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Humans using machines, humans as machines: Implications for teaching and learning[1]

David Leech Anderson
Illinois State University

What is the relationship between computers and human beings? Whether or not humans are essentially computers, as some theories assert, learning does involve "information processing." Some educational methods (computer-based and otherwise) require students to handle information in a mechanical way that undermines both the development of critical skills and a genuine understanding of the material. This essay is a reflection on the ways in which computers in education can undermine student learning, especially in the development of advanced cognitive abilities, and the ways in which it can greatly enhance it, by providing challenges that foster critical analysis and genuine understanding. Inspiration is drawn from Neal Stephenson's novel, *Diamond Age*, and his belief that students ought to live "interesting lives" and be "subversive." Examples of interactive virtual learning experiences are drawn from David Leech Anderson's work with *The Mind Project,* a research and curriculum project in the cognitive and learning sciences.

Keywords: computer-aided instruction, educational technology, The Mind Project, Turing Test, Ray Kurzweil, Neal Stephenson, subversive, virtual labs

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Introduction

I am a philosopher and a cognitive scientist; I have one foot in the humanities and one in the sciences. When I teach philosophy, the central method is to pour over the details of primary texts with my students using a piece of chalk and a chalkboard. I also teach cognitive science. When I do, central elements of the curriculum are interactive, computer-based virtual experiences which I have spent the past decade helping to produce as Director of *The Mind Project* (Anderson, 2002 to 2008). The students' primary instructor in those contexts is a *machine*.

From the time that I first entrusted my students to the care of a machine, I have been exercised by the worry that this is ultimately a pact with the devil and that I have sacrificed my most deeply held convictions and sold my soul to a master that will ultimately devour its subjects. What follows are reflections on the human-machine relationship and how I have (tentatively) come to peace with this homo-machina collaboration.

The Relationship between Computers and Humans

How are we to understand the relationship between technology and humanity? And in particular, how are we to understand the relationship between computers – the quintessential technology of the 21st century – and human beings (Wiener, 1948, pp. 57, 96.)? In considering the role that computers might play – for good or for ill – in the intellectual development of students, it is difficult to avoid some of the deeper, more metaphysical questions about the nature of human cognition and the relationship that human intelligence might bear to the "artificial" intelligence exhibited by computers today and promised for the future.

In Spring of 2008, I spent a delightful day with Ray Kurzweil, a brilliant engineer and a famous futurist who predicts that by 2029 there will be robots as intelligent as humans and ten to fifteen years after that it will be possible to download your "mind" into a computer-controlled robot which will make you immortal. If the robot breaks down, just replace the parts; if the software becomes corrupted, just re-install the back-up copy that will be wirelessly saved every three minutes for your protection. You might lose the last three minutes of your mental life, but once the software is reloaded, you will be *identical to* that version of yourself (i.e., you'll be the *same person*) that existed a mere 180 seconds ago (Kurzweil, 1999 and 2005).

Some people reading this are young enough that if Kurzweil's predictions are accurate, these readers will live forever. Nice work if you can get it. But are these predictions reasonable? There is a long and fascinating history of research and speculation into these issues (Wiener, 1948; Moravec, 1988). Suffice it to say that there are countless technological breakthroughs that would have to be made to accomplish these goals and most experts in artificial intelligence are not as sanguine as Kurzweil about their likelihood, especially in such a short period of time; furthermore, the technology will be the easy part compared to settling the deeper metaphysical questions about the essence of personhood and the tracking of "personal identity" through time and through "body transplants" (Phillips, 2000). What is important for the current discussion is not the accuracy of Kurzweil's predictions, but rather the powerful influence of the theories of mind and person that he is presupposing.

Kurzweil is assuming that *you* are fundamentally computer software. This view begins with the widely held assumption that your mental states (your beliefs, desires, commitments, pains, fears, and hopes) play a central, constitutive role in your identity as a person. It is then postulated that those mental states are reducible to the functional states of your brain, which are information processing states implemented in the neuronal signals in your brain that can be read off of the firing rates, weighted connections, and dynamic interactions of clusters of neurons. Kurzweil's claim is that these essential features of your brain can (in principle) be captured as input-output functions and uploaded into any machine capable of implementing those functions. So long as the machine states of the robot play the same *causal role* as those biological states in your brain and central nervous system, then your mental states will be preserved. This theory of mind is most descriptively referred to as the "computational theory of the mind" and is a species of a broader theory known as "functionalism." Functionalism comes in many flavors (Levin, 2004; Anderson 2003) and has been (arguably) the most popular theory of mind among analytic philosophers and cognitive scientists for the past thirty years.

