A Nation in Progress

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ABSTRACT

The decay and restoration of civilization depends on food, energy, water, sanitation, and healthcare. These essential elements are built on pillars of education, information, knowledge, and wisdom. The bridge built on these pillars are responsible to pave the way in order to transform untrained minds to responsible adults. This is the bridge of teachers. This essay discusses how the salt of the earth, i.e., the teachers, if supported, empowered, and encouraged, has the power to instill a resplendent sense of the future in our leaders, who were once children, taught and cared by teachers. Professional support, professional development and professional partnerships must be at the heart of programs for teachers. If implemented, teachers can and will change the will and aspirations of students, sow compassion and stimulate their minds to pursue ethical globalization in our ever connected world, to lift many boats. This essay reflects on a tiny sliver of education and suggested professional development for teachers.

A Nation in Progress – Public Education and STEM as Purveyors of Workforce Development (Mitigate Risks from Chronic Job Insecurity)

Shoumen Palit Austin Datta, *externally engaged with US pre-college and post-secondary education for nearly half a century*

PREFACE

It has been 40 years since the release of *"A Nation At Risk"* (1983[1]) but have we succeeded as a society to better mitigate risks due to erosion of erudition, excellence and égalité?

Do we now know any better how to reduce the social anathema of chronic job insecurity? Attrition due to skills gap affects[2] 14%-20% of the nearly 160 million[3] employed[4] adults in the US workforce. For these adults and their families, there may not be any "upside" about career uncertainty[5] as touted by one magazine. Job dissatisfaction may affect ~80% of the employed US adults but job losses due to lack of skills and/or failure to re-skill destabilizes lives of ~20% of the workforce. This Pareto-esque (80/20) dynamics may be due to remediable injustices and fundamental insufficiencies noted in the 1983 report.

Do we have better tools to address chronic job insecurity affecting ~20% of US workforce? Suggestions in this essay are not a panacea for all ills. It is not equally applicable to the entire segment (~20%) of the job insecure workforce. It is neither a quick fix nor an easy approach. It is one solution among many.

We propose a series of tasks to catalyze a combination of convergent efforts, over time, before one can expect any outcomes. The latter should not be a deterrent. The level of difficulty calls for those who are dedicated, astute in building strategic bridges and capable of undertaking the risks that leadership demands. At its core, the leaders must understand why job insecurity as an adult may be inextricably linked to elementary and secondary education. Implementing this suggestion requires intrinsic incisive insight and a desire to pursue a purpose which is greater than merely the sum of its parts.

PURPOSE

The reader may note that the central thesis of this essay is akin to a prescription but not aimed to cure job insecurity. We present ideas for instruments, which, if combined and implemented, may help teachers to become better STEM-informed (referred to as "professional development" in public education). The apparent "gap" between the thinking in the **PREFACE** section (job insecurity of adults) and this section (**PURPOSE**) is not a gap at all but ***causality*** in action. One of the fundamental ***causes*** of job insecurity in adults may be rooted in their inability to re-skill, unlearn and relearn to adapt to dynamic changes. Learning is the domain of elementary and secondary education. Teachers are the quintessential bridge between the life of a student and the adult in the workforce. Public education is the seat of workforce development and teachers are its sentinels. The teacher's perception[6] may often percolate through young lives into adulthood and shape their destiny. The education of a boy may change the destiny of a man. The education of a girl can change the destiny of a nation. The fulcrum of our collective destiny pivots on the teacher. In education, the purpose and prescription must focus on that bridge – the teacher – which connects us to our future.

PRELUDE TO PRESCRIPTION

The resplendent goals of education are still treasured and cherished – to inspire, to create, to find the next Toni Morrison, the next Marie Curie, the next Ada Lovelace. But, in the post-pandemic 21st century there is also an urgent need for kindness, social cohesion and stability in "home economics" for millions. The road from the profound to the pragmatic runs through the teacher, in reality and in virtual reality. Empowering teachers through the accepted practice of professional development (PD) is a K-12 staple.

In the last couple decades, credibility, excellence, and delivery of "free" STEM knowledge has increased exponentially. It may behoove public school districts to use, adopt and adapt professional development to embrace the structure of these opportunities to enhance ***the quality*** of teacher's knowledge. The inspired, erudite and skilled teacher is the major conduit to improving the student's ability to become a lifelong learner, which is quintessential to combat job insecurity as an adult, through re-skilling.

It is an enormous challenge to re-charge the teacher's arsenal of knowledge and tools. There aren't any shrink-wrapped packages. Most teachers do not have the time and energy to take on additional PD. It is critical to provide approved (administrative) time for PD by decreasing operational classroom tasks as well as providing financial assistance (additional remuneration). The infrastructure of the district PD process must provide recognition and supplemental funding for teachers. Resources are always in short supply and state/federal grant funding or private donors may be instrumental (key) for implementation.

PROLOGUE TO PRESCRIPTION

STEM includes but is not limited to information technology. Science and engineering ***principles*** are at the heart of ***causality***. Understanding causes/reasons behind facts and figures are crucial to learning and acquiring analytical (thinking) skills. Using or memorizing facts and figures without the knowledge of its derivation may not be harmful in the short term as long as the technology does not change. Changes in technology are inevitable. The need to change outcomes or modify processes can drive technologies to obsolescence. But, fundamental principles may remain unchanged. Technology is an outcome or "tip" of the proverbial iceberg. Learning new technologies can be quick and often easy but when the technology changes then the "*one trick pony*" syndrome makes it quite arduous to rapidly acquire a different skill (re-skilling as an adult in the workforce). However, re-skilling is easier if the individual can reach into her knowledge base (principles) and re-build the "tip" with relative ease to become proficient in a new tool or technology because she understands the ***causal relationships*** (what causes what and why – it is a key characteristic which is lacking in almost all information technology tools, e.g. coding, programming).

The oxymoronic dilemma at the interface between school and work is the lack of "job readiness" which is blamed for the chasm between principles and practice, the one without the other is merely a tempest in a teacup. Principles and causality are the bedrock of knowledge and science which are salient to developing critical and analytical thinking skills. On the other hand, pragmatic application of technology is the bread and butter of business performance which influences the hiring process and criteria. Skills training in technology is not the realm of public education but may fall within the extended umbrella of K-12 education if school districts develop apprenticeship programs or partnerships with industry for student externships in order to gain hands-on experience in the real world.

