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The Modalities to Develop an Educational System of Discovery, Innovation and Creativity

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Abstract

The world community, including both advanced and developing countries, modern and ancient cultures, are suffering from a crisis of test orientated, sterile education. During recent decades education theory has been preoccupied with modes of evaluation of students and teachers and has neglected the more central need for modalities that foster creativity, discovery and innovation in students. The role of curiosity and creativity are described as the Empress and Emperor in the Kingdom of Education. This paper holds that the seeds of research have to be planted during the Springtime of children's lives. The essential role of reflection, collaborative research and collaborative learning through small and large group research, reflecting the initiative and interests of the students themselves, is asserted. The crucial attributes that must be cultivated in students are described, keeping in view the aim of education, namely, to foster the discovery, innovation and creativity that allow the creative advance of civilization.

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1. Introduction

Global educational systems are in need of a fundamental transformation and reform. The need to find ways to liberate and cultivate the creative genius of humanity is increasingly felt in both the Chinese and western educational systems. The key imperative is to develop modalities which will foster discovery, innovation and creativity. Educational systems must both cultivate these modalities within the educational system and enrich the modalities of evaluation of students in such a manner as to improve the detection of these capacities that transcend test taking skills.

Educational systems have two fundamental aims: the first is to transfer into the present the accumulated knowledge and discoveries from humanity's collective efforts over prior millenniums. The second function is to cultivate those attributes and values in students which will foster new discoveries, new innovations, and new acts of human creativity in both the realms of science and culture. Current educational systems emphasize the former purpose to the neglect of the latter. If there is an overemphasis upon standardized testing and the development of students as "test taking machines" the deeper imperatives of education will be lost and unfulfilled. For over 22 centuries in China, standardized examinations, in one form or another, have provided a path to officialdom and civil service. These systems added a sense of democracy and impartiality and cultivated a reverence for knowledge and wisdom. However, there was overemphasis upon the past rather than the future, mastering accumulated knowledge rather than making new discoveries and new innovations.

In his book *China's Examination Hell*, Prof. Miyazaki described the long history of China's examination system. While he describes its many positive features, the final evaluation describes how this system led to a focus not only on memorization and mastery of the classics, but an obsession with the past rather than a creative development of the future.

2. The "Needham Question"

Professor Jan B.F.N. Engberts, of the Stratingh Institute in the Netherlands, writes (2009) "Overlooking the history of China, it is particularly the monumental work of Joseph Needham that has shown that in antiquity the technological creativity in the country has been unsurpassed by other ancient civilizations (Needham 1954-2004). But around the 15th century AD virtually all creative technological advances came to a stop with the unavoidable consequences for the economical situation in the vast country. The reasons why this happened (the "Needham question") have not been fully clarified."

It was my personal privilege to know Professor Joseph Needham when he was Master of Caius College, Cambridge University. Professor Needham is the principal author of the 25-volume magnum opus *Science and Civilization in China*. He was also Chairman of the Britain-China Friendship Association, and I was Chairman of the U.S.-China Friendship Association in Seattle. We both had deep respect for the creative genius that the Chinese people displayed in China's glorious ancient history. We also pondered what were those causes and failures that had suppressed the continuous blossoming of that genius. In *The Man Who Loved China* (2008), written by Simon Winchester, the contradiction between Needham's appreciation of China's ancient creative genius and the comparative stagnation in science, engineering and mathematics is described in detail.

3. The Theory of Creative, Synthetic Learning

In 2003, a conference on educational reform in China was held at Claremont Graduate University. I presented the concluding lecture, Creative Synthetic Learning and the Reform of China's Educational System. This speech has been published in Europe, translated into Chinese and published in several Chinese journals. The aim of the CSL theory is to overcome the problem that the Needham question frames.

In the important book *Aims of Education* by the great mathematician and philosopher Alfred North Whitehead, Whitehead asserts that education begins in research, and ends in research. In *Modes of Thought*, Whitehead similarly asserts that "philosophy begins in wonder, and when it has done its job well, the wonder remains." The CSL theory is summarized in the statement: the function of teachers is "to lead students upon journeys of curiosity amid communities of problems, which journeys are resolved in adventures of discovery and generalization of insight." Educational systems must nurture curiosity, which is acute, in the early stages of children's lives and children's education. Curiosity and creativity are like the tight buds of flowers, which unfurl through time into dazzling and brilliant displays. CSL maintains that the seeds of research must be planted in the springtime of children's lives and replanted successively, year after year.