What are we to make of this theory that humans are not simply influenced by computers, they *are* computers (and in something more than a mere metaphorical sense)? How plausible is this claim? Personally, I am not convinced. Unquestionably, the human brain does perform "information processing" tasks. Very few would deny that the brain states which are implicated in my belief that "There is a shrub in the yard" do, indeed, *carry information* about the current physical state of the plants in my yard. But that is a far cry from saying that my belief *reduces* to a computational state. Nonetheless, even if functionalism ultimately fails, there remain good reasons why so many researchers in cognitive science have had successful research programs built on the foundation of this particular model of the human mind. Even if it is false, it will likely turn out to be false in ways sufficiently subtle that the final truth will retain vestigial features of the functionalist picture as some part of the story, since mental states do (among other things) "carry information" about the world. Further, I suggest that insights can be gained by tracking the various ways in which both humans and machines "process" information – the ways in which human teachers and students handle information (sometimes intelligently, sometimes "mechanically") and the ways in which machines do the same (Wiener, 1948). Ultimately we are seeking insights that help us more successfully to promote rich, flexible, expansive intelligence in the classroom and in our lives.

Diagnosing Some of the Failures of the US Educational System

In 2003, the Organization for Economic Cooperation and Development (OECD) conducted a comprehensive study of the "literacy" of fifteen year olds in forty-nine countries. Called the Program for International Student Assessment (PISA), this study sought to measure students' ability to apply knowledge in real-world situations. The OECD identified three levels of accomplishment in the critical area of "problem-solving," with the highest being level 3.

Level 1: Basic problem solvers
Level 2: Reasoning, decision-making problem solvers
Level 3: Basic reflective, communicative problem solvers

The students were given real-world problems to solve and their success rate placed them into four categories: The lowest category were those students who did not even reach Level 1, followed by those who only achieved Level 1, those who achieved Level 2, and those who achieved the highest Level 3.

According to this report, to be competitive in the world's 21st century economies, workers will need skills which place them in the top two categories. By that measure, in 2003, fifteen year olds in the USA ranked 29th in the world in percentage of students who met the Level 2 threshold. US students are not in the company of those nations with the highest scores (Finland, Korea, China, Japan), rather they rank immediately below Latvia and the Russian Federation. And the vast majority of countries who rank ahead of the US, spend considerably less per student on education.

Some commentators who were shocked at the high percentage of US students in the lower two categories, insisted that surely the US excelled in the percentage of students who qualified as the "best of the best" (Level 3). Unfortunately, measuring only the percentage of students reaching Level 3, the US fares only slightly better with a rank of 25^{th} in the world.

There are undoubtedly a wide range of explanations for why US students fare so poorly in problem-solving tests and I do not pretend to offer anything like a definitive analysis of the problem. Nonetheless, I do believe that it is reasonable to suggest that problem-solving, like many other higher order cognitive functions, is not a set of facts to be memorized but a complex skill that can only be acquired by effective engagement with increasingly challenging problem-situations. Creating learning environments which consistently provide students with the opportunity for such cognitive engagement is no small task. In the science of learning literature, this goal is often described as one of "transference" (Bransford, J., Brown, A., and Cocking, R., 2000). Learning to solve one particular problem is a relatively insignificant accomplishment unless that skill generalizes and thus "transfers" to a wide range of other related but not identical problems.

The primary point of asking science students to conduct experiments on bread mold is not that the idiosyncrasies of bread mold are of particular importance to life in the 21^{st} century. Rather, bread mold is simply an occasion for them to learn the scientific method and to exercise the higher cognitive faculties required in its application. While the scientific method consists of implementing a relatively short list of basic activities – identify a research question, design and conduct an experiment, gather data, interpret data, draw salient conclusions – it is notoriously difficult to create a classroom activity so that students understand the significance of each step in the process and actually master the broader cognitive skills of which this one experiment is only an instance. The goal is not primarily to convey information about bread mold but to impart skills which will "transfer" to the next science experiment as well as to puzzles in other domains that also require disciplined reasoning.

