I taught in the College of Education at the University of Oregon for many years. This College of Education is a powerhouse in educational research.

My major teaching duties were teaching computer education courses to preservice teachers who already had extensive educational coursework. I also taught many inservice teachers. With each new batch of students, I liked to start out by pointing out the hundreds of educational research studies and papers that have come from the UO, and that this is a very small percentage of nationwide and worldwide educational research. I would then pose the following question for class discussion:

> Give examples of educational research that has made a significant difference in the quality of education of the types of students you are preparing to teach or have taught.

I was always disappointed by the paucity and quality of answers. My students did not seem to think in terms of how education is being improved by educational research and translating this research into effective, everyday teaching practices.

My further probes indicated my students had little insight into roles of computers in the theory-into-practice translation process.

Theory Into Practice: A Personal Example

A number of years ago one of my grandsons and his parents were living in my home. At the end of the second grade this boy's report card indicated he had made no progress in reading during that year. The teacher recognized that something was amiss, but lacked specific knowledge about what it might be.

Somewhat by luck and happenstance, my summer reading for that summer included Sally Shaywitz's book *Overcoming Dyslexia* (Shaywitz, 2003). As I read the book, I soon decided that my grandson had dyslexia. Subsequent testing indicated he was severely dyslexic. It took a long time to get the school to take action. The eventual intervention included about an hour a day of one-on-one help from well-trained and educated specialists. I am happy to report that recently my grandson was inducted into a high school National Honor Society and is now well prepared to go on to college.

This is a good example of translating educational research theory into practice. My grandson's grades K, 1, and 2 teachers did not recognize his dyslexia problem. And, once informed of this learning disability, the school system was slow to mount a strong intervention. The Individual Education Plan (IEP) planning process and implementation were slow and did not initially commit the necessary resources. Fortunately, I knew the right people in the school district leadership, and the end result was good.

This example illustrates a major challenge in our educational system. In summary, the challenge consists of:

1. Early detection of a (potential) problem.
2. The time, energy, and other resources to learn more about the problem.
3. The existence of previously done high-quality research that has focused on the problem and provided a foundation for the production and wide dissemination of effective methods for detection and solution.
4. High fidelity implementation of a solution. There is also the issue of cost effectiveness. Our overall educational system has limited resources and so must balance the use of these resources among many different worthy demands.

Wide Scale Detection and Solution

It is my opinion that my grandson's dyslexia problem should have been detected by his grades K or 1 or 2 teachers, and he should have immediately been referred to a specialist.

Recently I have been reading about dyscalculia, another widespread learning difficulty. Roughly speaking, dyscalculia is to learning arithmetic as dyslexia is to learning to read. The comorbidity of these two learning disabilities is about 60% (Mills, 2011). Both dyslexia and dyscalculia strongly affect perhaps six to eight percent of the population. Both can be detected at an early age. Quoting from Mills (2011):

> …about 60% of those diagnosed with either dyscalculia or dyslexia have the other condition as well. Further, it was already known that dyslexics had significant problems with math as well as with reading. Landerl's studies, however, showed clearly that the two conditions, dyscalculia and dyslexia, had completely different cognitive profiles and the symptoms were *additive* in the combined ("co-morbid") group. This suggested strongly that the two conditions affected different brain centers.

Dyslexia has been much more thoroughly studied than dyscalculia. Multi-sensory interventions have proven successful. Uses of computers range from providing dyslexic students with a word processor having a good spelling checker (see http://www.dyslexia-parent.com/oregon.html) to use of computer software designed to help "rewire" the brains of poor readers (see the work of Nadine Gaab described at http://www.youtube.com/watch?v=mG8pZx9O-y8).

Wouldn't it be nice if cognitive neuroscience researchers could identify the specific brain area associated with dyscalculia and develop interventions that would alleviate the problem? The good news is that this has been accomplished.

Early research is summarized in (Attridge et al., n.d.). Quoting from that source:

> There is evidence that humans and some non-human animals have an innate Approximate Number System (ANS) that allows us to rapidly, but only approximately, represent numerosity. Children and adults appear to use these representations to compare, add and subtract non-symbolic quantities with above-chance accuracy.
>
> Furthermore, it has been suggested that the ANS may be the basis of formal mathematical ability in humans, and a relationship between individual differences in ANS acuity and mathematical ability in children has been demonstrated. Following from this hypothesis, interventions have been designed to strengthen the relationship between ANS representations and symbolic number representations in children, with the hope of improving their mathematics skills.

Mills (2011) presents more recent research on the detection as well as success of computer-based interventions. He also reviews various poorly designed and/or poorly implemented interventions.

Intelligent Computer-Assisted Learning

We know a great deal about reinforcement schedules in learning, immediate feedback, wait time in accepting student responses in teaching, study skills, and so on. However, consider the challenge of training/educating millions of current K-12 teachers to implement such ideas with high fidelity. It is clear to me that our current preservice and inservice teacher education system is not up to this task.

However, such research-based practices can be implemented in well-designed computer-assisted learning systems. Modern systems of this sort are often called Highly Interactive Intelligent Computer-Assisted Learning (HIICAL) systems. In a variety of teaching environments such systems are proving to be considerably more effective than traditional teaching by traditional teachers (Moursund, 2012).

This educational progress is based on our increasing understanding of the capabilities and limitations of human and computer brains (Moursund, 2011). High quality HIICAL is not a magic drug (like an antibiotic) that cures some diseases. However, HIICAL is gradually becoming the tool of choice in a variety of educational and training situations.

Final Remarks

Good progress is occurring in educational neuroscience (Sousa, 2010). I have mentioned a few areas in this IAE Newsletter in which computer technology can help to solve some major educational problems.

Generally speaking, educational improvement interventions that are partially or fully computerized lend themselves to:

1. Easy gathering of data during the intervention process.
2. Incremental improvement based on an analysis of the intervention process data.

Of course, data gathering about summary results and long-term residual impact face the same problems that researchers face in dealing with non-computerized interventions. Information and Communication Technology is not the "be all end all."

As an example, consider stress related to growing up in poverty and other challenges students face in and outside of school. Merely providing students with computers to use at home and at school does not address such sources of stress.

Or, consider what we now know about roles of good diet and adequate exercise as they relate to the human brain. While computers may help a little in this diet and exercise area, they are far from being a solution.

Resources

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David Moursund

David Moursund earned his doctorate in mathematics from the University of Wisconsin-Madison. He taught in the Mathematics Department and Computing Center at Michigan State University for four years before joining the faculty at the University of Oregon.

At the University of Oregon he taught in the Mathematics Department, served six years as the first Head of the Computer Science Department, and taught in the College of Education for more than 20 years.

His professional career includes founding the International Society for Technology in Education (ISTE) in 1979, serving as ISTE's executive officer for 19 years, and establishing ISTE's flagship publication, *Learning and Leading with Technology*. He was a major professor or co-major professor of 82 doctoral students. He has presented hundreds of professional talks and workshops. He has authored or coauthored more than 60 academic books and hundreds of articles. Many of these books are available free online. See http://iae-pedia.org/David_Moursund_Legacy_Fund.

In 2007, Moursund founded Information Age Education (IAE), a non-profit company dedicated to improving teaching and learning by people of all ages throughout the world. See http://iae-pedia.org/Main_Page#IAE_in_a_Nutshell.

Comment by Ann Lathrop

I am intrigued by the introduction of "dyscalculia" into my vocabulary. This is a new word and a new concept for me. I thought immediately of one of my young friends who is struggling with math, wondering if there is help here. I will search for more information on ANS and dyscalculia, and will appreciate any comments of suggestions from other readers of this newsletter.

Ann Lathrop, Emeritus Professor, California State University, Long Beach, CA.

Afterword by David Moursund

My article does not speak specifically to the overall area of assistive technologies.

> Assistive technology or adaptive technology (AT) is an umbrella term that includes assistive, adaptive, and rehabilitative devices for people with disabilities and also includes the process used in selecting, locating, and using them. AT promotes greater independence by enabling people to perform tasks that they were formerly unable to accomplish, or had great difficulty accomplishing, by providing enhancements to, or changing methods of interacting with, the technology needed to accomplish such tasks. See http://en.wikipedia.org/wiki/Assistive_technology.

Curb cuts in sidewalks are often cited as an example of assistive technology that has assisted a much broader population than had originally been imagined. Think about voice input to a computer. There are lots of people who lack the finger and hand skills mobility/dexterity to use a computer keyboard. Voice input is a great aid. However, think about the much larger number of people who lack keyboarding skills, or want to do computer input while their hands are engaged in other activities.

Voice input certainly raises some interesting educational questions. For example, what roles might voice input play in young students learning reading and writing? How about voice input (or just keyboard input) for students whose cursive writing is slow and perhaps nearly illegible? Cursive writing is slowly disappearing in our society. Might voice input eventually replace most cursive writing, hand printing, and keyboarding? What are the advantages and disadvantages of voice input versus hand writing or keyboarding? These are challenging research and philosophical questions.

Research and development in artificial intelligence is making steady progress in developing aids to a human brain. This article talks about Highly Interactive Intelligent Computer-assisted Learning (HIICAL). However, I am sure you have heard Marshall McLuhan's statement that "The medium is the message." The HIICAL systems that students interact with are in some sense "smarter" than the students within the narrow area of the topic being studied. The HIICAL medium will grow in breadth, depth, and (artificial) intelligence. What should students be learning to do without the use of this medium, and what should they be learning to do with this medium as a readily available aid? These are deep and challenging research and philosophical questions.

Article 12

[IAE Newsletter #85. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-85.html.]

The Issues of Consciousness and Free Will: Part 1

Robert Sylwester
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The human conceit, long fueled by theology, philosophy, psychology, education, and law is that we're basically independent agents. We function principally on the basis of consciously directed reason and logic—something we call free will.

Well maybe. But think back to last night or the night before when you needed but couldn't get a good night's sleep because your brain was having an extended inane conversation with itself. How successful were you in consciously telling it to "shut up already and go to sleep"?

Initial widespread public awareness of the shift in scientific opinion on the issue of free will was fueled by the publication of two widely read and acclaimed books, Jeff Hawkins and Sandra Blakeslee's *On Intelligence* (2004) and Malcolm Gladwell's *Blink* (2005). Three 2011 books for general readers by internationally renowned cognitive neuroscientists have now added to the growing scientific belief that we're perhaps not as consciously autonomous as we formerly believed.

This article will focus on Michael Gazzaniga's *Who's in Charge: Free Will and the Science of the Brain* (2011). The next article in this series will explore the cultural applications of the underlying cognitive systems that regulate decision and response, focusing on *Incognito: The Secret Life of the Brain* by David Eagleman (2011). A later article will focus on the widely acclaimed book by Nobel Laureate Daniel Kahneman, *Thinking, Fast and Slow* (2011).

Who's in Charge?

Gazzaniga clarifies his basic position early. *We* are not the boss of our brain. If it wants to chat with itself when we really need to sleep, it will chat. Like the Internet, our brain doesn't have a boss. Further, who is the "I" who wants freedom of action? Are individuals in a mechanistic universe who are members of a social species really *free* to do whatever they want to do? And if I want that freedom for myself, am I willing to grant it to a cab driver who prefers to drive somewhere other than where I want to go?

Gazzaniga has written an often light-hearted book about a serious perplexing issue. The first half is an excellent non-technical functional introduction to our brain, woven into the story of the development of the cognitive neurosciences as only a true pioneer can tell it. He was a graduate student in Roger Sperry's lab when Sperry was doing the transformative split-brain research that would lead to his Nobel Prize. Gazzaniga designed many of the imaginative initial studies on the split-brain patients.

Brain Organization

The organizational perspective that eventually emerged is that our brain is composed of an enormous number of highly interconnected networks (or modules). Each processes a very specific task, such as to recognize a vertical line or a specific tone, or to bend the left index finger. Initial fragmented sensory/motor information becomes integrated as it moves hierarchically through the relevant brain systems to produce emergent properties that are greater than the sum of the initial activations. Thus, shapes, colors, and textures combine to become a face; individual sounds become melodic sequences that then become a song that emerges from a vocal system and face.

The large deeply folded sheet of cortex at the top of our brain is divided into two hemispheres that are connected by a massive fiber tract (the corpus callosum) that was severed during split-brain surgery to reduce intractable epilepsy. Gazzaniga discovered that the two hemispheres process different kinds of tasks, and function differently.

Goldberg (2009) has proposed that the fundamental hemispheric difference is that our brain must of necessity use different strategies to process novel and familiar tasks, and that the right hemisphere (in most people) seeks to understand novel challenges and develop creative solutions, while the left hemisphere recognizes familiar challenges and activates established responsive routines. Language is processed principally in the left hemisphere because it's an efficient established communicative system.