World educational systems must be transformed in such a manner that research parameters are systematically and continuously integrated within the educational curriculum so that the instinct and capacity for research proceeds from lower to moderate to advanced stages. It is a fatal illusion to think that students' educational experience can be obsessed with test taking and mastering past knowledge, and then, if, and when, they become a doctoral student, they are to do world class creative research. The modalities for discovery, innovation and creativity must be omnipresent throughout the entire educational experience.

In formulating a reformed educational system, we must have a clear sense of the attributes which we want to cultivate in students. Those attributes include:

- Integrity and independence of thought;
- Deep and relentless curiosity;
- Coherency of thought;
- Respect for the collective genius that is the legacy that the past bestows upon the present;

- An abiding sense of romance, adventure and delight in discovery;
- Compassion
- Integrative thinking that unites analytic and synthetic modes of thought;
- A bold, courageous and challenging spirit willing to question entrenched intellectual and cultural presuppositions;
- Ability at problem-solving
- Creativity;
- Students who are readers and, moreover, thinkers;
- Imagination capable of envisioning novel phenomena, relationships and modes of orderliness.

Discovery inevitably proceeds from repeated "explosions of curiosity" and relentless "explosions of synthesis of ideas." The journeys of curiosity on which students must be led are most fruitful when those journeys involve communities of related problems. In *Aims of Education*, Whitehead describes the educational process as involving three stages: 1) Romance, 2) Precision, and 3) Generalization. In proposing the systematic integration of research within the entire educational experience, we must recognize the importance of the Art of Generalization. Nothing, whether an abstract entity, like numbers or geometric shapes, or concrete entities like molecules, organic living complex organisms, or cultural creations, exists in insularity. Every entity, whether abstract or concrete, simple or complex, exists within a broader community of being. That is true of what we may describe as intellectual problems. Students must learn how to explore these communities of problems and discern the patterns, orderliness and generalizations that are manifest within such communities. We may say any phenomena P_x is subject to a variety of variables, $\{V_1, V_2, V_3 \ldots V_n\}$ and can exist and develop within a multitude of environments $\{E_1, E_2, E_3, \ldots E_n\}$. Research projects must explore the community of variables and environments within which phenomena exists if a generalization of insight is to be discerned or discovered. Adventures of Discovery that are resolved in Generalizations of

Insight are vital because it is within generalizations that wisdom exists, deductive power is magnified, and a unified understanding of Reality is attained. I will provide some suggestions of communities or sets of related problems to illustrate what journeys of curiosity amid communities of problems could mean in respect to mathematics, physics, chemistry, biology, literature, history, and architecture. A simple example I will reference is an experiment on the Laws of Motion and Laws of Collision for young children. We alter angles, lengths and weights and measure how various types of balls travel down a chute and collide. What are the lengths, speeds of motion and displacement upon collision as a function of these multiple variables? The children are fascinated. Similar experiments and research can be carried out for growing plants, raising fish, chemical reactions and the study of conflict in literature, to cite other examples.

4. Modes of Inquiry

Students also must participate in cooperative, small group research efforts. Research projects can come in a variety of modes: 1) individual research; 2) small group projects; and 3) large group projects. It is important for students to experience each of these three modes. The great mathematician and physicist Sir Isaac Newton said that "truth is the offspring of silence and unbroken meditation." Steve Jobs of Apple gives a modern example of the power of concentrated, focused, contemplative reflection as being the mother of innovation and creation. Some schools in San Francisco have introduced within the curriculum periods of meditation and reflection. The Chinese sage has practiced this truth; but we must also allow students in a modern context the opportunity for reflective, contemplative mental explorations. That is quite different from the stressed and frenzied atmosphere which is so common in today's educational systems, with their obsession with evaluation of students' test-taking capacities, rather than their capacities for creativity, discovery and innovation. Discipline and freedom must attain greater harmony in modern educational systems.

The great German mathematician of the infinite, Georg Cantor, expressed his perception of the crucial role of curiosity in the title of his doctoral dissertation which translates as follows: "In mathematics, the art of asking questions is more important than the skill at solving problems."

In his book *Collaborative Genius*, Keith Sawyer of Washington University describes the universality with which so many of the world's greatest technological advances and innovations, no less theoretical discoveries, arose through collaborative efforts of different scholars and inventors. We note that so many of the world's most prestigious awards for science, including Nobel Prize awards, involve collaborative efforts from scientists from different universities and different countries. Students must be exposed to these small group collaborative research efforts. Students' research should also involve broader collaboration. In particle physics, and the research done at CERN, as well as research in astrophysics conducted by observatories throughout the Earth and space stations, and in genetics, large teams of international scientists are gathering data, coordinating and evaluating it, seeking those patterns in the laws of nature that are manifest in data whose accumulation involves a broad community of researchers.