Not only is it difficult to achieve this kind of transference it is often difficult simply to recognize whether or not you have achieved it. Instructors are often chagrined to discover that their students who seemed to have done so well on the first experiment – who seemed to demonstrate a firm grasp of scientific reasoning – are shown to have done no such thing as they ineptly and mechanically attempt to impose features only accidental to the bread mold case onto the next experiment, say, studying the nature crystals.

Computers and Humans Behaving Mechanically

Distinguishing genuine comprehension from a mechanical simulation of it in the case of students (Roberts, 2002) bears relevant similarities to distinguishing genuine intelligence from good mimicry in the case of machines. And here it doesn't matter where you stand on the computational theory of mind. Rountine, mechanistic responses to complex situations is rarely evidence of genuine understanding. That is why Alan Turing, in his famous "Turing Test" for machine intelligence (Turing, 1950; Anderson, 2004), sought a method for evaluating behavior that would ferret out mindless, mechanistic behavior and only judge as intelligent those performances by machines that were flexible and sensitive to nuance and subtlety.

Notoriously, though, computers do not yet come close to passing the Turing Test and their performance continues to be recognizably mechanistic. If we can't build an intelligent computer, if we can only program pre-determined outputs for narrowly prescribed inputs, it may be that educational software, no matter how fancied up with Technicolor and 3D animations, will be limited to a mechanical feed-back system which can only serve to encourage simple, mechanical behavior in students. In that case, computers would seem to be the wrong tool for helping students to achieve Level 3 reasoning and problem-solving skills – not to mention a rich, nuanced understanding of the scientific method. If that is the case, then leaving computers out of the classroom and having humans do 100% of the teaching may be the only reasonable course of action.

This assessment is, of course, overly simplistic. In the first place, our conception of the "mechanical" should not be so narrow as to apply only to machines. Long before the computer was a gleam in the eye of any human being, generations of teachers had settled on the mechanical recitation of what were presumably educationally beneficial algorithms as the preferred method of instruction. "Repeat after me," was the mantra heard by many a student whose school days were filled with pedantic drills of alphabet recitations, arithmetical tables, and grammatical declensions all reinforced by an automatic feedback system (ruler-swats to the wrist) that rivals any contemporary computer system. Keeping machines out of the classroom is no guarantee of enlightened, non-mechanistic instruction.

Further, while narrowly mechanical behavior in human beings is inadequate for many intellectual challenges, mechanistic modes of instruction are not without their place. The deficiencies of U.S. students with respect to Level 3 problem-solving is not simply the result of too little exercise of the higher-order cognitive skills. It is also a result of too little rigor in mastering the "mechanical" dimensions of education. Reality has structure – mathematical structure, logical structure. Higher cognitive reasoning requires the ability to take these structures as objects and to manipulate them in thought. It requires the ability to compare, contrast, and integrate one abstract object with another; it requires the ability to discern when some particular piece of reality reflects a particular mathematical structure and when a particular line of reasoning is an instance of a particular logical structure.

Some might think that software that mechanically *drills* students to master certain content is pedagogically unenlightened and is the instructional equivalent of slaps to the wrist with a ruler. It need not be the case. Computers do implement algorithms; but so do flash cards. Mastering addition tables is inevitably a mechanical process. A computer is not an unreasonable tool to use to inculcate these skills. In fact, it can make the whole process more fun and engaging and make the entire enterprise more *humane*.

The Greater Danger of Computers in the Classroom

I am convinced that computers pose the greatest threat not when they are being obviously mechanical in their operation, but when the goal is for them to be anything but. One of the features of computers most prized as an information-delivery-system is its capacity to modify text-based information – which has, since the invention of writing, been a static method of conveying information – so that it becomes a dynamic, interactive system which can respond to a student's curiosity. This would appear to be a natural support to the much praised inquiry-based instruction which focuses on the students' responsibility to direct their own path of discovery and learning and eventually to apply that learning in new domains (Hudspith, B. and Jenkins, H., 2001). As a student's thoughtful inquiry causes her to question what lies beyond the content available in the primary text, all she need do is click on a hyperlink . . or continue to follow the slides of a powerpoint presentation . . and she will go down the path of critical inquiry, just as serious researchers have always done. Or will she?