Since faster and cheaper is the mantra for the quick and easy path to claim success (irrespective of how thinly veiled that claim may be), the world has turned to information technology for tools. One common example is the proliferation of programming initiatives laced with job opportunities to "code" software. There is no doubt that "code" is embedded in almost all objects and processes we touch. There is no doubt that if programmers can find a suitable job then they may enjoy affluence, even if it is ephemeral. There is no doubt that coding in schools is a shiny frontier which is in pace with the sign of the times. It is a tool, not a science. The science behind the tool is mathematics, often viewed as a mortal enemy. The application behind the tool is an example of event engineering which is convergence of science and mathematics with causality and analyses relevant to use cases (for example, software to order pizza).

PRESCRIPTION WITH A POTENTIAL

The thrust of the **"PRESCRIPTION"** is not to dissuade the diffusion of programming and other tool-based approaches but to induce teachers to increasingly build rigor into every task through causality rooted in mathematics, science, and engineering. Programming is a logic tool which creates infrastructure for software. The logic of information enables actions (data) which the software will execute when asked (command). The structure which creates the logic flow (the "cause" in the Boolean logic) is not in the software. Programming (coding) and software is devoid of causality (there is nothing that is "intelligent" in any piece of software). Causality and its output (the logic framework) is entirely in our brain. Science does not know how to capture such knowledge and experience in a command structure or programming logic (hence, our failure to produce any "intelligent" software). The structure of the logic is an analytical output of the programmer's brain which is the source of the knowledge of the operation (i.e., to create a software to order pizza the programmer must know how to order pizza). What the programmer codes in the software, is exactly what the software in the computer or phone will communicate/transmit. All communication tools and objects are as dumb as doorknobs. Thus, programming is a brilliant tool to transform causality and logic from the brain of the "coder" to a tool, the software program. Bereft of the knowledge of the process (science and engineering) and devoid of creating causal frameworks (mathematics), the brain is nothing but an empty vessel which programming skills cannot improve because it lacks the foundation to build analytical thinking (it may know "how" but not "why").

The thrust of the **"PRESCRIPTION"** is to stimulate creation of programs for technologies which continue to contribute to deliver science as a service for society. For example, biomedical research (molecular biology, genetics, biochemistry, microbiology, virology), medical engineering (physics of devices, remote diagnostics for elderly patients at home connecting home health tools to hospitals), environmental engineering (physics and chemistry of sensors to monitor air, water, food), public health engineering (water quality testing for heavy metals, lead, chemicals, pharmaceuticals), healthcare (wearable devices for heart rate, respiratory rate, pulse rate, and other metabolic signatures for general well-being, stress reduction, control of obesity) and industrial technologies (3D printing, robotics, nano-fabrication, nano-materials, energy, transportation). There is a great urgency for biotechnology and biomanufacturing[7].

The thrust of the **"PRESCRIPTION"** will fall apart unless we inculcate classroom teachers who possess depth of disciplinary knowledge as evaluated by the stamp of credibility from suggested research universities (see Table 1). Excellence begets excellence. Equating excellence with elitism is an excuse to make the lowest common denominator an acceptable standard in the name of equity, in the name of "the shoddy and the second-grade masquerading as good enough" (A Nation At Risk, 1983).

The thrust of the **"PRESCRIPTION"** will diminish, dwindle and perhaps even die if we fail to follow up the emphasis on principles with practice, that is, exposing students to industry partnerships (where hiring managers act as gatekeepers). The teacher-assisted classroom effort to sow principles must meet with practice where students can experience ***the continuum of principles and practice*** (for example, Cisco Networking Academy which pioneered the practice of creating telecommunications networks (using the internet) by high school students[8] in 1995-1996, based on core physics, mathematics and engineering taught by highly qualified classroom teachers).

The thrust of the **"PRESCRIPTION"** is to build "job readiness" in the context of workforce development for highly skilled (high paying) jobs without diluting the central mission of educational excellence. The latter is key to re-skilling if and when technologies may be replaced by digital transformation tools.

The thrust of the **"PRESCRIPTION"** is to mitigate future risks from job insecurity in the adult workforce by providing the support for teachers to help K-12 students to acquire the necessary level of rigor.

It is indeed a very "long walk" to find *freedom*[9] from the shackles of job insecurity which has chained a significant portion of our society and working adults. Dreams of a resplendent future will remain a mirage without investing in K-12 teachers. Nostalgia about halcyon days and the certainty of the past has been overtaken by the uncertainty of the future. Professional development (PD) in public school districts must reinvigorate its sluggish *modus operandi* to prepare its students to meet the challenges of that unpredictable future. Teachers are our only hope. Therefore, PD leaders must actively re-think the bigger picture beyond the horizon of the school district and the paramount importance of PD outside the four-walls of the classroom, far beyond the canonical *box*, far beyond the corner grocery store and far beyond the countries that border the North American solipsistic bliss. PD must evolve as a vibrant and creative multi-dimensional innovative engine to spread social harmony not only by eliminating illiteracy and innumeracy, but as a purveyor of growth through economic development.

THE PRESCRIPTION: PROFESSIONAL DEVELOPMENT IN PUBLIC SCHOOL DISTRICTS

The suggestion mentions specific programs, institutions and organizations for explanatory purposes. The views expressed are solely due to the author and is neither in consultation with nor endorsed by named institutions and/or organizations. At this time, it is unknown whether public school districts and named institutions may want to engage in constructive altruism and indulge in magnanimous collaborations to catalyze excellence in professional development for teachers, in order to improve student performance.

The **"PRESCRIPTION"** is relatively simple, at least in principle (in the perspective of the author who is acquainted with US K-12 public education but engaged in an external capacity, for the most part). **It is suggested that K-12 teachers take online courses offered by the most advanced research universities** (Table 1). Teachers can choose their courses but may also consult with an academic advisor if the course must align with the teacher's classroom teaching duties. Most universities will not offer any recognition (credits, for taking an online course). Recognition for the teacher is crucial, as a measure of personal growth. Evaluation of the teacher's performance (by the institution offering the course) is an essential element for the process of professional development in public school districts. The latter is an open question to be negotiated, preferably collectively, between the two groups: school districts and research universities. Course specific tests created by the higher institution must be the criteria for teacher evaluation (using online testing). Teachers must be allowed time to prepare and must be remunerated.

Table 1: Suggested Research Universities (most offer free online courses in subjects relevant to K-12 education)

	INSTITUTION	INFORMATION (ONLINE COURSES)
00	MIT	https://ocw.mit.edu/about/
01	Harvard	https://pll.harvard.edu/
02	Princeton	https://online.princeton.edu/courses
03	Yale	https://oyc.yale.edu/courses
04	UC Berkeley	https://extension.berkeley.edu/online/
05	Stanford	https://online.stanford.edu/free-courses
06	Cal Tech	https://onlineeducation.caltech.edu/
07	Cornell	https://sce.cornell.edu/courses/programs/online
08	University of Pennsylvania	https://www.onlinelearning.upenn.edu/
09	University of Chicago	https://www.edx.org/school/uchicagox
10	Johns Hopkins University	https://www.jhu.edu/academics/online/
11	Brown University	www.brown.edu/academics/undergraduate/open-curriculum
12	Dartmouth University	https://www.edx.org/school/dartmouthx
13	Columbia University	https://online.columbia.edu/moocs/
14	Oxford University	https://www.conted.ox.ac.uk/
15	Cambridge University	https://advanceonline.cam.ac.uk/

CAVEATS (Part A - relevant to professional development for teachers)

[0] Teachers and districts may prefer local colleges which may adapt content for PD (quality?).