Our conscious rational brain is thus equipped to recognize and respond to both the novel and familiar challenges that we confront. Although the constant chaotic sensory input into our brain is rapidly processed at a subconscious level, our (avoid, approach, or delay) response is unitary and feels conscious. Gazzaniga has proposed the intriguing concept of a left hemisphere *Interpreter* that creates a single, unified, coherent response out of the massive sensory input and memory retrieval. The narratives that emerge out of decision and action create our sense of self and the beliefs that bias our future decisions.

These discoveries intrigued many educators who then began to read the growing literature for general readers. Seeking practical applications, they often made claims that went beyond what the research had discovered. Well, scientists don't always get it right initially either, but by the beginning of the 21st century scientists and educators had developed a functional understanding of our brain and cognition, and educators were developing credible applications.

Bob Sitze's article in this book reports that theology and other fields had ignored or even became hostile to what was occurring. Thus generally uninformed, they will now have difficulty in getting up to speed in interpreting and applying neuroscience discoveries that relate to their field—issues such as free will.

Free Will

The clean, crisp, authoritative exposition Gazzaniga presents in the first half of the book becomes tentative as he jumps into the murky waters of consciousness and free will, which weren't originally scientific constructs. The cognitive neurosciences began to seriously explore their underlying neurobiology towards the end of the 20th century when Nobel Laureate Francis Crick (1994) suggested that advances in research technology now made such explorations possible (http://en.wikipedia.org/wiki/The_Astonishing_Hypothesis).

In a determinist era during which many deny the existence of free will, Gazzaniga argues that free will in humans is possible because the rules that regulate things at one level don't necessarily apply to subsequent levels. For example, quantum mechanics governs atoms and Newton's laws govern objects, and one set doesn't completely predict the other. That molecules don't exhibit free will doesn't mean that humans and societies can't.

Consciousness is a property that emerges out of the interplay of a constantly shifting multitude of specialized systems, and the thalamus seems to play a central role in this integration. Consciousness provides us with a unified sense of self, a personal subjective awareness of our existence and of the environment we inhabit. It thus abandons us during sleep and magically reappears when we awaken. And when we're conscious, we not only know something, but we know that we know it.

The issue of free will in conscious problem solving begins with the nature of problems. Factual problems have a single correct response, such as 6 x 5 = 30 or Salem is the capital of Oregon. The other kind of problem permits alternative responses, such as what to order from a menu or how to get from Portland to Seattle.

A major task of cognitive neuroscience research will be to discover how automatically processed sensory input morphs into conscious moral decision and action, and the innate and cultural constraints that bias the response. Is it a response to a factual problem that draws on learning and memory, or a response to a multiple solution problem that draws on feelings and preferences? Scientists have discovered that initial subconscious processing has already biased our decision up to ten seconds before conscious systems get involved.

What parts of this subconscious bias are innately and/or culturally determined? For example, we're born with an innate ability to acquire such properties as language and a moral code, but family and cultural constraints guide us to a preferred specific language and moral code.

Free will wouldn't be an issue if we were a solitary species. Social relationships are central to the moral/ethical elements of behavior. The concept of personal responsibility is meaningless unless others are present to be responsible to. Gazzaniga suggests that five universal moral rules exist that have precursors in chimpanzee behavior: Help rather than harm others. Be fair and reciprocal in relationships. Respect elders and those in legitimate authority. Demonstrate group loyalty. Be pure in body and behavior.

Gazzaniga ends his book with a thoughtful discussion of perhaps the most complex problem humans confront, and that's how to develop a legal system that recognizes the validity of societal needs, individual responsibility, and the biological factors that can limit a person's ability to behave in a culturally responsible manner.

We're not a mindless machine, regulated solely by physically determined forces (or by a controlling deity for all that). Rather, we are the product of all the life experiences that impact our emerging self. Responsibility is thus a contract between two or more people rather than a brain property—and pure determinism is meaningless in this context.

We've domesticated ourselves over evolutionary time by punishing and even killing those who don't follow the basic moral/ethical *rules* we've developed, and so we've become a basically cooperative social species. Still, misbehavior continues, and the educational, theological, and legal communities will have to wrestle with the issue of how best to make us even more human than we currently are.

The next article in this book explores the underlying neurobiology and cultural constraints of that issue, and the role that education can play in its resolution.

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Robert Sylwester

Robert Sylwester is an Emeritus Professor of Education at the University of Oregon. He has traveled widely, presenting more than a thousand talks and workshops. He was the major professor or co-major professor for more than 60 doctoral students.

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For more information about Robert Sylwester, see http://en.wikipedia.org/wiki/Robert_Sylwester and http://www.sharpbrains.com/blog/2008/01/06/learning-the-brain-interview-with-robert-sylwester/.

Comment by David Moursund

Bob Sylwester's article explores recent research about human free will. The research suggests that so-called human free will may not be quite as "free" as we think.

Science fiction writers (and some of us ordinary folk) are concerned about the possibility that we eventually will have evil, free-willed computer systems that will take over the world and subjugate humanity. Can one compare free will of a human brain with free will of a computer brain?

I'll bet that many of you have had an experience similar to the following. I climb into my car and drive out of the driveway with a clear intent of where I am going. But, my mind wanders, and I end up driving to someplace else. It is almost as if my car has a mind of its own.

Of course, that is silliness. However, it helps to raise the question of what it might mean for a machine to have a mind of its own. Do any of today's artificially intelligent computer systems actually have a mind?

I have always been somewhat confused by brain versus mind. I have both a brain and a mind. As a computer person, I learned the analogy that a brain is like hardware and a mind is like software. That helps me a little, but still not enough. I know that a computer has a "computer brain" and I know that it has software. That does not tell me whether a computer has a mind.

Alan Turing was a pioneer in the development of computers. In 1950, he proposed a test now called the Imitation Game for people working to develop intelligent computers. The goal is to develop a computer system that can carry on a conversation with humans, a system that is good enough that humans cannot tell whether they are talking to another human or to a computer. The conversing is done by keyboard.

There is an annual Loebner Prize contest of computer systems designed to pass the Turing (Imitation Game) Test. See http://www.loebner.net/Prizef/loebner-prize.html. If a computer system could pass this Turing Test, would we say it has a mind? It seems likely that within some modest number of years (perhaps within the next decade) a computer system will pass the Turing Test. Incremental progress is occurring on a year-to-year basis. However, even if a computer program passes the Turing Test, researchers in the field of artificial intelligence will be unlikely to make a claim that this computer has a mind or has human intelligence.

The great science fiction writer Isaac Asimov developed three laws of robotics designed to protect humans from robots with Positronic brains. The three laws are:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws. See http://en.wikipedia.org/wiki/Three_Laws_of_Robotics.

In more recent years people have been trying to develop a better set of "laws" to be built into today's computer brains in order to protect humanity. See http://singularityhub.com/2011/05/10/the-myth-of-the-three-laws-of-robotics-why-we-cant-control-intelligence/.

The robots of science fiction and current reality are clashing. We now routinely make use of artificially intelligent computerized weapons to harm human beings. We want our robots and robotic weapons to obey the orders of only a select group of people—certainly they should not the orders of our "enemies." We use computerized tools to take over and perhaps damage other computerized tools. For example, think in terms of computer viruses. Clearly, the robotic field has outgrown Asimov's three laws.

Sherry Turkle has spent a great many years doing research on how computerized robot-like toys affect children. I am fascinated by her writings. See http://blogs.discovermagazine.com/sciencenotfiction/2011/02/06/the-turkle-test/. Our educational system has given little thought as to what we should be helping our children to learn about intelligent machines.

Article 13

[IAE Newsletter #86. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-86.html.]

The Issues of Consciousness and Free Will: Part 2

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My previous article, "The Issues of Consciousness and Free Will: Part 1," focused principally on the beliefs about consciousness and free will that the renowned neuroscientist Michael Gazzaniga expressed in *Who's in Charge: Free Will and the Science of the Brain* (2011). The article ended with an introduction to the dilemmas the legal, educational, and theological professions are beginning to confront because of new discoveries about our brain's decision-making processes. The basic dilemma is how to decide what changes (if any) our society should make in defining inappropriate and criminal behaviors, and in determining the appropriate societal response to such behaviors. Since social skills are central to human development and interaction, this issue is obviously educationally significant.

David Eagleman, who directs the Initiative for Neuroscience and the Law at Baylor University College of Medicine, has written an excellent non-technical book with a principal focus on this issue, *Incognito: The Secret Lives of the Brain* (2011).

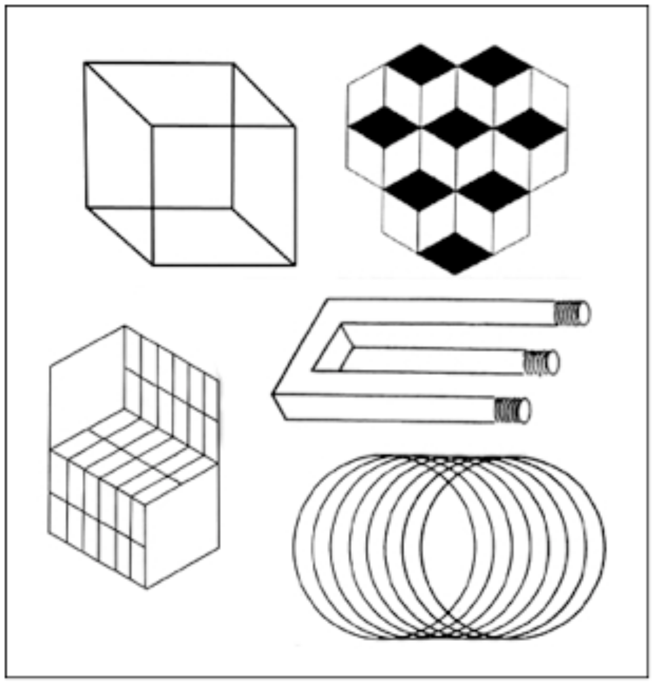
Incognito

My previous article also indicated that our brain is made up of an immense number of highly interconnected neural networks—each specialized to automatically process a very specific element of the external or internal environment. Related basic networks combine into more complex networks. Various line segments, colors, and textures can thus combine into massive networks that form the remembered image of a house.

We tend to think that we experience the totality of what's out there, but the reality is that we don't need to process every element of a familiar house in order to recognize it. All animals sample and act on only a small part of their respective environment. Honeybees, for example, access ultraviolet wavelengths and can manufacture honey, neither of which we can do. Conversely, we can gather their honey, place it in bottles, and use it in cooking—which they can't do.

The book's title implies Eagleman's belief that most of our brain's activity is hidden from conscious thought. Over evolutionary time we've been biologically programmed to automatically recognize/ignore, seek/avoid, resolve/fail most of the challenges that confront us. The automatic nature of conversation and jazz improvisation are examples. We have a conscious sense of the basic theme we're trying to communicate, but what comes out is principally the unconscious automatic flow of verbal or musical information.

Our brain networks occasionally confront competing information, such as in optical illusions that require a conscious resolution. Consider the common set of illusions (below) in which we consciously try to determine the orientation of the figure.



When a brain's challenges reach a certain level of complexity, it needs a relatively small but powerful conscious system to direct the huge number of evolved automatic systems. Think of consciousness as akin to the newly hired CEO of a company that has had a long successful leadership history. Staff, technologies, procedures, etc., function automatically and efficiently for the most part. The CEO's basic job is to monitor the automatic systems, to identify immediate and long-term goals that the automatic systems will carry out, and to take over in emergencies when the existing automatic (rule-bound) systems can't resolve a challenge. In my previous article, I indicated that Gazzaniga used the term *Interpreter* to identify this core element of our conscious brain system.

Cultural Constraints

We're a social species, so although our conscious system plays an important role in controlling our individual behavior, our species survival requires cooperative behavior. We thus evolved deeply embedded cultural rules and policies that help resolve disputes quickly and peacefully, even if some rules seem arbitrary. These rules were codified in such moral prescriptions as the Biblical commandments to respect elders, and to not kill, steal, lie, covet, or misbehave sexually. This was later condensed into "Do unto others as you would have them do unto you," and still later into the scientific concept of reciprocal altruism.

We seem to function with parallel moral systems, such as that killing is wrong, but it's all right to kill to protect self/kin. And just as we have a conscience to adjudicate internal conflict, we have cultural mores and a legal system to adjudicate conflicts among individuals. We're thus not completely free to do whatever we want to do without fear of censure. The continuing dilemma is whether to follow one's own desires and needs or those of the larger group. Home and school instruction and interaction (and religion for many) help to develop the requisite moral/ethical competencies.

Scientists have been exploring this dilemma through studies in which participants are asked to settle hypothetical moral conflicts—such as whether it's OK to steal to get needed food or medicine for one's family, or whether it's OK to do something that will cause the death of one person in order to save the lives of several others.

One such classic study of moral behavior is the hypothetical case of a young adult brother and sister who are traveling together. Neither is married. After a pleasant day on the road they check into a motel room. They later decide on a whim and without any coercion that it would be fun and interesting to have sex. The sister is on birth control pills but the brother gets and uses a condom to be safe. Afterwards, they decide that it was enjoyable but that they'll keep it a secret and not do it again, resolutions they follow.