The Mind Project employs a number of interactive web based tools to deliver learning materials in the field of cognitive science. Having committed considerable time and energy (not to mention tax dollars) to the creation of computer-based instructional materials for this project, I would like to believe that the incorporation of hyperlinks, videos, computer simulations, and the like would automatically produce the cognitive virtues and the mastery of content that is the goal of such instruction. I fear such may not be the case. I am convinced that one of the greatest threats to effective instruction today is the degree to which the content students receive is "pre-processed" and that the road of discovery which they travel varies between the equally unsavory destinations of "pre-packaged and pre-ordained results" and "unreliable Internet drivel".

The very devices for packaging and manipulating digital content that seem most ideally suited to encouraging the exercise of critical skills can easily turn into a formidable obstacle to their acquisition. A student's ability to analyze and digest content on her own can be all but derailed by the instructor's willingness to reduce the content to a slide with four bullet points. While it is tempting to lay much of the blame on the medium (e.g., Powerpoint, html & hypertext), the same unhappy results can also be achieved with old-fashioned paper handouts. Anything that offers pre-digested, digital chunks of content that substitute for reading and struggling with primary sources can deprive the student of the opportunity to engage in the very cognitive processing that *ought to be* a central goal of education. While it can be done in any medium, the temptation to pre-process is especially difficult to resist when using digital, computer-based instructional tools. An instructor, who is excited about the journey she herself has taken down a particular road of inquiry, will want to recreate that journey for her students.

But creating an interactive, digital re-construction of one's own journey will not necessarily afford students an opportunity to exercise the same cognitive skills that the author exercised when she originally made the journey. An Easter egg hunt where students merely "find" bits of student-friendly, knowledge-mcnuggets may require little in the way of higher cognitive functioning.

The result of this instructional pre-packaging of content is that too many of our students – not only those with high school degrees, but increasingly even those with college diplomas – are capable of little more than re-arranging and re-packing content provided by others or stumbled upon via uncritical Internet searches. They lack the ability to understand content that is in the least complex in its articulation and they are unequipped to distinguish between those sources that are reliable with bone fide credentials and those which are merely convenient and/or visually arresting.

Our students are, indeed, becoming children of the digital age. They are capable of following mechanical operations that specify how certain information-processing activities are to be carried out by appeal to the *formal properties* of that information ("take all of the data in the file labeled 'input.doc' and paste it into the "D" cells in the file labeled "output.xls"). Unfortunately, this is no substitute for the critical ability to evaluate *the semantic content*[2] of the information and judge of its reliability, significance, and potential for future benefit. Sadly, the description of what some of our students *are* capable of doing is a description of what many existing (not very complicated) software programs do when they process information. Why are such students lacking in important

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[2] John Searle makes hay out of the distinction between the formal (or syntactic) properties of sentences and the meaning (or semantic) properties of those sentences in his notorious Chinese Room Argument. I use that distinction here for different ends, but the distinction is a related one. See Anderson (2006).

workforce skills? Because they are capable of doing little more than what dumb, obviously unintelligent computers are capable of doing. And since computers will always be a less expensive means for achieving that end, humans whose abilities have peaked with the performance of this kind of operation are obsolete in this economy and not candidates for lucrative careers and possibly not even for a living wage. Sadder still, they are wholly unequipped to live an "examined life," enriched by critical reflection on one's most deeply held convictions and one's formative life choices.

Neal Stephenson's Philosophy of Educational Technology

We have been asking how computers might be used in education in such a way that they do not promote *narrow, didactic, mechanical* thinking but rather foster *rich, imaginative,* and *nuanced* cognition. As I have struggled with these questions, there has been no one – no philosopher, no expert on pedagogy, no cognitive scientist – who has inspired me more than has Neal Stephenson, poster-child for the cyberpunk generation and science fiction novelist extraordinaire.