[1] Teachers may need an advisor familiar with advanced academic course content to [i] sort courses which are relevant to subjects taught by the teacher and [ii] guide the sequence/stream of courses.

[2] Evaluation of learning through university-directed online testing is the challenge (the agreement).
[a] The university must agree to prepare course-specific tests and host online testing environment for the teacher (to record teacher performance with respect to PD). A negotiation between the district and university is necessary for the university to agree to [i] provide a test (for a fee?), [ii] offer some form of recognition for the teacher (for a fee?), [iii] establish guidelines for online test and location monitoring (for high volume of computer based testing, the task may be outsourced (for a fee) e.g., Pearson VUE).

[3] District-dependent strategic and pedagogical guidance may be necessary to use the learning and content acquired by the teacher. Translating the value of knowledge from teacher to student is not always a matter of direct delivery. District-based STEM support will be necessary to translate the knowledge to strengthen principles and find practical paths to inculcate new skills, if appropriate. Case by case analysis may be more productive compared to blanket actions or "one-shoe-fits-all" protocols.

CAVEATS (Part B – beyond professional development for teachers: translating value from teachers to students)

[0] Inspired by content from the most advanced universities and creating connections with higher academic circles may induce teachers to experiment beyond the traditional curriculum, persuade students to reach beyond their grasp and undertake events to stretch the conventional wisdom.

[1] These activities calls for specific teacher-university relationships, university-supported proposals for students[10] and teachers as well as grant applications, for example, American Chemical Society[11], American Physical Society[12], Association of Physics Teachers[13], NSF Teacher Scholarships[14], NIH Pre-College Teacher Grants[15], US Department of Energy[16], US Department of Agriculture[17], National Institute of Standards and Technology - US Department of Commerce[18] and the usual sources (NSTA[19], NASA[20], NAS[21], etc.).

[2] Propelled by principles, students need exposure via industrial liaison programs to transform principles into practice (skills, job-readiness, externships). On one hand there are job shadowing opportunities (eg CSX, J&J, BCBS) which may be appropriate for some students while other students may find R&D options more interesting (for example, corporate programs from Intel, Northrop Grumman, General Motors, RSA, Pfizer, GE, Boeing). These are difficult to achieve if reaching out in an *ad hoc* mode. Creating relationships with senior level management and cultivating corporate camaraderie may be the slow path for a long term investment with bona fide returns in terms of R&D engagements.

[3] District level STEM infrastructure to support the momentum outlined in [0] through [2], above, will require additional grants and funding proposals (both RFP and open solicitations to federal and state agencies). The suggestion is to propose defined STEM programs outlining the transformation path pursued by an academic vision as a seed or starting point, which evolves in reality involving students, jobs, entrepreneurial innovation, economic development and science in the service of society.

[4] There are no limits for school district level grants and funding opportunities because every federal agency and department, directly or indirectly, works to create jobs and improve the economy. The supply chain of talent necessary for federal programs to succeed depend on the quality of public education. Hence, STEM programs are explicitly and implicitly invited to help the national economy. The latter is an investment by the nation. Districts can be beneficiaries. To gain the attention of national program managers, proposals from districts must be bold yet attainable within the limits of public education (not re-packaged offers that are important yet are too common, e.g. mentorship programs).

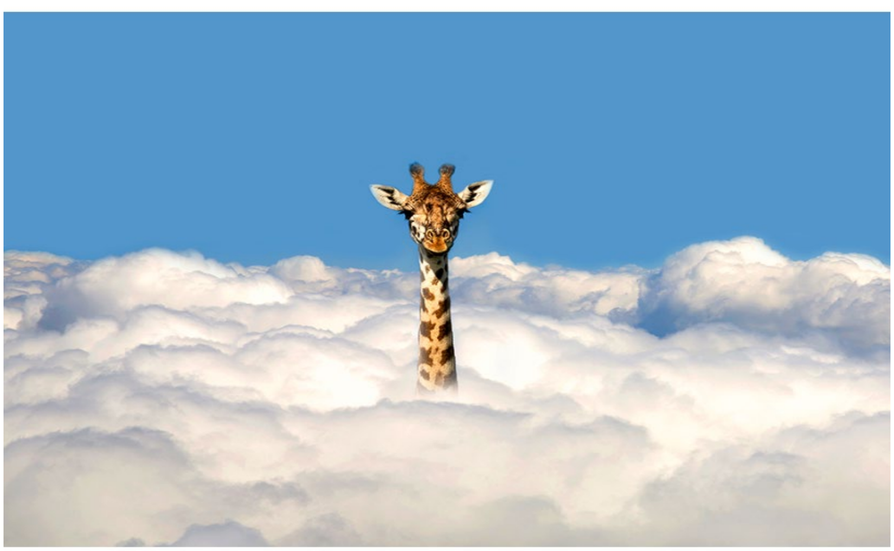
[5] STEM imagination, invention, and innovation, are hackneyed buzz words which ooze potential if presented in a PowerPoint talk. However, they fall short of “experimentation” which is the horizontal glue that binds these words into phrases which often includes entrepreneurship. STEM laboratories are the experimental stations of the future but few students experience experimentation unless they are in a PhD program. Thus, the clarion call for entrepreneurial innovation may be a marketing slogan because public education student assessment quagmire[22] still lacks experimentation within its horizon, except for a few isolated[23] examples of excellence. This is an opportunity for district leadership to boldly propose building experimental labs (in select schools) which exemplifies the ethos of experimentation necessary to coalesce imagination, invention, and innovation. Money (funding) may not be the insurmountable barrier (private donors, corporate foundations). The key to experimental lab schools are highly qualified teachers.

TEMPORARY CONCLUSION

The convergence of [I] creative funding pursuits by school districts, [II] excellence in professional development for teachers and [III] integrating STEM experimentation for K-12 students, may offer a glimpse of future-ready education better capable of responding and adapting to evolving socio-economic realities, the health of nations[24] and the elusive quest for dignity. To answer the question whether we are better prepared to deal with the challenges of chronic job insecurity, we turn to the instruments of STEM and find success stories. Having said, one must hasten to note that STEM is increasingly substituted by "technology" alone. Is STEM synonymous with technology? In attempting to answer this question one must open the "Pandora's Box" which may not be palatable for many. The dominance of certain forms of tools of technology stems from a far deeper problem which is beyond the reach of public education and even most academic institutions.