When asked if the sibling behavior was OK, study participants overwhelmingly deemed it immoral and/or disgusting, but few could give a logical reason why. Are some moral beliefs so deeply ingrained that they are beyond conscious awareness? When the incest taboo emerged, societies had only a primitive (at best) understanding of reproductive biology/genetics and contraceptive technology, and the taboo was reinforced by a seeming biological aversion to sexual behavior between close relatives. Although the adult consensual siblings in the vignette knew what they were doing, and the chance of a pregnancy was remote, the taboo still exists in the minds of most people.

Similarly, the issue of same sex marriage is currently creating cultural confusion because our scientific understanding of the biological underpinnings of romantic attachment is ahead of our cultural ability to accept it.

Legal and Educational Challenges

Eagleman does an excellent job of explaining the issues confronting the criminal justice system as science is coming to grips with the reality that many criminal behaviors are more complex and biologically driven than previously believed. Our supposed free-will brain isn't the only player in determining our identity. It partners with our endocrine and immune systems, and the three are inseparable from the chemical systems (from nutrition to air pollution) that influence our development and behavior. Add in the vagaries of our complex social system, and you can see why it is problematic just which part of our personal community is the principal perpetrator who should go to jail.

Eagleman doesn't suggest that we simply forgive criminal behavior, but rather that society should begin the torturous path of trying to connect culpability to neuroplasticity, societal response to biological reality. The goal, for example, should be to place young offenders with still maturing frontal lobes into an effective residential school that will focus on developing self-control, and to place those with frontal lobe or other damage that precludes social restoration into a humane setting that will also protect society from them. Costs and recidivism would eventually decrease, and social satisfaction would increase as punishment becomes only a part of the societal resolution, rather than most of it.

Schools (and possibly religious organizations) would play an important support role in reconceptualizing the criminal justice system, since it requires a society that understands our brain and its support systems and willingness to question existing a priori assumptions.

Human biology and cognition must thus become embedded into the entire K-12 curriculum, so that students truly understand our social body/brain by the time they become voters. We now see political and marketing strategies succeed with deceptive and dishonest allegations. It's because of our low collective understanding of the underlying neurobiology of decision, behavior, and probability. The era in which our understanding of our brain and cognition was somewhat speculative is over. It's thus time to get serious about helping students develop the ability to understand their own unconscious/conscious brain, and how to assess the credibility of allegations—to know and properly respond when they're being manipulated.

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Comment by David Moursund

Our educational system fully subscribes to the need to have all children become reading and writing literate. As computers became increasingly common, the idea of computer literacy arose. Arthur Luehrmann (1931–) is best known for the large number of computer in education books he wrote, and for a 1972 article in which he introduced and defined the term **computing literacy.** Luehrmann's article, *Should the computer teach the student, or vice-versa?* was initially presented at a conference and was later published in Robert Taylor's 1980 book: *Tutor, Tool, Tutee.* See http://www.citejournal.org/vol2/iss3/seminal/seminalarticle1.pdf.

Luehrmann drew a parallel between reading and writing literacy and what we might mean by *computing literacy*. (Later the term *computer literacy* replaced the term computing literacy.) We read (use the product of writing) and we write (as an aid to our brains and an aid to communication). Luehrmann wanted students to become effective, understanding users of computers from a computer programming point of view.

Eventually this idea received widespread support. Millions of students were introduced to computer programming in the language BASIC or Logo. However, eventually this approach to computer literacy died out in our schools. Computer literacy moved in the direction of students learning to make effective use of tools such as word processors, spreadsheets, databases, email, and Web browsers.

In more recent years there has been some revival of teaching students to program in the newer graphics-oriented, highly interactive programming languages that have been developed for children. Scratch (http://scratch.mit.edu/), Alice (http://en.wikipedia.org/wiki/Alice_%28software%29), and Squeak (http://wiki.squeak.org/squeak/377) are representative of these newer programming languages.

Now we have cognitive neuroscience. What might we mean by **cognitive neuroscience literacy**? What do we want students to be learning about their brains? See, for example, http://faculty.washington.edu/chudler/introb.html and http://www.findingdulcinea.com/guides/Science/Science-of-the-Brain.pg_03.html. Is it useful for a student to understand neuroplasticity? What about understanding how serious concussions (such can occur in contact sports, bicycle accidents, and skateboarding) are? How about understanding stress and how it debilitates the brain? What about diet, exercise, and the brain?

How about robots and robotics? There has been a rapid rise of robots instruction in after school settings and competitions between teams at local, regional, and national levels. See http://iae-pedia.org/Robotics_and_Education and http://robots.net/rcfaq.html.

Computer technology has also brought with it computer viruses, greater ease in plagiarism, more identify theft, and a wide range of other crimes. Many people ask, "What's wrong with pirating electronic copies of music, video, or software? The owner still has the original." This is a new type of crime that our society has to learn about and deal with.

In closing, I must reiterate three of my favorite questions.

- What do we want students to learn about the capabilities and limitations of a human brain versus those of a computer brain?
- How should we help students learn to effectively use the combination of these two types of brains?
- What do we want students to learn about how computer technology is changing their world?

Article 14

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Surprise: It Makes Us Who We Are

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This article shows how recent advances in cognitive neuroscience equip us to form and transform students' beliefs about their own capabilities.

Boy Scout Bobby thought he was a poor speaker but instantly changed his belief to that of a courageous orator. Lillian used to think she was "cool" but she transformed her belief to "nerd" in a heartbeat. Jeremy didn't think he was "smart enough" until his teacher's comment profoundly altered that self-assessment. Each of these life-changing events took only a moment and each surprised the recipient.

Our beliefs about our world and ourselves make us distinctive. They shape our behaviors, ideas, and responses. Beliefs about self-efficacy, confidence, and self-esteem typically arise from unpredictable events (Pinker, 2003). It's not simply the events themselves but the *meaning* of the events to the recipient. Lacking context, children naturally look to others to explain appropriate responses to unexpected events (Sylwester, 2010).

Recent neurological and cognitive findings illustrate how and when beliefs are instantly formed, or transformed. We may now deliberately influence those in our care with the positive attributes and dispositions necessary to function effectively in this new millennium.

Important Context

I once went to a hypnotist's show when I was a budding teacher. "Wow!" I thought, "Now that's influence!" Hypnosis momentarily changed what people believed about themselves or their situation. I thought that hypnosis must tap into a cognitive system that creates moments of soaring suggestibility. If I could uncover that system, I could create a life of confidence and aspiration in my students. The idea of spontaneous and dramatic influence captivated me, and became my doctoral program's focus.

My research gathered hundreds of stories of influence events—moments when people instantly changed beliefs about themselves and saw their situation or themselves differently. I term these Spontaneous Influence Events, SIEs (Rousell, 2007). SIEs are instantaneous, unexpected, and the subjective meaning is based upon a cognitive perception.

Spontaneous Influence Events

Envision a young Boy Scout delivering a presentation to the parents of the Scout troop. He stumbles with the oration, becoming visibly anxious, and upon finishing sits dejected beside his parents. In a case of classical conditioning, he might develop the most common fear in North America: a fear of public speaking. Except in this case the Scoutmaster took the podium after the bumbled presentation and lauded the young man for demonstrating the courage and dedication inherent in all good Scouts, the ability to overcome adversity and steadfastly remain committed to his purpose. Disaster averted, the surprised little boy begins to grin, accepting the truth of the Scoutmaster's gracious comments (Canfield & Hansen, 1995).

The key component for an SIE is surprise. Learning instantly when surprised is part of our genetic heritage (Adler, 2008). We now also recognize *surprise* as the catalyst for instant belief formation and transformation.

Surprise Triggers Instant Learning

Surprise triggers the release of a cocktail of neurons creating a general "all alert" emotional arousal (LeDoux, 2003). During a surprise, contextual clues help the surprised person interpret this event as threatening or enticing. The Scoutmaster's remark undoubtedly surprised him, spinning his emotional response into a positive experience.

Not all life-changing moments have a positive result. Consider the following surprise anecdote recalled by a graduate student.

> When I was in fifth grade I looked up to my eighth grade cousin. To me she was perfect in every way, so naturally I tried to imitate her. That is until the day she came up to me while I was doing my homework and said, "You know you are just a nerd. You're never going to be pretty or popular like me, so you should give up and stop trying to look cool." I became almost invisible because I believed my cousin.

In an instant, her personal belief changed from "I'm cool" to "I'm a nerd." The transformation triggered new emotional and cognitive responses.

Unconscious Emotional and Cognitive Assessments

Our brain accesses the environment, sensing opportunity or threat, and then immediately releases neurotransmitters to optimize the response to a situation (Damasio, 2010). Emotions, operating below our *radar*, allocate resources based on these assessments. This assessment is value driven. If important, allocate more resources, if unimportant, allocate fewer. Emotions also activate either "avoid" or "engage" behavior. The transformation of a belief or self-assessment of "I'm cool" to "I'm a nerd" triggers new emotional and cognitive responses.

From a cognitive point of view, since "being cool" is now off the table, a cognitive assessment of "don't waste effort here" allocates fewer resources. As a nerd, underlying negative emotions activate *avoid* plans of action, such as withdrawal. She now has fewer cognitive resources and an emotionally activated *avoid* mindset. When she was cool, she had greater cognitive resources and an emotionally activated *engage* mindset. It's easy to see how a self-perpetuating cycle ensues.

This new belief then generates a complementary worldview. When "cool" she inevitably interpreted casual glances from others as admiring. As a nerd, she now interprets casual glances as embarrassing. This self-affirming process characteristically cascades into a self-fulfilling prophecy.

Into Practice

Armed with the knowledge of how influence events arise, we can watch for those "surprise" moments in our children, students, and those in our care. Doing the opposite of what a child expects may create a life-changing moment. The following example comes from Kristen, a practicing teacher.

> I teach junior English. Jeremy, a quiet student with low self-efficacy, misses a lot of school. I learned recently that he works at a computer shop with his father, repairing and assembling all sorts of electronic equipment. He has impressive skills that I'll never possess. One day he arrived late while students were already in working groups. I assigned him to a group. He asked if he could go to the resource room because he didn't think he was smart enough to contribute to the group. Typically, I feel sorry for him and acquiesce. I decided to surprise him. I told him in a matter-of-fact tone, "Are you kidding me. You're one of the smartest kids I know. Anyone who can do what you do with computers is brilliant." He joined the group and participated. Since then, his attendance, while still low, vastly improved and he doesn't ask to go to the resource room anymore.

When someone expects correction but receives encouragement, you've triggered surprise and an opportunity to boost a positive belief or transform a negative one. That's the time to underscore a skill or aptitude.

Responsible education policy and practice should include the deliberate construction of belief formation and transformation in their discussion of effective teacher practices. These neurological and cognitive advances should be common curriculum in child development studies. We would do well to add alert sensitivity of student emotions to our pedagogical repertoire.

Applied neuroscience in the classroom may prove to be a key to school improvement in the 21st century. Curriculum overhauls and teacher development only deal with part of the issue. School improvement plans may prove anemic without explicit plans to foster self-efficacy in the students.

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Michael A. Rousell

Dr. Michael A. Rousell is a certified psychologist and assistant professor of Education at Southern Oregon University. His two-decade study of life-changing moments culminated in his award winning book, *Sudden influence: How spontaneous events shape our lives* (2007, Praeger).

Comment by Mary Key Morrison

Thanks for an interesting article. I was especially interested in your comments on surprise and instant learning. My work is on humor which of course has many elements of surprise. I will check out LeDoux again—I know I have it somewhere here as I used it when I wrote my book...somehow I missed that piece…and the connection—so thank you!

Comment by rogstar

Great article. I'm going to purchase the book.

Comment by David Moursund

Michael's article reminded me of a 1959 event in my life. While in college at the University of Oregon, I was in the ROTC program, and I had just returned home from a six-month stent in the army. I visited the computing center at Oregon State University where they had a new computer.

I didn't see the actual computer. But I did see and get to use a Teletype (sort of an electric typewriter) that was the computer operator's console. The computer itself was in another room. I got to run and play with a Tic-Tac-Toe (TTT) game that someone had programmed.

I was somewhat intimidated by both the Teletype and interacting with a computer to play a game. In my mind at that time, computers were overwhelmingly smart. They were "giant brains." I, on the other hand, was smart at the level of being able to play TTT quite well.

Imagine my surprise when I beat the computer in a game! All of a sudden a computer changed from being overwhelmingly smart to something that depended on computer programmers who were humans (like myself). The smartness of that TTT programmer left something to be desired. Or, perhaps the programmer made a deliberate attempt to develop a program that played well but could be beaten?

That one event led me in the direction of learning to use computers in math. My math doctoral dissertation was in *numerical analysis*. Numerical analysis is the study of algorithms and procedures that use numerical approximation (as opposed to general symbolic manipulations) for solving math problems. In those days numerical analysis was undergoing major change to adjust to the steadily increasing power of computers. Computers were becoming a routine tool of numerical analysts.