Stephenson's remarkable novel (1995/96), *The Diamond Age: A Young Lady's Illustrated Primer,* serves as an extended exploration of the questions raised in this paper. It is a thoughtful reflection on technology's potential for influencing humanity. It tracks and comments on the possible impact of a nanotechnological revolution on humanity writ large (in the form of social units and cultural identity) and it does the same on the impact of a revolution in educational technology on one five year old girl. I will focus on the young girl.

The protagonist of the novel is Nell, a girl of five who is in a dysfunctional, physically abusive family situation. Nell has an older brother, Harv (Harvard), who never escapes this environment and comes to a sad end. Nell, on the other hand, happens upon a "book" that is actually a computer powerful enough to create virtual environments on the pages which not only teach Nell much academic knowledge, but also nurture her creativity, tutor her to be a brilliant strategist and problem-solver, and even teach her much wisdom about life drawn from many cultures.

For example, through the character of a mouse ("Dojo") who is a martial arts master, she learns everything from humility, to self-defense, to proper nutrition. And this is just one tiny portion of the instruction she receives – beginning before she is old enough for primary school. When all is said and done, this "computer aided instructional device" is the most important teacher of this child from age five to seventeen. Nell starts out as a casualty and ultimately becomes a warrior, a brilliant programmer, a stateswoman, a general, and an inspirational leader. Like the nanotechnological machines that produce virtually all industrial and consumer products in his fictional world, Stephenson's fertile mind produces so many compelling ideas about human learning that it would take a volume, not an article, to explore them. I will briefly discuss two *leitmotifs* that have been of most profit to me.

One of the novel's most creative and successful characters is Lord Alexander Chung-Sik Finkle-McGraw who did poorly in traditional schools: "The coursework was so stunningly inane, the other children so dull, that Finkle-McGraw developed a poor attitude" (Stephenson, 1996, p. 20). Fortunately, Finkle-McGraw spent little time in school as his parents home-schooled him and exposed him to a wide range of fascinating experiences that nurtured his mind and spirit. He grew to have the kind of flexible, supple mind that Stephenson associates with genuine intelligence and the kind of daring attitude towards life that gave him the courage to take the risks necessary for greatness.

Stephenson identifies two primary ingredients necessary for producing a mind and outlook like Finkle-McGraw's. The first is a property shared by one of the other main characters in the novel, John Hackworth. Like Finkle-McGraw, Hackworth is not just a competent programmer, he is a gifted hacker. When Finkle-McGraw and Hackworth are discussing what distinguishes the rare, gifted programmer from the merely competent engineer, they alight on the simple, even innocuous characteristic possessed by most of those who prove so gifted – they have all led "interesting lives." Finkle-McGraw says:

> This implies, does it not, that in order to raise a generation of children who can reach their full potential, we must find a way to make their lives interesting. And the question I have for you, Mr. Hackworth, is this: Do you think that our schools accomplish that? Or are they like the schools that Wordsworth complained of? (Stephenson, 1995/96, p. 24)

They conclude that schools in their time, as in Wordsworth's, do *not* promote "interesting lives."

Finkle-McGraw eventually commissions Hackworth to create an educational computer to provide the essential ingredients of a truly enriching education, so that he can give it as a present to his granddaughter so that she will not suffer through a dull and uninspired life which would otherwise be her fate if her education were the product of the schools of the day. So the first challenge confronting Hackworth is to create an instructional computer whose tutoring and virtual experiences will ensure that its user has an "interesting life."

The second property that Finkle-McGraw identifies as essential for an enlightened education comes as a complete surprise to Hackworth. As soon as he hears it he recognizes that it is indeed the essential ingredient that was lacking in his own education. He believes that it is because he lacked this ingredient that he has remained a paid employee and has not built his own company (like Finkle-McGraw). The ingredient is *subversiveness.*

> Finkle-McGraw couldn't prevent his granddaughter Elizabeth's parents from sending her to the very schools for which he had lost all respect; he had no right to interfere. . . But why not give her a gift that would supply the ingredient missing in those schools? That ingredient was subversiveness. Lord Alexander Chung-Sik Finkle-McGraw, the embodiment of the Victorian establishment, was a subversive. He was unhappy because his children were not subversives and was horrified at the thought of Elizabeth being raised in the stodgy tradition of her parents. So now he was trying to subvert his own granddaughter. . (Stephenson, 1995/96, pp. 81-82)