However, for the purpose at hand, constructive convergence of cross-pollinating ideas, if materialized into action, may begin to seed change. One easy convergence is to make PD for teachers (online courses, classes from venerable universities) available to all K-12 students, for credit. Exposing teachers and students to the same online material will ignite sparks, may unleash latent creativity and sow seeds (including seeds of discontent) outside the canonical "box" bounded by conventional wisdom. Both teachers and students can obtain diplomas, certificates as well as degrees (e.g., micromasters[25]) from the best institutions in the world, for free or almost for free. Polishing the chrome is often essential for PR and politics of the public education system but it should not detract the true advocates from building and cementing the convergence of the foundational elements, i.e., mathematics, languages and music.

Academics are prone to pontification and this essay is not an exception. There ideas aren't novel and these seeds have been sown before. But, seeds are sterile, unless cultivated. The latter requires an overarching vision which embraces education as a purveyor of *civilization*. These lofty ideas are the laughing stock of pragmatic personnel in classrooms, fighting fires, daily. Although leaders can't escape firefighting, they must strive to reach above and lead, in order to pursue the aims of education[26].



EPILOGUE: IMPLEMENTATION OF PRESCRIPTION 1989-1999

The author's intent to assist public education is neither a knee-jerk reaction nor the pursuit of a "job" but rather a personal mission in the context of purpose over profit, for greater good, but not for free.

This section provides specific (select) examples of the elements of **"PRESCRIPTION"** which the author helped to implement, in a few public school districts in the US, during 1989-1999. The first version of the **"PRESCRIPTION"** was a draft scripted around Fall of 1989. The current version (now available from the MIT Library) was recently edited and uploaded for public access.

1989 (author's primary engagement - Research Fellow in Medicine, Department of Medicine, Thyroid and Neuro-Endocrine Labs, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts and Instructor in Molecular Medicine and Metabolism at Harvard Medical School). Public education outreach from Harvard Medical School involved science education mentorship. The author connected with Timilty Middle School[27] students and teachers. The school was located in one of the most challenging areas of the highly segregated city of Boston.

1991 (author's primary engagement – Research Associate, Whitehead Institute, Massachusetts Institute of Technology, Cambridge, Massachusetts and Instructor in Molecular Medicine and Metabolism at Harvard Medical School, Boston, Massachusetts). Part of a small team of scientists at MIT who initiated the Whitehead Institute Teacher's Program[28] to offer highly rigorous short courses and hands-on science experience as well as seminar series[29] for high school science teachers from the greater Boston area. The program is flourishing and expanded in many dimensions even after 30+ years since its inception.

1992 (author's primary engagement – Research Associate, Whitehead Institute, Massachusetts Institute of Technology, Cambridge, Massachusetts and Instructor in Molecular Medicine and Metabolism at Harvard Medical School, Boston, Massachusetts). Focused on Boston Latin School[30] (founded 1635) to:
[1] start an inspirational seminar series and "fire side chats" for students to engage with local scientists (dozens of Nobel Prize winners from MIT and Harvard participated in this multi-year seminar series including Bruce Alberts, at the time the President of the US National Academy of Sciences).
[2] Upgrade STEM laboratories (physics and biology). The author's personal request for funding lab upgrades at Boston Latin School (US$ 250,000) was granted by Mrs Helen Land, wife of Edwin Land[31] (1909-1991) , the primary inventor of Polaroid.
[3] A series of efforts with Bernard Lown[32] (inventor of the direct current cardiac defibrillator) aimed at engaging students to understand how satellites could (Bernard Lown's SatelLife[33] launched in 1991) help to offer limited healthcare access for resource constrained communities in Africa through remote diagnosis and guidance for minor medical procedures, an idea[34] socialized during 1920's.

1995 (author's primary engagement – Scientist, UCSF and UC Berkeley Joint Program in Molecular Parasitology & Infectious Diseases, University of California San Francisco [UCSF] School of Medicine, San Francisco, California and Instructor in Medical Genetics, UCSF School of Medicine, San Francisco, California). [1] Participated with UCSF Science Education Partnership (through Bruce Alberts[35]) to start high school biotechnology and genetics program as a part of experimental labs in schools within the San Francisco Unified School District (SFUSD). [2] Helped to start a new SFUSD high school (Thurgood Marshall Academic High School in the challenging neighborhood of Hunter's Point, San Francisco) which created at least one new global trend to help high school students become future-ready.

1996-1998 (author's primary engagement – Special Assistant XIV to the Mayor, City and County of San Francisco, San Francisco, California and appointed as Special Assistant to the Superintendent of Schools, San Francisco Unified School District, San Francisco, California). Items relevant to this period are also
[1] listed on pages 31-32 in my **CV** which may be downloaded from the MIT Library using this URL https://dspace.mit.edu/handle/1721.1/146158 (search for PDF under 'additional downloads' section)
[2] collected in the PDF **"1996-1998"** available from https://dspace.mit.edu/handle/1721.1/146158

In brief, the author was instrumental in many aspects of education. Selected highlights are as follows:

[0] **1995-1996** was an intense period of building major partnership with UC Berkeley to usher "The Berkeley Pledge" with the then Chancellor Chang Lin Tien[36] and execution by The Vice Chancellor and Provost Carol Christ (current Chancellor[37]). The outcome of this effort created the "online" Interactive University[38] at UC Berkeley (1996) which partnered with neighboring public school districts including SFUSD. At this time the word "MOOC" did not surface in any vernacular. The project was co-funded by generous grants from the National Telecommunication and Information Infrastructure Authority (NTIIA) of the US Department of Commerce. The author's role in the "Pledge" and the era of "online" learning[39] was also documented and editorialized by the press (see "clippings" in the PDF marked **"1996-1998"** available from MIT Library https://dspace.mit.edu/handle/1721.1/146158).

[1] Helped to connect schools to the internet through organizing the first official Net Day 1996 in the San Francisco Bay area. Specifically, bringing the President[40] and the Vice-President of the US to install RJ45 cable to physically "wire" public schools to the information highway – the internet – just released to the public in 1995 by the National Science Foundation (NSF).

[2] Helped to create the Cisco Networking Academy (1996) which started as a Cisco Systems sponsored classroom project at Thurgood Marshall Academic High School, SFUSD. Sponsored by Cisco Systems and working directly with John Morgridge[41], we were able to integrate networking as a high school program. High school students were taught by school teachers (highly qualified electrical engineers from UC Berkeley who were classroom teachers) to wire network routers, create internet network infrastructure, structure ethernet/subnets and other elements of an end-to-end network which included IP addressing (IPv4, Internet Protocol version 4, at that time in 1996), security systems, router protocols and network configurations which included creating domain name servers (DNS). The global success of the Cisco Networking Academy was touted by the US Congress and is still a staple in many schools and colleges.