In my many years of working with calculators and computers in education, I have seen many students undergo an "awakening" as they were surprised by experiencing first hand some of the things a computer can do. That first step, from being rather scared and overwhelmed to experiencing meaningful success, is a joy to watch.

Article 15

[IAE Newsletter #89. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-89.html.]

Thinking, Fast and Slow

Robert Sylwester
Emeritus Professor of Education
University of Oregon

Hard copy books and periodicals are expensive to produce and distribute. Publishers typically go to a lot of trouble to make sure that readers have a sense of the credibility of what they read. Non-fiction works have notes and citations, and students can use them as they develop a term project with a reasonable certainty that the sources are correct.

The recent development of computers changed everything. Anyone can now post anything on the Internet and value-oriented radio and cable channels. It's thus now becoming the responsibility of the viewer/hearer to determine the credibility of such material. The presidential election cycle will provide an excellent example of the kind of misinformation and downright lies that will be sent out by folks who can be reasonably sure that most print-oriented voters will not have had the kind of training to assess the credibility of what they get on TV or in Internet documents.

Nobel Laureate Daniel Kahneman's latest book, *Thinking, Fast And Slow* (2011) is a simply superb book on thought and decision-making for a time like this—clear and precise in writing, humorous and gentle in manner. It will provide you with a sense of both the genesis and nature of credibility in human thought. It will also orient you to the major task that schools must now include how best to teach students about the nature of thinking and credibility in a post-credible world.

Systems 1 and 2

Researchers have coined the terms *System 1* and *System 2* to talk about two relatively distinct ways in which a human brain deals with challenges. System 1 operates as fast as a brain can operate, and at a subconscious level. System 2 is called into action when System 1 deems it needs help. System 2 is slower, more deliberate, and more reflective.

Genes: Two forms of narrative flow through us. One very ancient form is based on (consists of) the 20,000 or so human genes that are constructed from combinations of only 20 amino acids. These provide the genetic instructions on how to build and protect a body. Since many body parts are biologically conserved from earlier life forms, we do share parts and functions with other life forms. Egg and sperm split the basic instructional task on such things as body placement and skin color. To put it simply, a gene transmits and supports hereditary characteristics. When the environment creates circumstances that most examples of a species can't overcome, only the outlying variants will survive, and they can pass on their enhanced genetic capabilities to the next generation. The concept of *learning* for such species is thus an evolutionary process in which generations gradually adapt to environmental change.

This cognitive system incorporates rapid reflexive systems (such as emotion and attention) that become what Kahneman calls System 1. This automatic system, which we share with many animals, operates with little or no voluntary control. It focuses rather on imminent individual (other than categorical) dangers and opportunities. Malcolm Gladwell devoted his widely read book, *Blink: The Power of Thinking Without Thinking* (2005) to this central approaching/aversion system in humans.

Memes: Providing genetic instructions is only part of the human parenting charge. Our upright stance and consequent narrow birth canal results in a child whose brain is only one-third its adult size. Most human cognitive brain development thus occurs during the 20+ years after birth, as compared to other mammals whose female birth canal is slightly larger than the almost fully developed brain that passes through it at birth.

In *The Selfish Gene*, (1976) Richard Dawkins proposed the concept of memes to explain the analogous important transmission of cultural information. Susan Blackmore wrote an extended non-technical exploration of the concept in *The Meme Machine* (2000). A meme is a bit of useful cultural information that often evolves from one person to another. Think of the changes that can occur over time in acquiring and preparing food/shelter or even in the elements of a joke. Genes thus transmit biological information between generations, and memes transmit useful cultural information within a generation. Permanent records (such as books and films) increase our life span in effect, because they represent useful information that's passed on by those who had mastered environmental challenges, and then lived to report it.

Language in its various forms is the common memetic transmission device, and it functions much like genes. Combinations of 20 amino acids can construct multiple gene combinations, and 20 or so alphabetic letters construct language in a form of brain-to-brain coupling, something most children easily master. Motherese and mirror neurons play initially important roles, but parents, siblings, and schools significantly enhance the further mastery of language skills. Nowadays these language skills include memory, writing, mathematics, and texting as key elements of this complex system.

Consciousness exists for most animals within the immediate here and now. The human frontal lobes allow us move well beyond the here and now. Our curiosity and logic allow us to create tools and extract food and minerals, to build homes, to construct ships and trains. These activities also involve subjective negotiations about how much something is worth. Much of Kahneman's book is thus focused on the complex task that our human working mind has in determining the value of something.

It's one thing to identify value when comparing a product that someone wants to sell and another wants to buy, but it's something else to choose from among two presidential candidates who are vying for the position. It's no surprise that Kahneman devotes much of his text to the issue of *gambling*, to select a future value (as we do in elections). Subjective predictive acts, such as these, are the most complex challenges humans face.

Kahneman's book is at its most charming when he takes us through many fascinating issues that economists confront as they try to differentiate between the System 1 stress-driven automatic choices that early humans made and the much more difficult, non-automatic, slower System 2 conscious choices that our extended brain now allows us to make.

Think of 2 + 2 = 4 as basically a System 1 decision, and 67 + 24 = 91 as a System 2 decision. The processing time slows when we need more computational skills, so we often just estimate the solution (System 1). This is often OK, but it's generally better to think in terms of a computational (or statistical) rather than causal solution to many more complex or risky problems. System 2 thus overcomes the rapid and often incorrect impulses of System 1.

The reality is that we often make decisions that are not in our best interest, because System 1's innate nature is so deeply ingrained within us. That's probably why it takes 20+ years to go from being not much more than a reflexive wet noisy pet to arrive at the position of being a reflective adult. And then we still make foolish errors. It probably comes down to *blink* if you really truly understand a rapid-feedback problem, but *think* in all other cases.

Educational Challenges

Kahneman tells a story about an Israeli experience he had that occurred when the new math/science programs were being developed in the US. He and others were asked to develop a high school curriculum on how to teach judgment and decision-making skills.

After almost a year, the team had developed a basic syllabus, written a couple chapters, and field-tested several lessons. It was a good time to estimate the project completion, and the most knowledgeable person on the team predicted that it might take seven years. Although discouraged, the team decided to continue, and finally completed the task eight years later. The initial enthusiasm for the project had waned in the Ministry by then, and the curriculum was never used.

Many of us recall the earlier excitement about the new math/science programs, and how we believed that they would transform K-12 education. They didn't, but the reality is that some of their best elements are still being used by teachers who were students then, and by subsequent curricular teams. I further see elements in manuscripts I review for publishers—ideas that I can remember being *tossed out*, but are now tightly and effectively written. Good curriculum doesn't emerge easily. My advice if this concept seems important in your career:

- Get and read Daniel Kahneman's superb book, and think about how to translate his psychological/economic advice into curriculum. The book is full of wonderful ideas that an imaginative educator can mine.
- Check out the Web for information that you can download on thinking, logic, decision-making, and statistical information. Start with: http://en.wikipedia.org/wiki/Statistics, go on to http://www.nizkor.org/features/fallacies/, and then to http://en.wikipedia.org/wiki/Reason, and then to: http://www.skepticalscience.com/Debunking-Handbook-now-freely-available-download.html ……
- Read the next issue of this newsletter. It will focus on Esther Fusco's *Effective Questioning Strategies That Build Thinking and Learning*. Solutions begin with questions, and Esther's book focuses on that initial perspective.

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Robert Sylwester

Robert Sylwester is an Emeritus Professor of Education at the University of Oregon. He has traveled widely, presenting more than a thousand talks and workshops. He was the major professor or co-major professor for more than 60 doctoral students.

His most recent books are *A Child's Brain: The Need for Nurture* (2010, Corwin Press; see an excerpt at http://www.sharpbrains.com/tags/robert-sylwester/) and *The Adolescent Brain: Reaching for Autonomy* (2007, Corwin Press). He wrote a monthly column for the Internet journal *Brain Connection* during its entire 2000-2009 run (archived: http://brainconnection.positscience.com/library/?main=talkhome/columnists). He is a regular contributor to the IAE Newsletter.

For more information about Robert Sylwester, see http://en.wikipedia.org/wiki/Robert_Sylwester and http://www.sharpbrains.com/blog/2008/01/06/learning-the-brain-interview-with-robert-sylwester/.

Comment by David Moursund

Humans have made a good start on understanding the roles of genes and epigenetics in helping an organism adjust to changing conditions. Our human oral and written communication skills facilitate memes, informal education, and formal education—and these are powerful aids to preparing for and coping with change. We have developed aids to our physical and mental capabilities, and these also are powerful aids for coping with change.

As I read and thought about fast and slow thinking, I was reminded of a car ad I saw recently. My car has a rear-facing TV camera and also goes "beep, beep, beep" as I back up. The car in the ad had a vision system that could detect objects in the path of a backward moving car and apply the brakes. Aha! An example of a technology-based fast response system. It senses a possible problem and acts more rapidly that a human can react. Humans routinely make use of radar and sonar—senses that are not part of our biological makeup. I find it interesting to think of such technological developments as a new type of human evolution.

This reminds me of an article I just read about homing pigeons. Quoting from http://news.sciencemag.org/sciencenow/2012/04/global-pigeoning-system.html?ref=hp:

> Release a pigeon thousands of kilometers from home, and it'll fly across seas, forests, or deserts to return. It's not sight or smell that allows this amazing navigation; migratory birds can sense the magnetic fields that vary across Earth's surface. Now, scientists have identified a collection of brain cells that let pigeons interpret these magnetic fields.

Homing pigeons have evolved to have a sense that is different from a human's five senses. These operate at a subconscious (System 1) level. A pigeon does not say to itself, "Hmm, I have a serious direction-finding problem to solve. I sure hope I remember the details I learned in school about map reading and use of a compass."

Now, think about a person making use of a Global Positioning System in his or her car, with that system automatically specifying when to make turns in order to reach a prescribed destination. In some sense it is like an added human System 1 capability. This fast (automatic, non-thinking) System 1 capability requires some training in order to use, but nowhere near the amount of education and training needed to learn to effectively navigate using a printed map and a compass.

Computers and other technologies are powerful change agents that produce rapid change. In some sense, computer applications are like automated memes. Probably you have heard of a computer-disseminated video going "viral." It spreads throughout the world very rapidly, affecting many millions of viewers.

Such technology adds a new dimension to the fast and slow response systems that nature has provided to us. They also present challenges to our educational system. A meme can go viral, perhaps reaching hundreds of millions of people in a few days. Contrast this with the pace of changes in our educational systems that occur over time spans of years, not days.

Article 16

[IAE Newsletter #90. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-90.html.]

A Critical Need for 21st Century Education

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> You can tell whether a man is clever by his answers. You can tell whether a man is wise by his questions. (Naguib Mahfouz; Egyptian writer and winner of 1988 Nobel Prize; 1911–2006.)

Classroom Instruction and the Brain

In the late 1970's, I read the book *Thinking Goes to School* by Hans Furth and Harry Wachs, (1975) followed by an article written by Herman Epstein (1978). The two readings had a powerful impact and changed the direction of my career. From that point on, I looked at classroom instruction through a neurological lens. I recognized that only through active processing could information be retained and more importantly retrieved. I realized that learning emerged when an intriguing event, activity or story engaged the learner and stimulated active processing.

At the time I was a middle school reading teacher, and consequently I began to structure the learning with my new perspective in mind. I organized each lesson by asking myself questions. What am I going to do to engage the learner in the lesson's objectives and concepts? How am I going to do this in a novel way? How will I structure the lesson for the most involvement? What strategies will I use to connect students' background knowledge to the current concept or topic?

This mental set has matured over the years and has been influenced by the writings of others like Lev Vygotsky (1962) and Louise Rosenblatt (1995), who also stressed the need for the learner to have the background knowledge to actively bring to the text or the learning situation. This attitude is alive and well now in all my university classes. For me, my instructional practice is strictly about engaging and interacting with my students in order to facilitate cognitive development.

Lesson Design and Questioning

As I design a lesson, I assess the concept being taught and the student in order to determine if there is a match between the concept level and the student's background knowledge. This assessment process is key to engagement and to the creation of a safe learning environment. While I am striving for some cognitive disequilibrium (Piaget, 1974), I work to avoid frustrating the students and shutting down their learning.

An essential strategy that I use is questioning. The questioning process in my lessons is challenging and creative and always interesting. When used appropriately, effective questioning strategies promote diversified interactions among students in the classroom. Whenever I select this method, I simultaneously:

- build knowledge
- explore complex concepts
- enhance students' self-confidence and
- produce a dynamic learning environment.

Questioning, as a strategy, allows me to assess students' responses and determine their levels of understanding. This reinforces the notion that students' knowledge development is personal and often distinctive. Effective questions help me to begin to differentiate the instruction and support students in synthesizing prior and new knowledge while also expanding their understanding of the learning process. It is a scaffolding process that results from the thoughtful responses of students. In developing an understanding of the power of questions, I have learned that I can build students' comprehension, cognition and guide their understanding in all areas of their learning. Effective questions combine all the ingredients, and teachers can use the strategy in all subject areas and with students of all grade levels.