Subversiveness is the second *leitmotif* that we will explore. To help Hackworth to understand the role subversiveness might play in a child's education, Finkle-McGraw sends him Coleridge's poem, "The Raven," with a note that includes this comment:

> Coleridge wrote it in reaction to the tone of contemporary children's literature, which was didactic, much like the stuff they feed to our children in the "best" schools. As you can see, his concept of a children's poem is refreshingly nihilistic. Perhaps this sort of material might help to inculcate the sought-after qualities. (Stephenson, 1996, p. 83)

It may be something of a dramatic flourish to call this sought after property, "subversiveness." If we aren't careful, it could easily be reduced to something no more substantive than a bumper sticker that reads "Question authority!" That

Stephenson is thinking of something quite substantive that is relevant to our present concerns, is shown in his pre-occupation in the rest of the book with the importance of being able to handle subtlety and ambiguity. He has one important character say:

> The difference between stupid and intelligent people – and this is true whether or not they are well-educated – is that intelligent people can handle subtlety. They are not baffled by ambiguous or even contradictory situations – in fact, they expect them and are apt to become suspicious when things seem overly straightforward. (p. 283)

Being able to handle subtlety and ambiguity takes intellectual maturity. To operate mechanically (or "stupidly") is to assume that everything fits within neat, determinate boundaries – both in the sense that one countenances no "borderline cases" and in the sense that one assumes that reality inevitably conforms to whatever categories one is presently using to comprehend it. With this approach, one is simply insensitive to vagueness, fallibilism, and the prospects of a conceptual revolution that might subvert the assumptions one holds most dear. If one is sensitive to these possibilities, then one is open to subversion.

Stephenson exhibits this kind of subversion in a fairy tale that *The Primer* tells to Nell. Rather than finding a Disney-style happy ending in this tale, Nell finds that she does *not* escape the evil stranger who threatens her – she fails miserably in this task; and she is *not* rewarded for being smart and brave, regardless of what clever tricks she attempts. Nell made a mistake early on in the adventure by trusting this dangerous fellow, and now there is no happy ending. After hours of failure all she can do is cry.

Books for young children are not supposed to make them cry. But this interactive book is designed to make Nell wise and enriched in the long run, not merely happy in the short run. Complexity and ambiguity are not to be obscured by trying to fit them into neat, simple boxes; rather they are to be embraced and their nature plumbed, for as long as it takes to force them to reveal their secrets. Stephenson's approach to education is sometimes dark, but it is also effective. Not long after the distressing lesson from *The Primer*, Nell's life is saved as she refuses to fall for the seductive appeals of a real world stranger who intends to do her harm.

In the space remaining, I can't do justice to Stephenson's views on the role of "interesting lives" and "subversion" in education. Nonetheless, I will suggest that they address some of the challenges that we face when machines are allowed to teach our children. I continue to worry that the curriculum projects that currently occupy me inevitably suffer from many of the weaknesses that I have decried in this paper. Even as I will now describe some of the approaches that we are taking at *The Mind Project* to give students "more interesting lives" and that seek to "subvert" their expectations, I know that we will fall short of these ideals. To quote an earlier passage of this paper "creating an interactive, digital re-construction of one's own journey will not necessarily afford students an opportunity to exercise the same cognitive skills that the author exercised when [making] that journey." Yet in this business, if one never risked hypocrisy, one would not live a very interesting life. So risk hypocrisy I will.