[3] Helped to connect students and their families with computers by offering computers for homes. Physical computers (~5000) were provided by [a] NASA Moffett Field, California, through an earlier version of the US Department of Energy Laboratory Equipment Donation Program (LEDP) which was a part of the national workforce development program[42] and [b] Computer for Schools Program in collaboration with John and Diana Detwiler (Detwiler Foundation) using prison inmates to refurbish[43] donated computers for use by California public school students[44]. A shrink-wrapped electron microscope donated by NASA was stored in the basement of a SFUSD high school[45] due to lack of resources.

[4] A few of these (above) appeared as an article in the 1996 December issue of US News & World Report as well as a highly justified unvarnished criticism in *The Atlantic*[46] and 15 seconds of "whipping" by CNN[47]. The quote at the end of this article (document) is from *The Atlantic*. The USN&WR "cover" is included as a PNG in the PDF "1996-1998" available from https://dspace.mit.edu/handle/1721.1/146158

[5] Professional development of teachers were pursued through corporate donations by liaising with Silicon Valley behemoths for additional remuneration for highly qualified teachers (hired into SFUSD).

[6] Professional development of teachers with respect to content was pursued by creating programs with UC Berkeley and Stanford University to enable SFUSD teachers to take any course/class at no cost to the teacher. The program at UC Berkeley was created (1996) and driven by the then Vice Chancellor and Provost Carol Christ[48] with catalytic help from friend and well-wisher Charles Townes[49] as well as Glenn T. Seaborg[50]. At Stanford University the program was discussed and tentatively approved by Provost Condoleezza Rice[51] but its initiation was diffused. Professor Carol Christ went above and beyond to create a "fellows" program for SFUSD teachers (Josephine Miles Fellows) to provide recognition (she met with all teachers, each month). Teachers received a stipend from corporate funds and UC Berkeley provided for refreshments, transportation and parking decals (significant in the UC Berkeley campus).

[7] The author co-founded a group referred to as "Associated Scientists" with 200 science teachers from the State of California and with help from Professor Stan Metzenberg[52] and Glenn T. Seaborg, former Chancellor[53] of UC Berkeley[54] (among many other things including the discovery of 10 new elements[55]). The team "Associated Scientists" re-wrote the Mathematics and Science K-12 curriculum standards for the State of California (wide coverage in the global press and a few clippings are in the PDF **"1996-1998"** available from the MIT Library https://dspace.mit.edu/handle/1721.1/146158). These standards received a perfect score from the American Federation of Teachers [AFT] in their 1998 report[56] *Making Standards Matter*. Review of ASSOCIATED SCIENTISTS is included in the biography of Glenn Seaborg (2001) *Adventures in The Atomic Age*, pages 293-294 (ISBN 0-374-29991-9).

[8] The author was nominated to Chair the National Workforce Development Taskforce for STEM and its influence on economics of technology. It was sponsored by Dr Mary Good[57], then Undersecretary of the US Department of Commerce (other federal departments, White House Council of Economic Advisors, ITAA and UC Berkeley were also a part of this task force along with corporate behemoths from Silicon Valley). Please see PDF "1996-1998" available from https://dspace.mit.edu/handle/1721.1/146158.

[9] The author and Glenn Seaborg (the author's mentor who was also a co-author of "A Nation At Risk" 1983 report sponsored by the Reagan administration) planned to create a foundation for teachers in order to enhance their quality of life through grants and opportunities for professional development. The discussion of the foundation (during 1998) included Andy Grove[58] but the effort came to a halt in 1999, due to a fall and subsequent death of Glenn Seaborg[59] (followed by lack of further interest from Andy Grove). Notes from these discussions are reportedly available from the Glenn Seaborg Archives in the US Library of Congress (Box 276, ID MSS78514, Archives of the Library of Congress[60]).

POST-SCRIPT *(Personal Events)*

For the purpose of disclosure, the author wishes to add that for a few years (2009-2013), when the author was convalescing after (colon) cancer surgery, the author was moved to a southern state in the US and was banned from air travel. During this time, the author became a certified classroom science teacher and taught chemistry, biology and mathematics (9th, 10th, 11th grade). This was the author's effort to understand at the very granular level the complexities, bureaucracy, and daily minutiae that classroom teachers experience in public schools. This was a remarkable venture for the author for nine months (Oct 2009 through Jun 2010). The author was "placed" at a different high school for the 2010-2011 school year due to re-districting but the author resigned from the position after meeting the Principal of the "new" high school. It was a lesson in recognizing how school leadership matters with respect to school's morale. The author is indebted to Dr Donna Richardson[61] for this gift of understanding, which she delivered to the author almost every school day (Oct 2009 through Jun 2010). After the high school experience, the author proceeded to experience even more challenging educational jobs (high risk, unsocial and incarcerated teen-age girls and vocational school drop-out students who were being re-educated using classroom and on-site "virtual school" hybrid programs). Finally, the author taught in four local community colleges to gain experience relative to the 80% of the US workforce who attend community colleges. During teaching various classes (chemistry, biology, physiology, anatomy) in these various institutions in a southern state in the US the author discovered nuggets of excellence among students, extremely horrible social treatment by a couple administrators and an utterly mind-boggling sinister academic individual (department chair) who fired the author (October 2013) for teaching "more" chemistry than prescribed by the community college curriculum (because one male student objected to learning "more" than necessary). The latter was a divine intervention and the author's wife[62] agreed to allow the author to travel (after verification by colonoscopy). The author started commuting to MIT on 10/13/2013.

APPENDIX 1: IS STEM SYNONYMOUS WITH TECHNOLOGY?

Funding education in technology for professional development of teachers[63] is worthwhile and bringing it to bear on student activities is laudable. Corporate politicians carefully crafted technology initiatives to push forward computer science (CS) but ignored the other subject specifically mentioned in that call for CS[64] by the "coder-in-chief" (a pathetic moniker designed to grovel for attention from TV news). The message was re-shaped in a form which blatantly pandered for publicity and peddled prosperity for a sub-sector of technology, in the name of STEM.

STEM is not synonymous with technology. It should not be framed to glorify technology at the expense of science, engineering and most importantly, mathematics. But, mathematics is hard and news cycles are short, hence the "faster" approach of "coding" taken up by funding agencies to provide glitter. It is certainly better than doing nothing but CS deserves equal and essential complementarity by improving diffusion of and rigor in mathematics (among other things).