A contemporary example is taking place at the University of Maryland Baltimore Campus (UMBC), where collaborative learning is encouraged whereby young scholars are both students and teachers to each other. The Meyerhoff scholars within UMBC, who are all encouraged to use collaborative modes of learning and research, have attained a 90% rate of entrance into graduate schools. "Nationwide, most college students who start off in the sciences either change to a different major or don't graduate. UMBC keeps undergrads engaged by including them in research typically left to graduate students." UMBC President Freeman Hrabowski says "We need hands on experiences. We need to be encouraging that curiosity."

Educational systems must integrate research projects in each of these three modes, i.e. individual, small group and large group research explorations. There is also great value in students being required to do research projects in both science and mathematics, and the humanities and culture. The book *Bell Labs* describes how this famous center of scientific innovation encourages and indeed required collaboration and interaction among specialists from different fields. For example, at lunch, mathematicians would have to sit with a physicist, a chemist, a biologist, or an engineer. The interdisciplinary cross-fertilization of ideas has led to tremendous discoveries throughout intellectual history which would not have occurred if Great Walls separated and isolated intellectual disciplines one from another.

In integrating research within the curriculum, the educational system needs some new structures. For example, for each student there may be 6 major research projects within the school year, some in humanities and some in natural sciences and mathematics. As indicated, some research projects should be individual, some small group, and, where possible, some large group in composition. Students must be trained to both reflect individually and collaborate as teams engaged in research, discovery and innovation.

The choice of the topics of these research projects should reflect: 1) the interests and curiosity of the students themselves; 2) the issues in agriculture, industry, science, culture, social development, etc., that are present in contemporary society; and 3) the guidance of the teachers. There should be in the schools a team of teachers who are in charge of organizing and supervising these research projects. There should also be some teachers who are experts in the fascinating history of discovery. When students realize the intrigue and struggles displayed in the history of discovery, they can develop an appreciation of the powers of persistence and imagination. The tales of discovery are to be told as they provide impetus for future discoveries and innovations.

5. Axioms of CSL Theory

The CSL and MDIC educational structures have several fundamental axioms:

A_1 The experience of adventures of research into communities of related phenomena, journeys of curiosity and adventures of discovery both 1) stimulates and 2) sustains processes of learning.

A_2 Discovery requires the development of expertise and precision by immersing students within a specific "nexus of curiosity."

A_3 The capacity for discovery and creativity is enhanced when a student's "nexus of curiosity" is part of a broader interdisciplinary background of knowledge;

A_4 Collaborative research environments enhance processes of both understanding and creative discovery. Dr. Dzirasa at Duke University studies the brain and mental illness. He says "the problems are too complex for one scientist to solve alone. That means the first critical step to success in his lab – and most other labs, he says, is building the right team" (2011).

A_5 For no two individuals P_1 and P_2 are their respective nexus of curiosity identical, i.e. $\neg [N\text{-}P_1 = N\text{-}P_2]$. Each person has his or her own unique nexus of curiosity. Nonetheless, to various degrees, N-P and $N\text{-}P_2$ may overlap or intersect. It is for these two fundamental reasons that both individual expertise evolves during the learning process and mutuality of learning is possible and desirable among people. Teacher/student is a symmetrical, not an asymmetrical relation.

These axioms are fundamental to the process philosophy which underlies Whitehead's *Aims of Education* and CSL Theory and the perspective of Modalities of Discovery, Innovation and Curiosity. The concept of a nexus of curiosity has significance that extends beyond formal education. The teleological activities of all complex, advanced living organisms are defined by the specific nexus of curiosity that defines the persona of the organism. These nexuses of curiosity have a plethora of manifestations whether in science, theology, aesthetics, games (whether athletic, intellectual or chance), literature, drama, natural history, political developments, family events, etc. The personality of an individual advanced organism is defined by the nature of the lures to which the future impels the organism.

The acquisition of knowledge, whether formal or informal, has its foundations within the fundamental nexuses of curiosity which constitute the teleology and purposefulness of humans as students of Reality in all its complexity, diversity and beauty.