Making Students' Lives Interesting and Subversive

Reading a great novel can transport one into exciting places and times; reading a great academic book can stretch one's mind in exhilarating ways. So it would be a stupendous mistake if we were to continue the trend of fostering educational practices that replace books with Powerpoint slides or any other computer-based activities. But even if we do succeed in keeping the reading of primary texts alive-and-well within our educational system, there remain many other things that make for an interesting life that cannot be done in the pages of a book. Here computers have the possibility of creating a world for students which allows them to *do things* in the classroom – fascinating, compelling things that most people would not otherwise do at any time in their life. For example, *The Mind Project* is currently developing virtual experiences which will enable middle school and high school students (as well as college students) to enter fascinating worlds and (for a moment) to "live" fascinating lives. Among the virtual experiences in development are three that transport students into the world of neuroscience research as they become:

- An endovascular neuroradiologist performing a coiling procedure on a patient who has an aneurysm in the brain
- A neurosurgeon implanting radio-controlled electrodes deep within the human brain to stimulate certain neurons which then eliminates symptoms of Parkinson's disease and other neurological deficits.
- A neurobiologist performing experiments on rats that may help to solve some of the mysteries surrounding the role of the neurotransmitter, dopamine, in addiction, Parkinson's disease, and other illnesses.

These modules will teach the students a great deal of "information" about what we currently understand about the workings of the brain. However, they are intended to do a great deal more. They are intended to inspire by putting student and teacher alike into the midst of current scientific debates. This is important because science teachers are leaving the profession after an average of about 5.5 years of service and too few students are entering careers in science, technology, engineering and math (STEM). One reason is that that neither students nor their teachers are being engaged in "real" science – they rarely (if ever) get to experience the excitement of battling over controversial theories and the drama when a groundbreaking experimental result “subverts” established conventions. Science is not a list of facts; it is a methodology, a process, a way of life. Too often students are being taught the history of science – packaged “facts” about what the discipline knew ten years ago, when the textbook was first being written – rather than being thrown into the midst of *current* science. Teachers and students will love what they are teaching and learning when they are not simply importers and exporters of information, but are scientists struggling to solve the mysteries of the universe. The virtual experiences offered by the Mind Project are designed to take teachers and students into the world of a research scientist and give them the opportunity to fall in love with that kind of a life. It is our hope that these experiences will go a little way towards making their lives more “interesting.”

It would certainly make one’s life interesting if one could become a brain surgeon. While few actually get the opportunity, it is a mind-expanding experience for those who do. In virtual labs currently in development by the Mind Project, students will become brain surgeons – at least for a few days. They will implant stimulating electrodes and chemical microsensors into a virtual rat’s brain and test theories about the nature and function of dopamine, a neurotransmitter that has a role to play in everything from the body’s “reward” system (such as pleasure) to the proper functioning of the motor systems (such as arm and leg movement). Students will perform experiments on the rats to learn about dopamine’s role in cocaine addiction and to explore recent controversies about the mechanisms that produce Parkinson’s symptoms.

It is one thing to make life “interesting” by means of such virtual labs. But what of *subversion*? How can subversion be integrated into a curriculum that is often regimented to produce high scores on high-stakes T/F and multiple choice tests? It may seem a meager step, at best, but

The Mind Project is subverting convention (and some would say, common sense) by investing a great deal of time and resources to create a virtual version of experiments *that have not yet been conducted* in defense of a theory about dopamine *that might not even be true*.

The only way to bring students into current debates that are raging within the sciences *right now!* is to create a version of the real world (*a la* Stephenson's "Primer") with all of its unpredictability and the drama of possible failure. Dr. Paul Garris has a theory ("the bucket theory") that challenges orthodox explanations of how it is that Parkinson's patients remain symptom free until 80% of the affected dopamine neurons have died (Bergstrom, et. al 2003 and Sandberg, et. al 2003). This battle is going on in the journals right now. Some people are persuaded by the data Garris has produced in his lab; but the jury is out and more experiments are being conducted on all sides.

We can't pretend to know whether five years from now "the bucket theory" will have become the consensus view, whether it will have been soundly refuted, or whether it will still be a matter of dispute. If the theory is refuted, won't that have made the entire investment a waste of time? We don't think so. Our job is not just to teach "the facts." Our job is to inspire students to dedicate their lives to seek revolutionary insights that might impact humanity in a significant way. Our job is to convince them that the genuine spirit of inquiry is not found in looking back at all of the "right answers" we have thus far accumulated but rather is found in looking forward to that next "inspired question" that might actually subvert the widely praised (and generously funded) status quo.