Mathematics and science has taken a back seat in K-16 education where "tools" are celebrated but the "fundamentals" are left in the cold, as boring, and hard. This is the "new delusion" brought on by the scientific illiteracy of politicians and political illiteracy of scientists. Most administrators are consigned to the doldrums where they are almost forcibly immersed in the bureaucratic quagmire of pushing out Paul in order to please Paulina or pulling down Pamela to acquiesce with Peter.

This essay is not veering off course but wishes to point out a few facts which may not bring plaudits to the author. It will be remiss of the author to avoid the discussion for sake of "pleasantries" or to make things "palatable" to readers (suggested by a reviewer employed by a foreign but friendly government). As a basic scientist, the author may be intrinsically biased toward science (physics, chemistry, biology), medicine and mathematics. However, analytically, there is nothing wrong with promoting computer science and/or programming (coding) even though there is an immense chasm of difference between computer *science* as a scientific/engineering discipline versus coding, which is a tool, similar to a recipe.

Some of those who create recipes are indeed gifted researchers who are also deeply grounded in the fundamentals of science[65] even though the outcome or external "impact" surfaces merely as a recipe in a cookbook or an online "pop-up" when e-shopping for grocery delivery using a smartphone. If one delves deeper into this line of reasoning, it may be awe-inspiring to observe that the simple process of browning[66] bread (regulated during the process of baking bread), if used in a Montessori[67] approach in school projects (project-based[68] or problem-based learning, PBL[69]), could enable students to learn about convergence of trans-disciplinarity in the real world. Browning of bread can teach chemistry, biology, food, nutrition, physiology, cardiovascular disease, diabetes and related[70] aspects (chemical engineering, software, data analytics, physics about instrumentation) as well as mathematical[71] rigor quintessential for quantitative analyses and metrics embedded in each sub-topic. Chemistry can be taught at any K-16 level just by asking children if they like chocolate[72] or what is in their paintbox[73] or discussing restoration of old paintings[74] with middle/high school children. Lithium-ion battery[75] and redox[76] will keep children engaged, while the chemistry of shaving[77] may generate some pubertal guffaws. The wireless TV remote is an excellent item for a project-based understanding of convergence. These discussions can teach entire science and mathematics curricula. However, it is very difficult to execute such multi-disciplinarity and complementarity in the K-16 curriculum because teachers may not have the grasp over various overlapping disciplines (or the ability to conduct assessment of learning akin to a Venn diagram).

The reason for outlining this granularity is related to the fact that programming may be embedded in the items mentioned in the last paragraph, which we ignore when "coding" is just learning by rote. Programs for coding in secondary schools (e.g. *Girls Who Code*) and in most colleges/universities often dive into programming specific languages[78] for the express purpose of writing "lines of" code as the index of success. (There is value in this tool. Examples of economic growth from rural India is evidence, but the turmoil, heartache and *pennies as payment* rarely makes it to the Wall Street Journal or BBC or ZDF). Is it unreasonable for US public education to pander for "coding" as if it is a solipsistic bliss?

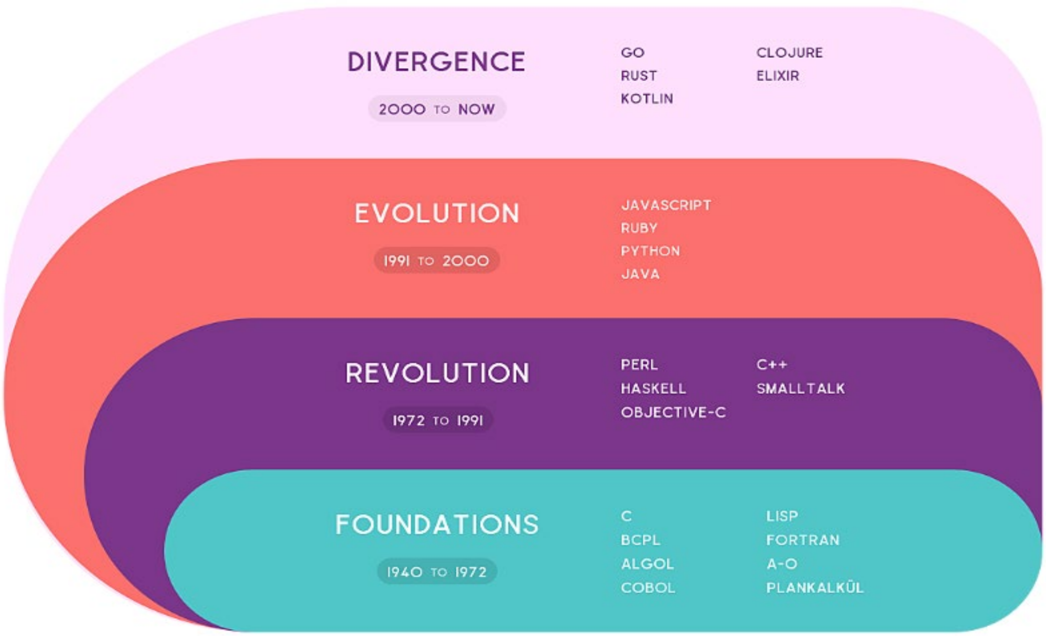


Figure 1: Lacking from K-12 Educational Initiatives: Philosophies of Software Languages[79]

Dissecting the extraordinarily rich trans-disciplinarity of programming (coding) and the foundations of languages may illustrate a few of the salient issues. Programming "language" is an outcome which tries to capture and learn from the attributes of natural languages, e.g., grammar (noun, pronoun, verb, adverb, conjunction, preposition), syntax[80] (descriptive content, subject, predicate) and semantics[81] (meaning). Programming and software is lost when it meets with lexical semantics and clueless when dealing with cognition (contrary to fake claims by the media, which corporations create for marketing purposes, where a lie can travel half-way round the world even before truth can put on its trousers[82]).

Linguistics and study of language infrastructure are critical foundations which informs the logic structure that generated the initial series of programming languages (code) during the middle of the last century (20^{th} century). The combination of data and code through object oriented programming (OOP) was the "revolution" in the last few decades of the last century. The origin of this "revolution" are traced back to "patterns" arising from architecture, designing and planning[83] cities and buildings. The 21^{st} century evolution and differentiation is linked to predecessors, for example, Julia[84] is a "modern" and improved language compared to Python, which was once considered progressive. Rust is even more directly linked to C++ and appears to resemble C, if C were to be developed in the 21^{st} century.