The Questioning Cycle

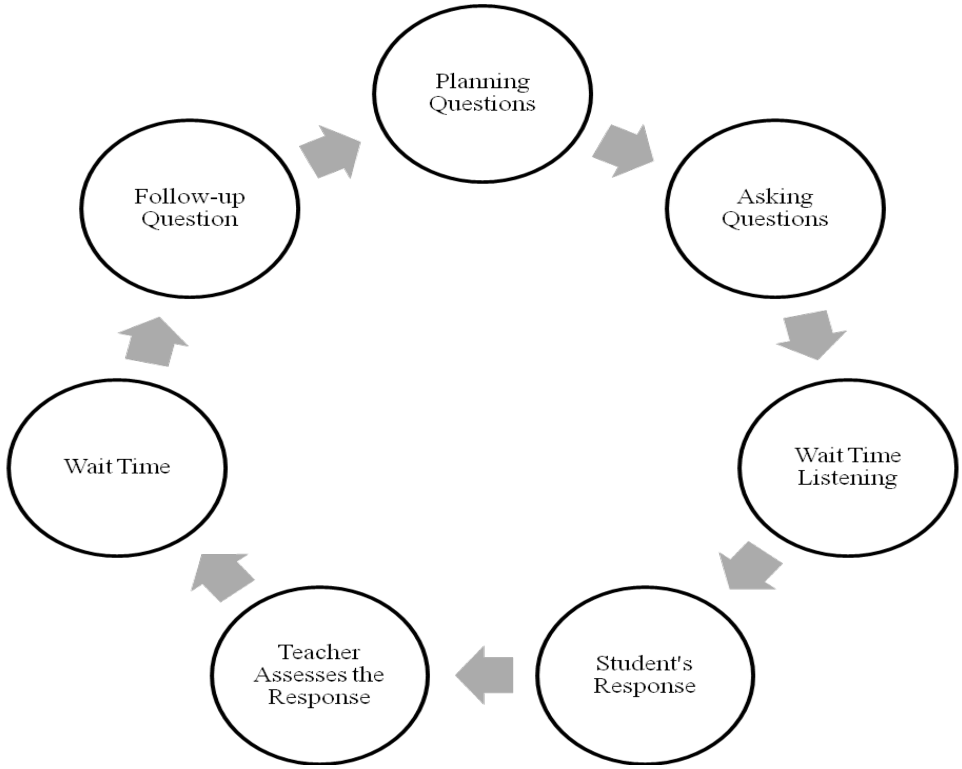
I carried these views into my administrative life. In schools where I was the principal, I encouraged faculty to recognize questioning as a means of supporting cognitive development. Over the years, I built on these experiences and developed them into a structure. I called this the Questioning Cycle and shared it with teachers I worked with.

The main principle in the Questioning Cycle is that questions are one of the most important tools a teacher can use to build a community of thinkers. Fruitful questions promote an environment that appreciates thinking, problem solving and decision making. They encourage students to consider and accept diverse ideas, even those that may seem foreign. Another principle that underlies the Questioning Cycle is that it is a systematic method to collect information about students' knowledge while they explore a topic, concept, or idea.

The teacher uses the steps in the cycle as follows:

- planning the question,
- asking the question,
- allowing wait time,
- listening to the student's response,
- assessing the student's response,
- allowing wait time,
- following up the student's response with another question; and
- re-planning based on all the students' responses.

Steps in the Questioning Cycle – Lesson's Goals and Objectives



The teacher plans a question and then goes through a series of follow-up questions with the student. When teachers ask these questions they generally begin by defining the concept and building the student's content vocabulary related to it. Peers are called upon to participate in the interaction at appropriate moments during the flow of the conversation (Fusco, 2012).

As teachers use questions to stimulate conversation, the discussion allows students to reveal their real understanding of the concepts being explored (Fusco, 1983). A guided discussion helps students explore the concepts and issues that they face in their subject areas and recognize how these ideas relate to their world. After students engage in interesting discussions, they may go to their text, classroom resources or the Internet to get further information that builds their knowledge and helps to explain the ideas they pursue.

Questions that are meant to inspire thoughtful reflection are especially important. As students become more reflective in their responses, they grow more successful when reading complex text. They become used to asking good questions of themselves when they are reading and discussing text.

The Nature of Answers

In using the Questioning Cycle, it is important for teachers to recognize that they must become invested in the *answers* that students give to their questions. In this context, the teacher is not necessarily looking for a "correct" answer, but instead is using questions to build cumulative learning or to encourage elaboration of an idea. No longer is a single answer a correct response to a question. Instead, all responses become valuable data and are appropriate because they reflect the students' cognitive levels. Responses are perceived as more than a mere retelling of the details of a text and become a vehicle for informal assessment of students' cognitive level and a guide for selecting appropriate future lessons.

Obviously, students' responses will comprise diverse answers that range from restatements to generalizations to hypotheses, and this range itself depends upon the concept contained in the lesson and the level of questions asked. Teachers might realize that more in-depth study is needed, that another avenue needs to be pursued, or that the student lacks interest in the topic.

Learning for the 21st Century

In John Dewey's early book *How We Think*, he continually advocated for making learning an active reflective process that engages students' thinking about real issues and ideas. Since his writing, many scholars have continued to advocate for a paradigm of questioning that moves away from a low-level factual approach to one that emphasizes the rigorous thinking and processing of information that was also central to the Socratic Method.

The Questioning Cycle addresses these concerns in a way particularly relevant for the 21st century. The interaction promoted by the Questioning Cycle produces a collaborative exchange that brings a quality and depth to students' learning and maximizes the likelihood that students will be able to apply their knowledge to challenging real-world situations. As Mariale Hardiman writes in her book *Connecting Brain Research with Effective Teaching: The Brain-Targeted Teaching Model*, "Most effective educators...know that the acquisition of content, skills, and processes is only the beginning of a quality instructional program. They realize that good teaching does not stop with the acquisition of knowledge. It also provides students with opportunities to use knowledge meaningfully by developing high-order thinking and problem-solving skills and connecting knowledge to real-world applications" (2003, p. 70).

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Ester Fusco

Esther Fusco is currently an Associate Professor at Hofstra University in Hempstead, New York. She is the Chair of the Department of Teaching, Literacy and Leadership. Initially, she served as an adjunct at Hofstra for fifteen years before becoming a full time faculty member. Prior to becoming a full time faculty member at Hofstra, Dr. Fusco was the principal of the Port Jefferson Elementary School for eight years and the principal of the Babylon Elementary School for eight years. In Babylon she also served as the Director of Curriculum K-12 and the Director of Special Education. Dr. Fusco was a Middle School Reading Coordinator and Elementary Gifted Coordinator in Shoreham Wading River School District. Currently, Dr. Fusco is the Facilitator for the ASCD (Association for Supervision and Curriculum Development) National Network on Language, Literacy and Literature and the Chair of the Balanced Literacy SIG for International Reading Association. Dr. Fusco has authored several children's literature programs and numerous articles on curriculum and instruction and a series of books on portfolio assessment.

Comment by Mary Kay Morrison

Great article Esther! Thank you for your insights and great information!

Comment by David Moursund

When I first started teaching, I thought teaching was easy. My first teaching experience was a remedial college math course for students who had already studied the content in high school. My job was to cover the book and follow the syllabus given to me. I lectured, worked examples, answered questions, assigned homework, graded papers, and gave tests. All of this was done in direct imitation of how I had been taught while I was a precollege and then a college student.

It took me many years to learn that I did not know much about teaching and learning. As I became a teacher of teachers and eventually began to seriously study teaching and learning, I became somewhat overwhelmed by the huge challenges inherent to being a good teacher.

I also began to learn about the difficulty of translating theory into practice. *Wait time* is one of my favorite examples. See http://agpa.uakron.edu/p16/btp.php?id=wait-time. Both the research on this topic and my gradually growing insights into learning for deep understanding convinced me of the value of a long wait time in interacting with students.

But, how long is long? Is it the same for all students? How can I formulate a question so that it takes a student more than 10 seconds to develop a good answer? What can I do to help ensure students are doing deep (or, at least deeper) thinking during this wait time?

I served on several doctoral committees of students exploring such questions. I also gained insight into how a Highly Interactive Intelligent Computer-Assisted Learning (HIICAL) system could individualize wait time for a student, deemphasize lower-order skills, and place increased emphasis on higher-order skills and problem solving.

Gradually I learned to role model important ideas about teaching into my teaching. For example, I learned about project-based learning (PBL) and the idea of the teacher and students working together to develop rubrics. I then implemented this PBL in my teaching through both discussing the idea in class and having students actively engaged in implementing this idea as we worked together to define my PBL assignments.

As another example, I learned about problem posing (question posing) and about lower-order and higher-order in Bloom's Taxonomy. In quizzes over reading assignments, I would often ask my students to individually make up a higher-order question over something that they felt was important in the reading and then answer it. To me, this became a "three for the price of one" activity. I could tell if a student had done the reading, had understood higher-order versus lower-order, and had learned to pose higher-order questions.

I no longer think that good teaching is easy. Rather, I marvel at those who are good teachers! So much to learn. So little time in which to learn it.

Article 17

[IAE Newsletter #91. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-91.html.]

Cognitive Neuroscience, Computers, and Math

David Moursund
Emeritus Professor of Education
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Using brain/mind science and computers to improve elementary school math education is a free book that I field-tested in 2004. This book has recently undergone careful editing and updating, and I added a new chapter and appendix. The new 2012 book is available free from Information Age Education (Moursund, 2004, 2012).

I found it interesting to analyze the content written eight years ago from the point of view of what we knew about cognitive neuroscience, computers, and math education in 2004 versus what we know today. I also found it interesting to see how math education research and cognitive neuroscience have helped (and, unfortunately in many cases, failed to help) improve our math educational system during the past eight years.

A Little History

The Sumerians developed reading and writing about 5,200 years ago. The written language that was developed included symbols for numbers. Schools were developed to teach reading, writing, and sometimes a little arithmetic. Reading, writing, and arithmetic have been part of a literate person's informal and formal education for more than 5,000 years.

It is clear that human genetics and early childhood development predispose us to learn oral communication. Oral fluency provides a strong foundation for learning reading and writing. While many people find it difficult to develop a contemporary level of competency in reading and writing, our educational system is geared to addressing such difficulties.

In recent years we have come to understand that an infant's brain has some innate math-related knowledge and skills and is predisposed to learn some math-related topics. In his 2000 book *The Math Gene,* Keith Devlin argues that the ability to learn a natural language is closely linked with being able to learn arithmetic. There is no innate reason why so many students who learn to read and write should end up hating math and claiming that they cannot do math.

A natural language such as English changes over time. New words are added, some words fall into disuse, and definitions and usage change. The amount of literature written in natural languages grows over time, and some of it lasts for many centuries. And, of course, there is a steady increase in the totality of written accumulated human knowledge. Thus, teachers of reading and writing face a continuing challenge of preparing their students to achieve an appropriate contemporary level of literacy for their adult lives.

In some sense, the discipline of math grows more rapidly than the reading and writing domains of the language arts. Math is a vertically structured discipline in which the creation of new math knowledge and skills is built on thousands of years of accumulated math research. The steadily growing use of math in the sciences, economics, business, and many other disciplines creates a math education challenge that is quite different from the types of challenges faced in language arts education. While relatively few people find the need to solve a quadratic equation, graph a polynomial function, calculate the correlation between two sets of data and follow an argument based on statistics and probability, or prove a geometric theorem in their everyday lives, our educational system has decided that all students need to study such topics in order to graduate from high school (CCSS, 2012).

We want today's students to learn topics from algebra, geometry, probability, and statistics—subjects that had not yet been discovered back when the first schools were created. Electronic calculators and computers represent still newer content and powerful new aids to doing math, and these can be integrated into a math curriculum. Thus, math curriculum specialists are faced by a continually changing challenge of what to include in the math curriculum, what math all students should study, and what math is needed for various careers and for further study of math.

We have had thousands of years of experience in helping children learn reading, writing, and simple arithmetic. However, we have had only modest experience in trying to meet requirements that all students should study algebra in the eighth grade and learn various topics from geometry, probability, and statistics before they complete high school. Currently, now more than 50 years into the Information Age, we still have not yet decided on what calculator and computer content to thoroughly integrate into the K-12 math curriculum or how to assess student learning of this new aspect of a math curriculum.

Conrad Wolfram' excellent 17-minute TED talk on this topic is available at http://www.ted.com/talks/lang/en/conrad_wolfram_teaching_kids_real_math_with_computers.html. In this talk he outlines his thoughts on how to use computers to implement a major change to our current math educational system.