During my undergraduate years, I had the privilege of being in a class with a small group of math students who were taught by the coach of the math team which won the Putnam exams, a prestigious award, two years in a row. Our professor gave us a problem which could not be solved until Newton and Leibnitz had invented calculus. He did not give us the solution. Maybe in 1 day we could have mastered the solution, but he sought to have us try to solve the problem which eluded discovery for 2 millennia. At the end of the week, after trial and error, many dead ends and guidance, we came to the solution. But more than the solution, we had discovered the profound difference between learning what was discovered in the past and the process of discovering itself. We were given the gift of experiencing the adventure of discovery. This same gift must be given to students. Recent research in Germany has shown that students of varying levels of ability do quite well when given the challenge of discovering solutions as opposed to merely being told how to solve problems. The eliciting of curiosity, and the act of pondering, are very potent fertilizers for the development of the human mind. We cannot allow that lesson to elude transformation of our educational systems.

6. Adventures of Discovery in the Context of a Lifetime Inquiry

In generating awareness of the issues and challenges facing contemporary society, students should be exposed to and allowed to interact with modern agriculture, industry, scientific institutions and cultural centers. There should be contests within classes, within the school, and among schools, regionally and nationally. In CERN conditions are created that produce cauldrons of creativity of elementary particles, and then there are highly sophisticated detectors to detect the characteristics and trajectories of those particles. Educational systems must create cauldrons of creativity and curiosity. Those systems must have broader modalities to detect and cherish these crucial attributes in students.

A recent report, "Why Science Majors Change their Minds" (*New York Times*, Education Life, November 4, 2011), describes how the over emphasis upon standardized tests, dry formulas and rote learning fail to sustain interest in science, engineering and math in college students. When college students have projects, creative problems and research integrated within their course work, their interest and enthusiasm are not merely provoked but that interest is sustained. The experience of adventures of discovery extends enthusiasm and curiosity throughout a life-time of inquiry. Professor of Education Mitchell J. Chang of the University of California, Los Angeles, points out "We are losing an alarming proportion of our nation's science talent once our students go to college." Professor of Engineering David E. Goldberg of the University of Illinois points out that "It's (the standardized testing path) dry and hard to get through. So if you can create an oasis in there, it would be a good idea." The oasis is the integration of research projects in the standard curriculum.

American educational systems are appreciating the value of collaborative group efforts in learning and research. Group efforts allow students to learn from each other, challenge each other, modify and refine their views and synthesize different perspectives and insights. In so doing, group research deepens and refines understanding and replicates more accurately the processes by which discoveries are made and knowledge advances to higher, deeper and more comprehensive levels.

The Association of American Universities, which represents the largest group of research universities, announced a five year initiative to encourage faculty members to use more interactive teaching techniques. The Dean of Notre Dame's engineering department Peter Kilpatrick indicates that "his engineering school has gradually improved its retention rate over the past decade by creating design projects for freshmen...and, he says, efforts to create more labs in the middle years could help raise it further."

CSL maintains that not only in college but throughout the entire education process, the integration of research both stimulates and sustains interest in the creative advance of knowledge. Integrating research projects and parameters within the educational system does not eliminate the arduous task of transferring the knowledge gained in the past into the present, nor does it eliminate various forms of tests. CSL theory adds to those processes the integration of research parameters throughout the educational experience. It does so in order to foster realization of the second fundamental aim of education, that is, to advance new discoveries, new innovations, and new acts of creativity.

CSL seeks to honor education as an intrinsic and compelling value. Recent trends in our world dominated by commercialism and materialism have rendered education an extrinsic value subservient to shallow careerism. In my nation, higher education is producing the "3 Bs" i.e. barristers, bankers and brokers, rather than scientists, mathematicians, engineers and creative artists. The world needs students motivated by the intrinsic love of knowledge and the human adventures of discovery and creation. The systematic, comprehensive and lively integration of research within the educational experience is the linchpin to restoring – as Chinese moral traditions taught – knowledge and wisdom as intrinsic and dynamic attributes in the process of advancing human civilization.

7. Conclusion

In the conclusion of *Science and the Modern World,* Whitehead advises us: "When man ceases to wander, he will cease to ascend in the scale of being. Physical wandering is still important, but greater still is the power of man's spiritual adventures – adventures of thought, adventures of passionate feeling, adventures of aesthetic experience."

In the Kingdom of Education, Curiosity must be Empress and Creativity Emperor. It is only in such a Kingdom that human civilization will not merely replicate the past with its failures, successes and limitations, but will creatively advance the past to new insights of understanding, innovation, discovery, compassion and justice.

When the CSL theory, seeking to foster the blossoming of human discovery, innovation and creation, asserts that the seeds of research must be planted in the Springtime of a child's life, we must remember that the bud emerges only after the seed is planted and the flower appears only after the bud unfurls.

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