Students and teachers who become a part of *The Mind Project* learning community will not only learn about the "facts" that presently have earned a consensus in neuroscience; they will join a team of inquirers (from age eight to eighty) who are engaged in an ongoing debate about such topics as the role of dopamine in healthy human motor activity and its failure in Parkinson's patients. It is our goal to have a thriving learning community that provides the online resources and the human support to help people to remain a part of that search and that drama for years to come.

Conclusions

I believe that technology need not de-humanize the educational process. In my most sanguine moments I am optimistic about the possibility of creating interactive systems that, at the right pedagogical moment, can challenge and inspire students in ways that even the most gifted instructors will find difficult to duplicate. But self-deception is not easily avoided and surely the best way to resist the most seductive and destructive aspects of technology is to be always vigilant, scrupulously assessing one's enterprises, and ever ready to reform or abandon those that fail the test of fostering "interesting lives" and encouraging "subversive" engagement.

References

Anderson, D. (2000/2008). *The Mind Project*, http://www. mind.ilstu.edu.

Anderson, D. (2003). Introduction to functionalism. *The Mind Project.* Retrieved May 10, 2008 from http://www. mind.ilstu.edu/curriculum/functionalism_intro/functionali sm _intro.

Anderson, D. (2004). The turing test. *The Mind Project*. Retrieved May 10, 2008 from http://www.mind. ilstu.edu/curriculum/turing_test/turing_test_curric_ long.php.

Anderson, D. (2006). Searle and the Chinese room argument. *The Mind Project.* Retrieved May 10, 2008 from http:// www.mind.ilstu.edu/ curriculum/ modOverview. php? Mod GUI=203.

Anderson, D. (2007). Consciousness and realism. *Journal of Consciousness Studies, 14*, 1-17.

Bergstrom B. and Garris P. (2003). 'Passive stabilization' of striatal extracellular dopamine across the lesion spectrum encompassing the presymptomatic phase of Parkinson's disease: a voltammetric study in the 6-OHDA-lesioned rat. *J Neurochem 87*, 1224-1236.

Bransford, J., Brown, A., and Cocking, R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Committee on Developments in the Science of Learning. Washington, D.C.: National Academy Press.

Hudspith, B. and Jenkins, H. (2001). *Teaching the art of inquiry*. Halifax, NS: Society for Teaching and Learning in Higher Education.

Kurzweil, R. (1999). *The Age of spiritual machines*. New York: Penguin Books.

Kurzweil, R. (2005). *The singularity is near: When humans transcend biology*. New York: Penguin Books.

Levin, J. (2004). Functionalism. In *Stanford Encyclopedia of Philosophy*. Retrieved May 10, 2008 from http://plato.stanford.edu/entries/functionalism

Moravec, H. (1988). *Mind children: The future of robot and human intelligence*. Cambridge. MA: Harvard University Press.

Phillips, W. (2000). *The extraordinary future*. Retrieved May 10, 2008 from http://www.mind.ilstu.edu/curriculum /modOverview.php?modGUI=247.

PISA (2003). OECD programme for international student assessment (PISA), Retrieved May 10, 2008 from http://www.pisa.oecd.org.

Roberts, K. (2002). Ironies of effective teaching: Deep structured learning and constructions of the Classroom. *Teaching Sociolog,. 30*, 1-25.

Sandberg S., Bergstrom B., Venton BJ, Mithyantha J., Wightman R. and Garris P. (2003). 'Passive Stabilization' model of compensatory adaptation during the asymptomatic phase of Parkinson's disease. In J. Kehr, A. Fuxe, U. Ungerstedt, and T. Svensson (Eds.), *Monitoring molecules in neuroscience. Proceedings of the 10th International Conference on In Vivo Methods* (pp. 218-220). Stockholm, Sweden: Karolinska Institutet.

Stephenson, N. (1995/96). *The diamond age or, a young lady's illustrated primer*. New York, NY: Bantam Books.

Turing, A. (1950). Computing machinery and intelligence. *Mind, 49,* 433-460.

Wiener, N. (1948). *Cybernetics: Or the control and communication in the animal and the machine.* Cambridge, MA: MIT Press.

Wiener, N. (1950/54). *The human use of human beings.* Boston: Houghton Mifflin.

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