Math Cognitive Development and Rote Memorization

As infants are learning their native language(s), their parents and other caregivers often speak in "motherese" and keep the vocabulary quite simple. However, a young child is also immersed in an environment of adult conversations that include vocabulary, ideas, and experiences far above his or her current language development levels. A child's language development is pushed by being in such a "rich" language environment.

This same thing happens in math, but there is a major difference. Although math is a language, not much math is spoken in everyday conversation, and the math that is spoken to young children is often not yet relevant to a child's life.

I grew up in a household in which both my mother and father had advanced degrees in math and taught math at the college level. My young brain was routinely exposed to math content conversations and math thinking. I entered kindergarten having grown up in both a rich natural language environment and a rich math language environment. This early head start has served me well throughout my life.

Piaget and other researchers developed the field of cognitive development (McLeod, 2009). Quite a bit of Piaget's work has stood the test of time and/or served as a good starting point for more modern research. The rate of cognitive development varies among students and depends on a combination of nature and nurture. Moreover, cognitive development in math does not necessarily progress as rapidly as does overall cognitive development.

Piaget's four basic stages of cognitive development are sensorimotor (birth to age 2), preoperational (ages 2 to 7), concrete operations (ages 7 to 11), and formal operations (ages 11 and beyond). At the formal operations level, children begin to develop a brain/mind that can deal with the type of abstractions that are fundamental to mathematics. However, even in kindergarten, students are being exposed to some of the abstract notation, vocabulary, and nuances of math. For math students who have grown up in a math "poor" environment, the math that is being presented is considerably above their level of math cognitive development.

Like any curriculum, math has both breadth and depth. In some sense, a new "breadth" topic is a leveler. Many students studying the new topic are essentially starting from scratch, and the teacher does not assume a great depth of prerequisites. However, when a topic is designed to add depth to a student's math knowledge and skills, the teacher and curriculum make assumptions about the prerequisite math knowledge, skills, and math cognitive development of the students. The students who don't meet the prerequisites are apt to be in way over their heads. This frequently leads to a rote-memory learning approach, with little underlying understanding on the part of the student. That, in turn, leads to the student falling further behind when a new "depth" topic is taught that assumes an understanding of previous topics.

The Past Eight Years (2004-2012)

Our math educational system has made a number of changes since I was a child. Still, to me it seems that the system exhibits considerable resistance to change. For example, in 1979 the National Council of Supervisors of Mathematics and in 1980 the National Council of Teachers of Mathematics strongly supported the integration of calculators into the elementary school math curriculum.

In those days, calculators were still rather expensive and somewhat fragile. Now, more than 30 years later, calculators are very inexpensive, use solar-powered batteries, are quite rugged, and are routinely used by adults. However, many elementary school teachers still strongly resist their use in school. Where calculators are allowed on state and national tests, the test questions are usually designed so that a student gains very little advantage in using a calculator. The newly developed Common Core State Standards (CCSS) in math place increased emphasis on understanding, more emphasis on depth in a less broad curriculum, and little emphasis on use of calculators and computers as an aid to problem solving (CCSS, 2012). In contrast, the CCSS standards being created for science have drawn considerable criticism because they place very little emphasis on use of computers in science.

During the past eight years many schools have explored the idea of having classroom sets of laptop computers and/or tablet computers. Some schools and school districts have acquired one laptop or tablet per student, and many allow students to carry them home.

However, the big push for laptop and tablet computers in our K-12 schools is mainly for their use in computer-assisted learning, distance learning, and information retrieval. There has been only very modest progress in the integration of these powerful Internet-connected tools as aids to representing and solving math problems. Little progress has occurred toward allowing laptop and tablet computers on state and national math tests.

The past eight years have brought considerable advances in understanding the learning disability *dyslexia* (a major challenge to learning to read) and the learning disability *dyscalculia* (a major challenge to learning arithmetic). There is a high level of co-morbidity between dyslexia and dyscalculia (Butterworth, 2005).

Our schools have made good progress in early detection of dyslexia and other reading problems. Early and strong interventions often occur. The same cannot be said for the math learning difficulties that students encounter because of some combination of dyslexia, dyscalculia, and other math-related learning disabilities. This is in spite of the fact that we have made good progress in understanding some of the brain function specifics of dyscalculia.

Here is one of my favorite quotes:

> When you spoke of a nature gifted or not gifted in any respect, did you mean to say that one man may acquire a thing easily, another with difficulty; a little learning will lead the one to discover a great deal; whereas the other, after much study and application no sooner learns then he forgets…. (428/427 BC–348/347 BC.)

There is considerable research literature on forgetting and ways to teach and learn that will decrease forgetting. (See http://frank.itlab.us/forgetting/.) While CCSS (2012) emphasizes learning for understanding, our steadily increasing emphasis on high stakes testing is causing an increased emphasis on math rote memory learning that is soon forgotten.

The problem of teaching over the heads of many students—because their level of math cognitive development and level of math maturity is below what is needed—has gotten worse. This is being caused by a strong movement to make algebra a required eighth grade course and the requirement that students take an increasing amount of math for high school graduation. To me it seems like the people who are pushing algebra into the eighth grade and increasing the math requirements for high school graduation are ignoring what we are learning about math cognitive development. The work of the van Hieles done more than fifty years ago showed that even then we understood the problem of putting students into a math course that was too much above their current level of math cognitive development (van Hiele Model, n.d.)

For many years preservice teachers have learned about the idea of students learning reading and writing across the curriculum. We want students to learn to read well enough in each school discipline so they can use their reading skills to further their learning in each discipline they study in school. Unfortunately, during the past eight years I haven't seen any progress in having students learning to read math well enough to make use of reading math as a major aid to learning math. Students are not learning to make effective use of the math-oriented Web resources.

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David Moursund

David Moursund earned his doctorate in mathematics from the University of Wisconsin-Madison. He taught in the Mathematics Department and Computing Center at Michigan State University for four years before joining the faculty at the University of Oregon.

At the University of Oregon he taught in the Mathematics Department, served six years as the first Head of the Computer Science Department, and taught in the College of Education for more than 20 years.

His professional career includes founding the International Society for Technology in Education (ISTE) in 1979, serving as ISTE's executive officer for 19 years, and establishing ISTE's flagship publication, *Learning and Leading with Technology*. He was a major professor or co-major professor of 82 doctoral students. He has presented hundreds of professional talks and workshops. He has authored or coauthored more than 60 academic books and hundreds of articles. Many of these books are available free online. See http://iae-pedia.org/David_Moursund_Legacy_Fund.

In 2007, Moursund founded Information Age Education (IAE), a non-profit company dedicated to improving teaching and learning by people of all ages throughout the world. See http://iae-pedia.org/Main_Page#IAE_in_a_Nutshell.

Afterword by David Moursund

Brain/mind science and computer technology are powerful educational change agents. This is especially true in math education, since today's computer tools can solve or help a great deal in solving the types of math problems students encounter in their K-12 math education.

In our educational system, the content, pedagogy, and assessment are affected by a strong human tendency to maintain the status quo unless it is quite evident that the status quo is not working very well. To a very large extent, the informal education that parents provide to their children imitates the informal education they received from their parents. To a very large extent, changes in school curriculum content move at a glacial pace.

I find it interesting to compare the math content in the K-12 math and science curricula. Almost all of the math content being taught is hundreds of years old. Science educators are faced by the challenge of making science research reasonably quickly available to students.

That statement, of course, depends on whether we include computers and computer technology as part of math content. There is a large overlap between the disciplines of mathematics and computer science. That is, the discipline of mathematics includes a great deal of computer science. Thus, people who develop the math curriculum content are faced by the challenge of what aspects of computer science should be included in the math curriculum.

My 50+ years of involvement in math education suggest to me that very slow progress is occurring in integrating math-oriented aspects of computer science into the math content being taught at the K-12 levels.

The brain/mind aspects of my new book discuss potential roles of cognitive neuroscience in changing the pedagogical and assessment aspects of math education. I see some progress occurring, but it also seems quite slow.

Article 18

[IAE Newsletter #98. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-98.html.]

Tellin' Ain't Teachin':
The Need for Frequent Processing

Spencer Kagan
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> If teaching were the same as telling, we'd all be so smart we could hardly stand it. (Mark Twain—pen name of Samuel Clemens; American author and humorist; 1835–1910.)

If our academic content is gum, and the discussion and thinking about the content (processing) by students is chew, then brain science gives us a clear directive: Increase the ratio of chew to gum. A lot of gum with no chew leads to little learning.

First, we will overview the neuroscience rationale for increasing the frequency and amount of processing. There are many ways to have students process learning: taking notes, writing summaries, making drawings, discussing ideas. Here I will focus on just one way, what I believe to be the most powerful form of processing: student interaction over the content. After providing the neuroscience rationale for increasing the amount of student interaction over content, we will turn to the issue of *how* best to have students interact. It turns out that some common ways of having students process our academic content do not lead to equitable educational outcomes. These common approaches to processing actually contribute to the achievement gap! If we want all students to benefit from the chew, we must carefully structure their interaction as they process the content.

Neuroscience Support for Frequent Processing

This section summarizes six reasons for providing processing time to students.

1. Processing Clears Working Memory

Working memory has limited capacity: We can only hold a certain amount of information in consciousness at one time (Cowan, 2005). This limit is very adaptive; if we were juggling 100 things in working memory, our attention would be so divided we could not function or survive. Nevertheless, the limited capacity of working memory has extreme implications for educators.

As we lecture to our students, we fill working memory. After about ten chunks of information we have exceeded the limit of working memory's capacity for even the best of our students. The exact capacity of working memory differs for different individuals depending on their age and the complexity of the encoding process that an individual has developed. It differs also for different types of content and whether there are internal or external distractions. In all cases, however, the capacity is quite limited.

As is often said, to continue lecturing beyond the capacity of working memory is like pouring more water into a glass that is already full. If we continue to lecture beyond the capacity of working memory, either the next chunk of input is ignored, or goes in at the expense of something already there. Long lectures reach the point of diminishing returns. Punctuating the lecture with frequent processing repeatedly clears working memory so students can take in new information with undivided attention.

Often, during workshops on this topic, I ask participants if they have ever had so much to do or so much on their mind that they felt "cloudy headed." That is, they felt they couldn't concentrate, and couldn't take in any more information. All hands go up. I then ask how many have had the experience, when they felt like that, of sitting down and writing a To Do list or list of things they have on their mind. All hands go up. Finally I ask, "How many of you, after writing that list, felt much better—felt you could again concentrate, that you could take in new information?" Once again all hands go up, usually with a smile or laugh of recognition. What has happened in those moments? When working memory is full, we know we cannot take in any more information. By writing down what is on our mind, we move things from working memory to the piece of paper, so we don't have to keep those things in working memory. We clear working memory and so can take in new information with a clear mind. By frequently clearing working memory while we teach, students can attend to a great proportion of our content with undivided attention, rather than with a "cloudy head." This then provides the first brain-based rationale for frequent processing: *Frequent processing clears working memory allowing for students a greater proportion of full, undivided attention to our content.*

2. Processing Stores Content in Long-Term Memory

During processing students discuss the content, analyze it, and relate it to prior knowledge. They connect the new learning to their own prior knowledge and to the new knowledge provided by those with whom they are interacting. They are actually rewiring their brains, making dendrite connections. The information is placed in more places in the brain, and so there are more associative links. This dramatically increases the probability of later recall.

A person gives us a telephone number to call. We hold the number in short-term memory long enough to make our call. After making the call, someone asks us for the number. We say we can't remember. It is gone! Why? Content does not move from short-term to long-term memory automatically. The two memory systems are completely independent (McGaw, 2003). To remember the number—or anything else—long-term, we must move the content from short- to one of our long-term memory systems. Each of us has different ways of doing that. If it is a telephone number, some of us look at the relation of the numbers to each other, some of us create a visual image of the number, others of us link the numbers to words or even make a number sentence, and yet others use one of the many mnemonic devices. Whichever process is used, the numbers are placed in long-term memory through thinking about the numbers, processing them. Processing is the golden key to move content from short- to long-term memory.

This then, provides the second brain-based rationale for frequent processing: *Frequent processing moves content from short- to long-term memory, increasing the probability of later recall.*

3. Processing Produces Retrograde Memory Enhancement

Emotion cements memory. Emotion is a signal to the hippocampus: You better remember this! James McGaw and his research team at the University of California, Irvine, established the principle of Retrograde Memory Enhancement (McGaw, 2003). The principle is simple: Anything followed by emotion is better remembered. It is why almost all of us remember where we were when we first heard about the 911 terrorist attacks, but few of us remember where we were the day before or the day after. The principle is rooted in the brain's primary function: survival. What are emotional events? They are the good stuff and the bad stuff; the painful stuff and the pleasurable stuff. Remembering those events helps us survive. Touch the hot stove, and you remember not to do that again. Enjoy the first kiss, and it is likely you will remember it and go back for more.