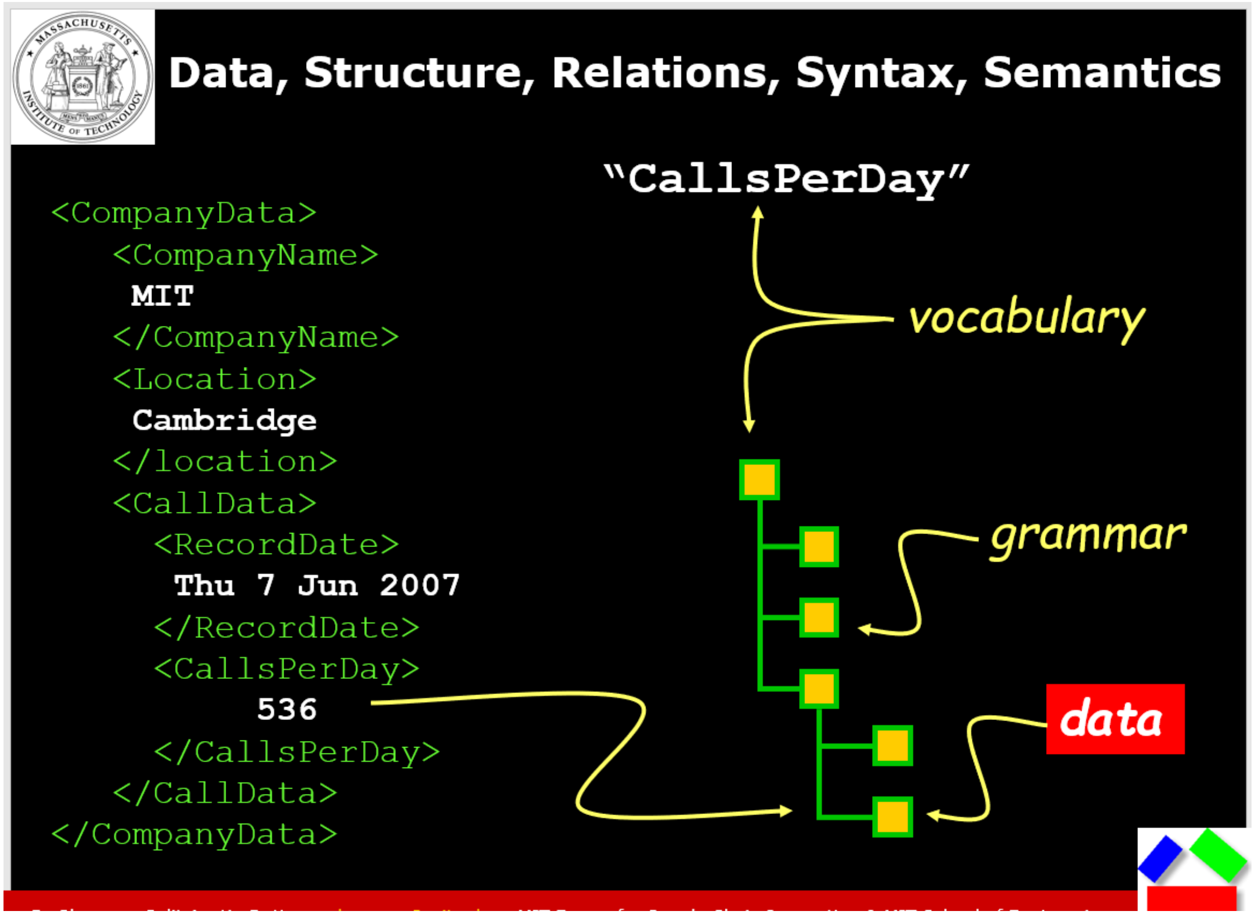


Figure 2: Linguistics, cognition, grammar and patterns in our mind during language development are influencers of programming[85] (coding) yet students (and teachers) are in the dark about the inextricable link between learning languages and coding. In this example, neither "RecordDate" nor "DateofRecord" are real words but programmers synthesize arbitrary syntax, intending to capture the same outcome (semantics). The syntax is created in the brain of a human, not in the computer. Code cannot capture causality. Thus, programming (coding) and resultant software used by computers are semantically challenged (i.e., dumb). Syntax, as shown in this HTML example, is only good for the specific use case. Hence, this code in the software is incapable of merging data (for example, from different phone logs) because hard-coded syntax produced by different programmers are unlikely to be ***exactly*** *identical*.

It follows, therefore, that if one can grasp the foundational tenets, then such an individual may be better suited to adapt, unlearn and relearn whatever may follow in the market of programming languages (revolution, evolution, differentiation, divergence, convergence). Job insecurity due to changes in programming technology (code) may become less of a thorny socio-economic problem if students were acquainted with the *modus operandi* which is at the heart of change. Technology drifts every few years much to the chagrin of employees who may prefer job stability, regular paychecks and peace of mind. Preparing students to deal with inevitable challenges due to the dynamics of technology may help them to be fortified when they are the adults in the workforce.

The foundations of programming languages are inherited from the foundations of natural languages which are built on the structure[86] of linguistic infrastructures[87] we are still exploring[88]. Our inability to distill into programming languages the nature of semantics and cognition during natural language acquisition and pattern development in the mind[89], is one reason for our complete failure to include causality through code. Elements of linguistics are at the core of programming languages. Syntax is language derived from and based on the natural language[90] of the programmer (varies immensely if the mother tongue of the programmer may be, for example, English, Chinese or Spanish). Individuals may choose to describe the same content (thing, object, process) in different forms of syntax. The choice of words is based on the linguistic proficiency of transforming thoughts into spoken words based on vocabulary. Programming instructors are unlikely to discuss these facts which are not simple.

These problems are further exacerbated when programming extends into ill-understood (unknown) domains, e.g., artificial neural networks[91] (ANN). The vain attempt to generate “intelligent” software (mostly through marketing propaganda of “artificial intelligence”) is plagued with inconsistencies of extrapolation and mimicry of biological functions (for example, neural networks) in human-designed programs or software processes. The basic circuitry of a neural network is regulated by electro-chemical signals which are extremely difficult (if not impossible) to reproducibly quantify in humans and higher animals. The claim that an “artificial” neural network may represent the logic patterns in our brains is infinitely cherubic, if one is familiar with the basic science of neurology and is aware of the granularity of details for even a simple (mono-synaptic) neural signal communication. Mimicry of artificial neural networks using patterns even from worms (*Caenorhabditis elegans*[92]) may be too complex with too many dependencies and/or interrelationships, some of which may be latent.

Let us assume that one has created a rudimentary Boolean[93] logic structure from some form of so-called artificial neural network with programming (coding) to perform operations. What are the operatives and what are the mathematical basis of the tools deployed/necessary for the operation? Can we transform the outcome to become information[94] which can offer value to users? Is making an app[95] the Holy Grail? Computation and programming is better suited to deal with the tsunami of data (humans can’t process very large volumes of data). In terms of logical outcome, the computer and programs (code) are only as good as rule based[96] expert[97] systems[98] which depend on the code and data that has been ***provided***.