What does this have to do with frequent processing? Usually, but not always, more emotion is generated in a lively interaction with a peer than is generated by a lecture by a professor. By frequently punctuating the lecture with processing time, the professor links the content to emotion. *Thus, processing releases the power of retrograde memory enhancement to make our academic content more memorable.*

4. Processing Creates Episodic Memories

Usually, a lecture provides facts and information that are stored in the semantic memory system. The semantic memory system handles isolated facts and bits of information. When content for semantic memory is not processed, not put into a meaningful context and internalized, it is far less likely to be maintained. When students cram for a test, too often they are attempting to put information into the semantic memory system, but because they are not fully processing the content they retain the information only long enough to spit it back on the test. A few weeks later, or often much sooner, and the information is gone.

The semantic memory system is more fragile than the episodic and procedural memory systems. Anxiety interferes with semantic memory: that is why sometimes even if we know the name of someone very well, our mind goes blank when we go to introduce them to a group in a social setting.

Procedural and episodic memories are more stable. As we get older we forget the names of things, but don't forget how to drive a car or brush our teeth (procedural memories) or the time we got married or the time we lost our car keys and had to walk home (episodic memories).

What does all this have to do with the desirability of frequent processing? As students interact over the content, they very often create an episodic memory. Why? Episodic memories are created when an event has a beginning and an end as well as a location, especially if there is emotion associated with the event. When students turn to a partner for an animated interaction, the event has a beginning and an end, a location, and is associated with emotion. *Such processing often creates episodic memories that are more stable than semantic memories.*

5. Processing Creates Novel Stimuli, Increasing Alertness

Processing breaks up the routine of the direct instruction, providing novel stimuli. By having students process the content at different times with different partners, we create additional novel stimuli. Further, what a partner might say during the processing time is additional novel stimuli. We become more alert when presented with novel stimuli, providing yet another brain-based rationale for frequent processing: *Processing increases student alertness, which in turn increases the probability of recall of the content.*

6. Processing Activates Many Parts of the Brain

While processing content with a partner, many parts of the brain are activated. Wernicke's area decodes the words of our partner. Broca's area encodes our own words. The temporal lobe processes not only words, but also decodes tone of voice. The visual cortex processes the face of our partner as well as their gestures and body language. Mirror neurons decode the feelings projected by our partner. Further, the prefrontal cortex is very active as we must either assimilate the information provided by our partner or adjust our way of thinking about the world (accommodate) because our partner has provided information that doesn't fit with our cognitive framework. *Thus, processing places the content in more places in the brain, creating more associative links, enhancing memory.*

How We Process Makes all the Difference!

Having grasped the importance of processing, some instructors use a simple "Turn and Talk" approach. They stop talking and ask students to discuss a problem or issue presented in the lecture. What they do not know is that these simple, unstructured interactions actually increase the achievement gap among students!

Picture a highly motivated, high achiever paired with an unmotivated, low achiever. The instructor does a Turn and Talk. Who will do most or even all of the talking? Whose mind will be off topic? When we test later, the motivated, high achiever has benefited from the processing, but the low achiever has not. We have inadvertently increased the achievement gap.

To improve learning and increase educational equity, I began a program in the early 1980s developing cooperative interaction sequences I called Structures. I call them structures because they are carefully designed to "structure" students' interaction patterns. To date my colleagues and I have developed more than 200 different ways of structuring the interaction among students (Kagan and Kagan, 2012). Some structures are explicitly designed to foster the formation of episodic memories; others develop procedural memories, yet others create semantic memories. Still yet others exercise working memory. Let's briefly examine two simple, all-purpose structures that can be used by any instructor for processing during any lesson: RallyRobin and Timed Pair Share.

RallyRobin

Let's imagine an instructor wants students to process the content by naming as many things as they can think of that answer a question. For examples, name all the alternative plausible hypotheses to explain a phenomenon, all the facts covered so far, steps in completing a project, or simply animals found in the rainforest. The instructor could do a Turn and Talk, which often results in the high achiever doing most or even all the talking. Or the instructor could do a RallyRobin: Students in pairs simply take turns contributing to the oral list. By structuring for turn taking, the instructor ensures equal participation and ensures that all students contribute. This reduces the achievement gap.

Timed Pair Share

Sometimes an instructor might want students to speak at length on a topic, say provide an opinion or an interpretation. One structure that allows equal participation for elaborated thinking is a Timed Pair Share. Each student in turn shares for a predetermined amount of time. Again, by using a structure that equalizes participation, we reduce rather than exacerbate the achievement gap.

Tellin' Ain't Teaching

For a variety of reasons, our students remember far more of what they say than what they hear. Listening is passive. While listening to a teacher, not nearly as much goes on in the brain as when students put their thoughts together, verbalize their thinking, and interact with others who might have different information or a different point of view. So, if our goal is understanding and retention, our best course is to frequently stop talking and let our students talk. But then, if we are going to have our students interact, we need to carefully structure that interaction so all students participate about equally. With frequent, carefully structured processing in place, we promote better learning for all students.

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Comment by David Moursund

I am inspired by Kagan's article. It is a very nice balance between theory and practice. I hope a very large number of teachers will take his message to heart.

This comment discusses two computer-related ideas:

1. Computer technology used in and/or during lectures.
2. Computer technology used to facilitate small group discussions and other types of student processing that are interspersed in the class period.

Computer Technology and Class Lectures

Computer technologies—including computer projection systems, document cameras, and computerized white boards—make it easy to incorporate multimedia into a lecture. "Clickers" can be used to increase interaction between students and the lecturer. Many teachers now routinely weave use of such technology into their lectures.

There is a movement toward students being expected to use computer-based materials to study course material in advance of a class meeting. The computerization of these materials allows the course instructor to gain information about what the students are doing and what concepts seem to be giving them trouble. In addition, the systems being used make it easy for students to ask questions that they hope will be addressed by the teacher either before the class meeting or during the class meeting.

Eric Mazur, a physics professor at Harvard, has been a pioneer in this approach to teaching. See http://www.columbia.edu/cu/gsapp/BT/RESEARCH/mazur.html. This approach is sometimes called *flipping* the instruction process and is now receiving a lot of publicity at the precollege level.

It is now common for students to bring a portable computer device to class. This might be a laptop computer, a tablet computer, or a smart phone. Computer technology adds a new tool to note taking. Students who are skilled at fast keyboarding benefit by being able to take more copious and legible notes during the lecture phases of a class. (As an aside, I am not familiar with research on the learning that occurs as a student handwrites class notes versus the learning that occurs as a student keyboards class notes. Certainly that is a researchable question.)

Of course, such computer technology can be used for communication with friends, playing games, and other types of activities not related to the course topic. Such use may be a major distraction to students sitting near the computer user.

Computer Technology and Small Group Processing Time

Kagan provides two excellent examples of activities that can be used during small group processing time. If computers and good connectivity are available, computers can be incorporated into various processing time activities.

For example, during processing time students may benefit by doing some "fact checking" and "seeking additional information" activities using their portable computing devices. They can develop and start to answer researchable questions. Such "just in time" online research may locate resources and ideas that can be shared with the whole class during debriefing time at the end of a planned processing time. In addition, students can share access to online resources that they have discovered during their outside-of-class studies.

Article 19

[IAE Newsletter #92. See http://i-a-e.org/newsletters/IAE-Newsletter-2012-92.html.]

Summary 1: We Have *Several* Brain Systems

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We constantly confront dangers and opportunities related to our need to survive and reproduce. Many folks believe that our three-pound brain processes all the recognition and response functions that are required for our survival and a qualitative life.

It's a bit more complicated than that. As indicated in the 18 previous articles in this series, we actually have several separate but functionally related internal and external recognition/response systems that the 21st century school needs to attend to in order to help us to survive life's challenges. We have personal brain and immune systems that are principally focused on self-survival. We're a social species, so we developed linguistic/cultural/political/moral and other systems that are focused on communication and the well being of our group. We've developed an expanded body/brain that uses tools to augment our sensory-motor limitations—from microscopes to telescopes, cars to ships to planes, calculators to computers, snail mail to e-mail….

A Personal Brain and Immune System

Our skull-centered brain is composed of hundreds of billions of neurons and glial support cells. It receives, integrates, and responds to the kinds of information on current and potential dangers and opportunities that our sensory/motor systems can process and pass on to our cognitive problem-solving systems.

Our diffused immune system, which in aggregate weighs about as much as our brain, is composed of a huge number of often free-floating specialized cells that are spread throughout our body (but principally within our skin and digestive tract regions). Our immune system recognizes and responds to the several pounds of microscopic microbes and pollutants that have entered and now inhabit our body. It identifies and then seeks to destroy those that are dangerous. In effect, our body includes a type of highly diffuse immune system "brain" that functions at a subconscious level and continually works to help keep us healthy.

So, for example, combinations of our very interconnected skull-centered brain cells respond to such larger visible external challenges as a rapidly approaching car or an opportunity for food, and cells in our diffused immune system respond to such tiny invisible intruders as flu viruses that make us ill and certain bacteria that upset our digestive system. Scientists now realize that the two systems are highly interconnected and balanced. A successful response to many of life's challenges requires the two systems to collaborate, and illnesses such as asthma can occur if they don't.

Our immune system's capabilities tend to diminish (and we become susceptible to infection) during an extended stressful situation that requires our body/brain to focus on developing a successful cognitive response. Conversely, when our immune system is temporarily overwhelmed with a viral or bacterial infection, we tend to lay low (perhaps stay home from work and take to bed) in an attempt to reduce the level of cognitive challenge.

Our inventive brain's development of vaccines is an example of our brain assisting our immune system. A flu shot boosts our immune system's ability to fight off a flu strain through the inoculation of a mild form of the disease. This action increases the viral recognition and response awareness, and this heightened response capability wards off the more virulent form of the flu if it later enters our body.

Our immune system often reciprocates. For example, our brain responds most vigorously to high contrast sensory information, and ignores or merely monitors steady states and subtle changes. This makes biological sense. Why expend cognitive energy on things that aren't currently problematic or erratically fluctuating? Our brain thus tends to ignore gradually developing problems, such as low levels of air pollution, until the pollution becomes visible and affects breathing. Our immune system will pick up the initial subtle signals of pollution, however, and use nausea, runny noses, and headaches to inform our brain that it should attend to an increasing environmental problem.

We thus have two basic systems that collaborate in recognizing and responding to external/mammoth and internal/minute challenges. School activities typically focus on students' brain systems, and tend to ignore their immune systems. Of course, schools insist (with varying levels of success) on inoculations before they'll admit a student. An important educational challenge is thus to help students and their caregivers understand the underlying neurobiology of the two systems that maintain our health and cognition.

A Social Species, Culturally Creative

We're a social species, highly dependent on collaborative interactions with others. Language is the principal conduit for such interaction. Speech is almost intuitive. In effect, we're born capable of mastering any language in the world, but we're not born proficient in any of them. Reading and writing are a learning challenge that typically requires quite a bit of school help.

Language communicates not only factual and emotional information from others, but also important elements of the culture itself. This deeply embedded cultural concept is well documented in a recent intriguing article in *New Scientist Magazine* (de Lange, 5/8/2012).

The 21st century is adding yet another widely accepted computerized communicative device that can very quickly transmit speech, print, and video to nearby and/or distant people. We're now totally into the world of email, Facebook, Twitter, etc.

The Role of the 21st Century School

These multiple information systems propose an intriguing thought: Is school now simply another form of *cognitive/cultural inoculation*, an educational flu shot? Our current curriculum inserts relatively mild versions of complex human problems such as sustainability, poverty, and global warming into student brains, so that those who master curricular challenges will be able to effectively recognize and perhaps think about responding to these very complex life challenges they'll confront later. Role-playing and simulations are good examples of school activities that allow students to develop important recognition and response skills in a non-threatening setting.

Schools should be concerned about our total *brain system*—our cognitive and immune systems, our social nature and its cultures, and now our increasing body/brain extensions, such as computerization and other technologies. The environment in which students learn should be intellectually stimulating—but also relatively free of the antigens, pollutants, and cultural deceptions and outright lies that can reduce cognitive capability and the quality of students' lives. The escalating advances in biology demand that the 21st century curriculum help students develop a functional understanding of our several brain systems. This is something certainly necessary in informed 21st century citizens who will confront many important legal, moral, economic, and cultural issues related to our increasingly complex recognition and response systems.

Schools in the pre-21st century focused on the geography of the world in which we live. It made sense. It was important to know why folks lived where they lived and how the geographic world affected life. The 21st century will introduce us to a new exciting *geography*—that of genes/viruses/brains, that of how the world's ethnic and cultural groups can best co-exist, and that of how the addition of technological tools to our body's total brain system changes who we are and what we can become.

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Robert Sylwester

Robert Sylwester is an Emeritus Professor of Education at the University of Oregon. He has traveled widely, presenting more than a thousand talks and workshops. He was the major professor or co-major professor for more than 60 doctoral students.

His most recent books are *A Child's Brain: The Need for Nurture* (2010, Corwin Press; see an excerpt at http://www.sharpbrains.com/tags/robert-sylwester/) and *The Adolescent Brain: Reaching for Autonomy* (2007, Corwin Press). He wrote a monthly column for the Internet journal *Brain Connection* during its entire 2000-2009 run (archived: http://brainconnection.positscience.com/library/?main=talkhome/columnists). He is a regular contributor to the IAE Newsletter.

For more information about Robert Sylwester, see http://en.wikipedia.org/wiki/Robert_Sylwester and http://www.sharpbrains.com/blog/2008/01/06/learning-the-brain-interview-with-robert-sylwester/.

Comment by Jane Healy

Quoting from Sylwester's article: "...and that of how the addition of technological tools to our body's total brain system changes who we are and what we can become. "

This, of course is the question that has driven my work for decades; it seems to me that the more we become aware of the scope of these changes, the more helpless we are in confronting them. I believe that it is crucial to more fully value human intelligences (including the visceral ones alluded to in the article) and move beyond the historic American tendency to idolize tech developments without adequate reflection on their potential effects/consequences. If we can't communicate these concerns to our students, we will be on a very slippery slope humanity-wise. Personally, I have argued that educators have been remarkably unreflective about their embrace of the latest gadgetry. (I wonder how many educators have read and pondered *Neuromancer* or how many explore with their students the powerful theme in *The Hunger Games* of human values vs. tech development and their relationship to autocracy.)

I see that one of the fast-food chains is going to provide screens for kids so that their parents won't have to converse with them while everyone is inhaling their food. Frankly, we are soon going to have to decide whether language, literacy, and reflective analysis are important enough to devote sufficient curricular time to re-install these modes of processing into the neural equipment of our students. But please inform the "standards"-makers that we need sufficient time to remediate minds that have rarely experienced a self-directed minute.

Article 20

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Summary 2: Educational Game Changers

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> If I have seen further it is by standing on the shoulders of giants. (Isaac Newton; English mathematician and physicist; 2/5/1675 letter to Robert Hooke; 1642–1727.)

We humans are blessed with the most capable brains of all creatures on this planet. Using our creative brains and our communication skills, we have survived and prospered. We have developed tools to aid our bodies and minds, and we have become quite dependent on these tools. As noted in the quote from Isaac Newton, such progress is cumulative.

The articles in *Creating an Appropriate 21st Century Education* range over a variety of topics. Within and between articles there is a continual play of theory versus applications of cognitive neuroscience. Computer technology is a major topic in the book because it helps facilitate cognitive neuroscience research and implementations of some of this research into educational practices. It is also an important content discipline in its own right.

For most of recorded history, the brain has been a black box. We lacked today's sophisticated instrumentation to peer into a brain as it goes about its various activities. We now have a much better understanding of the strengths and weaknesses of a human brain. We are at the beginning of integrating cognitive neuroscience and the capabilities of computer brains into our everyday school curriculum. We are developing interventions to help deal with disabilities, and we are learning to make more effective use of brain capabilities.

Change

A tool such as a spear or a club is an embodiment of information. This information is passed from generation to generation as elders teach their children to make and use the tools. Similar comments apply to hunting and gathering skills, and making and using fire, shelters, clothing, and medicines.

If we look back many tens of thousands of years, the pace of change was very slow. A hunter-gatherer could live a lifetime without seeing an appreciable change in tools and the techniques for using these tools.

The development of agriculture a little over 10,000 years ago was a major game changer. Permanent settlements and increasing population in settlements promoted and facilitated sharing and made more specialization possible. An inventor might spend years developing a better hoe, animal husbandry method, or pottery-making technique. This could then be shared with the growing population of the local community and the growing number of travelers among communities.

I think of reading and writing as human-developed *mind tools.* The development of these mind tools a little over 5,000 years ago was another major game changer because it helped in the preservation and sharing of collected knowledge and skills. Since that time, over a hundred million different books have been printed and distributed. This has helped the accumulated knowledge of the human race to grow at an increasing pace. Improvements in transportation and communication have added to this pace of change. Nowadays it is common for research groups around the world to be actively cooperating and sharing their progress.

I like to think back over the past couple of centuries that have brought us: the steam engine and industrial revolution; telegraph and telephone; photography and movies; cars and airplanes; plastics and synthetic fibers; radio, television, and radar; jet planes and rocket ships; computers, telecommunication systems, electronic games, and the Web; huge advances in medicine; CDs and DVDs; nanotechnology; the human genome project and progress in genetic engineering; portable media players, cell phones, and social networks; and so on. The recent pace of change overwhelms me. Perhaps you have heard people say: "Help—stop the world, I want to get off! The world is passing me by…."

Three Brains are Better Than One

I like to think and write about the idea of three brains working together to solve problems and accomplish tasks:

1. **The unschooled (naive, intuitive) human brain** (Gardner, 1991). Think about the learning of language, culture, and ways of dealing with the world that a typical child has achieved before starting kindergarten. The unschooled brain is very capable and in many ways its capabilities put the schooled brain to shame. It prospers in a rich cultural, language, and intellectual environment. On average, children growing up in such a rich environment experience considerably more rapid cognitive growth than less fortunate children.
2. **The schooled human brain** that is developed through formal schooling and self-education based on both the formal schooling and on individual interests and needs. Reading, writing, libraries, and Information and Communication Technology (ICT) are major aids to—indeed, can be thought of as components of—the schooled mind. Schooling helps a person draw on the rapidly growing accumulated knowledge of the human race. In recent years we have made considerable progress in the use of computer-assisted learning and distance learning as aids to developing the schooled mind.
3. **Computer "brains"** built into computers, robots, and computerized machinery. Artificial Intelligence (AI) (in England it is called Machine Intelligence or MI) is steadily growing in its capabilities. Ray Kurzweil (2005) is a world leader in analyzing and forecasting when computer intelligence may exceed human intelligence. (Also see http://iae-pedia.org/Ray_Kurzweil.)

Human Intelligence and Mind

The first two numbered paragraphs given above are about the human brain. The careful study of the functioning, capabilities, and limitations of a human brain has a long history. Quoting Plato:

> When you spoke of a nature gifted or not gifted in any respect, did you mean to say that one man may acquire a thing easily, another with difficulty; a little learning will lead the one to discover a great deal; whereas the other, after much study and application no sooner learns then he forgets… (Plato; Classical Greek philosopher, mathematician, writer of philosophical dialogues, and founder of the Academy in Athens, the first institution of higher learning in the western world; 428/427 BC– 348/347 BC.)

The development of intelligence tests in the early 1900s was a major milestone in the study of human intelligence. Tests were devised that were relatively good forecasters of a person's abilities to learn to deal with complex problem-solving tasks. However, these IQ tests do not provide good information about what is actually going on inside a brain.

Progress in a number of fields has led to the development of non-invasive and minimally invasive ways to "peer" inside a functioning human brain. Computer technology plays a major role in collecting and processing the data from such brain scans. Better instrumentation, faster computers, and better computer programs have contributed greatly to the discipline of cognitive neuroscience.

In recent years we also have learned about human (and other) genes and how some of them relate to cognitive development and disease. We have developed techniques and drugs that can enhance cognitive functioning. This type of research is progressing rapidly; however, it is still in its infancy.

Artificial (Computer) Intelligence

The third of the numbered paragraphs given above is about computer brains and robotics. The first electronic digital computers were called "brains" or "computer brains." One of the driving forces in the computer field has been to develop "smarter" computers. This led to the modern disciplines of artificial intelligence and robotics. Of course, science fiction authors explored the field of artificial intelligence and robots long before the development of electronic digital computers. See http://iae-pedia.org/Artificial_Intelligence.

The discipline of artificial intelligence has taken two approaches to its problems. One approach is to develop computer models of how a human brain represents and solves problems. The goal is to develop computer versions of the neurons and other components of a brain. Slow but significant progress is occurring in developing computer programs that can simulate the performance of parts of a human brain.

The second approach is to focus specifically on a problem to be solved. A good example is provided by the quest to develop a computer system that could play chess better than a human chess expert. This was achieved in 1997 by use of "brute force" methods. The IBM computer system that beat the world chess champion Garry Kasporov (Computer History Museum, n.d.) could analyze 200 million board positions per second. That is **not** how a human payer plays chess. The very best of human chess players can only analyze two or three board position per second. Good (human) chess players have learned to quickly decide which board positions to analyze. Their brains have been trained to make such decisions at subconscious level.

The word *artificial* in AI was a provocative choice. I grew up in a world that included trains, cars, trucks, bicycles, airplanes, and automated factory machinery. It never occurred to me and my peers to think of such tools as "artificial muscle." I learned to routinely use artificial muscle and fully integrated its use into my everyday life.

Contrast this with AI. Many people are greatly concerned about integrating AI and other computer capabilities into our everyday lives. This is despite of the fact that this integration has been gradually occurring over the years. All of us routinely make use of the progress that is occurring in AI and in robots that include some AI capabilities.

The Future

Both cognitive neuroscience and computer technology are now emerging from their infancies. Research and development in cognitive neuroscience, medicine, and genetics will lead to better functioning brains. Research and development in information and communication technology will lead to smarter, much more capable computer systems and robots.

Computer futurists such as Ray Kurzweil use the term *technological singularity* when discussing the time when computers will become "smarter" than humans. See http://en.wikipedia.org/wiki/Technological_singularity. Kurzweil believe that will occur by approximately 2045.

In a February 2011 Jeopardy game contest between an IBM computer system named Watson and two human expert players of the game, Watson won. The computer system accepted voice input from the human asking questions. The computer system did not have a human-like understanding of the meaning of the questions being asked, but it could quickly draw upon a huge databank of the types of information being sought in the questions and then match questions with the appropriate stored data. See http://i-a-e.org/iae-blog/game-of-jeopardy-computer-versus-humans.html.

Many of us are awed by student performance in national spelling contests and by human performance in quick recall memory games. Such human skills are developed through many years of intense practice. In my opinion, such education is a mostly a waste of human potential.

Educational Game Changers

There are a steadily increasing number of problems and tasks in which computers and computerized machinery are now more capable than humans. A simple digital wristwatch and the now commonplace Global Positioning Systems provide good examples. The development of automated aids to the human mind and body continues at an accelerating pace.

Young children readily adapt to the changes that have occurred in the past. After all, everything is new to a newborn child. All of us adults have marveled at how children seem to thrive in the world of computer-based games and tools. However, much of this thriving does not involve deep learning with understanding. Rather, it provides children (as well as many adults) with aids to entertainment. It does not help to develop the knowledge, wisdom, and foresight that are essential to productive and responsible adulthood in a rapidly changing world.

Our institutions of higher education have made progress in integrating computational thinking and the tools of Information and Communication Technology (ICT) into a wide range of disciplines. However, progress at the precollege level has been slow and remains slow. The National Education Technology Standards for precollege students developed by the International Society for Technology in Education more that 20 years ago have not been nearly as widely implemented as ISTE would like (ISTE, n.d.). The basic ideas of computer-aided problem solving have not been integrated into the precollege curriculum, instruction, and assessment. A great many college students face challenges of learning computer uses that could have been met and overcome during their precollege days.

Of course, similar statements apply to students learning about their brains, progress in cognitive neuroscience, and progress in many other disciplines. The totality of accumulated and accessible human knowledge is growing at a stupendous rate. Our current educational system seems mired in using the new technology and knowledge to continue to implement curriculum content that is out of date and not designed to deal with the current and steadily increasing rate of growth of accumulated human knowledge.

The types of educational game changers that are needed are not easy to implement. Perhaps the most fundamental challenge is for teachers, curriculum material developers, and curriculum designers to learn to think in terms of using three brains (unschooled, schooled, and computer) instead of two brains (unschooled and schooled) . It is not easy to learn to think in terms of the capabilities (and limitations) of a computer brain that is steadily growing in capability. It is not easy to learn to think in terms of how to make effective use of a computer brain in conjunction with one's unschooled human brain and one's conventionally schooled brain. In recent years, the term computational thinking has emerged as a description of a human brain solving problems and accomplishing tasks using a combination of human and computer brains. My belief is that computational thinking will be a unifying theme as the future of education unfolds. See http://iae-pedia.org/Computational_Thinking.

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At the University of Oregon he taught in the Mathematics Department, served six years as the first Head of the Computer Science Department, and taught in the College of Education for more than 20 years.

His professional career includes founding the International Society for Technology in Education (ISTE) in 1979, serving as ISTE's executive officer for 19 years, and establishing ISTE's flagship publication, *Learning and Leading with Technology*. He was a major professor or co-major professor of 82 doctoral students. He has presented hundreds of professional talks and workshops. He has authored or coauthored more than 60 academic books and hundreds of articles. Many of these books are available free online. See http://iae-pedia.org/David_Moursund_Legacy_Fund.

In 2007, Moursund founded Information Age Education (IAE), a non-profit company dedicated to improving teaching and learning by people of all ages throughout the world. See http://iae-pedia.org/Main_Page#IAE_in_a_Nutshell.