Programs cannot think but excellent in mathematical operations based on pre-programmed logic, rules and embedded structure/procedures/protocols. Mimicry of neural signals and quantification of signal strengths (referred to as “weights”) may serve as guides but devoid of contributing any mode of “new” thought. The nature of programming proficiency is influenced by the structure of natural languages. Taken together, we have a high performing logic tool which depends on code to enable computation.

The trinity of mathematics, biology and languages, form the invisible part of the iceberg where coding or programming is the visible tip of computation. Our penchant for quick results and gratification may be fueling our desire to *polish the chrome* (coding) and kick the can of hard facts (mathematics, biology, languages) down the long road for somebody else to *tune the engine*.

Are we being delusional? Are we being myopic? What is the impact of this mechanism on the future of technology and the future of our students in schools and colleges? We can make things entertaining and easy for students to feel accomplished, now, but only to observe social discontent, decades later. Is the design of information technology tools in public education skewed to statistically amplify the positives in our elusive quest for rapid rewards?

STEM laboratories in schools for basic[99] sciences, engineering and mathematics should not be sacrificed to unduly glorify technology, alone. Professional development for teachers must not exclude languages to focus on STEM, alone. Science, arts, humanities, and music, complement and cross-fertilize creativity with discipline and vice versa. The latter may inspire and induce imagination, invention, and innovation.

APPENDIX 2: POVERTY, FOOD, EDUCATION & ECONOMIC GROWTH – ONE EXAMPLE

Financial investments in some parts of the world has proven to be ineffective as tools to foster economic growth. Analysis revealed[100] that the schemes were tutorials in what *not to do* rather than data-informed initiatives to build educational capacity. Incentives for the purpose of curating data from randomized control trials are economic experiments in policy[101] rather than catalysts to support grass roots economic growth. Economic arguments about development[102] and freedom are incisive insights and sophisticated philosophical perspectives drawn from remotely observing events in lives where even hope fears to tread. August treatises about ending poverty[103] are pedestrian paperbacks produced to earn royalties. Fashionable discussion about poverty are for those preparing to display appropriate plumage at the Peacock Alley[104] in order to secure the next highly paid consulting job with the UN[105] Sustainable Development Goals[106] (which now appears to be rather "UN-sustainable" after 20 years of hand wringing[107]). The unvarnished truth about these economic episodes may be due to, albeit in part, the unequal distribution of global capital[108] where "money" decides what may ascend[109] or must descend. Financial decision makers, well versed in matters of wealth[110], appears to know the cost of everything but rarely grasps the value[111] or dignity[112] which is key to ethical progress of civilization[113].

Food[114], rather than financial incentives, may act as a better catalyst for education. Engaging hungry children to focus on learning is a difficult task for educators. If food is made available to children[115] the equation often changes. This example summarizes events from the 20th century in India including grants in the 1960's from the Rockefeller Foundation[116] to fund school lunch programs in certain southern states (Kerala, Tamilnadu). To feed hungry mouths, families started to send boys as well as girls to schools for free food. Education of girls enabled women to promote literacy[117] and numeracy. Women gained economic independence and practiced contraception[118] to reduce their contribution to population[119] growth. Attendance in the schools accelerated opportunities for learning but the tools were in short supply, except for pencil and paper. Generations of Indian children were fed with the rigor of mathematics, the default discipline, since only paper and pencils were/are readily available.

What began with food for school children, converged after decades. Socio-economic improvements and grounding in mathematics paved the path for the Indian software industry to explode in the late 20th century. India continues[120] its global dominance[121] in software[122] but also gingerly building new roads.

Poverty in resource constrained communities may not help science experiments and STEM laboratories but it cannot limit excellence in mathematics (if there is the will, pencil and paper). Since mathematics is the language of science, deep knowledge in mathematics enable students to pursue any field(s) they may choose, or any career, in any part of the world. The nexus of food and mathematics changed the lives of children and catalyzed economic growth of a nation with ~1.5 billion people, locally and globally. The lesson from this example: if we can do only one thing well, let it be K-12 excellence in mathematics.

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A *The Atlantic*

July 1997 Issue

The Computer Delusion

By Todd Oppenheimer

IS THE DELUSION CONTINUING ? UNDER A NEW BANNER < CODING > / < PROGRAMMING >

Thomas Edison predicted in 1922 that "the motion picture is destined to revolutionize our educational system and ... in a few years it will supplant largely, if not entirely, the use of textbooks." The noted psychologist B. F. Skinner, referring to the first days of his "teaching machines," in the late 1950s and early 1960s, wrote, "I was soon saying that, with the help of teaching machines and programmed instruction, students could learn twice as much in the same time and with the same effort as in a standard classroom." Ten years after Skinner's recollections were published, President Bill Clinton campaigned for "a bridge to the twenty-first century ... where computers are as much a part of the classroom as blackboards."

If history really is repeating itself, the schools are in serious trouble.

In (1986), Larry Cuban, a professor of education at Stanford University and a former superintendent, observed that as successive rounds of new technology failed their promoters' expectations, a pattern emerged. The cycle began with big promises backed by the technology corporations. Few people questioned the technology advocates' claims. As results continued to lag, the blame was finally laid on the machines. Soon schools were sold on the next generation of technology, and the lucrative business cycle started all over again.

The Conventional Wisdom?   Grassroots Reality Check?   The Naysayers Mantra?

WHY THIS SUGGESTION WILL NOT WORK

Dr. Stephanie O'Brien, Director of Science K-12, Smithtown School District, New York

I have spent my whole career in K-12 education and feel very few teachers would try to engage in this partnership. Teachers typically are looking for free PD and opportunities that are low cost or something funded through a BOCES or cooperative learning center that the district pays for. We are looking at a different generation of teachers who don't necessarily want to apply for grants to get more content knowledge from these institutions. The type of pedagogy at the college level, while content rich, often lacks the best practices in the field. It's often best when the high school teacher provides support on 'how to teach' and the college professor on 'the what and why behind what we teach' to support each other's PCK (pedagogical content knowledge), so both benefit. State and national standards dictate curriculum and teachers do not have time to deviate much and still maintain student engagement and understanding. No doubt, content knowledge is helpful, more important is how to teach kids to learn said content. Programs like Rutgers has a phenomenal science education department that has this topic specific PCK approach, yet not a top university, so not on the list. I am not sure the list should be top universities or top universities where they teach how to best teach the content. This is just my opinion. [Email from sobrien@smithtown.k12.ny.us to shoumen@mit.edu on 12-18-22].

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