PART FOUR

Institutionalizing Educational Quality

CHAPTER 8

THE UNTAPPED PROMISE OF EDUCATIONAL RESEARCH AND DEVELOPMENT

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Attendants rolled Fraulein Elizabeth Weiss, hugely pregnant, through the hall on a crude gurney in Vienna's University Hospital. She pleaded and screamed as they rushed through the already chaotic ward. "No! No! No doctors! Please, no doctors. Please," she cried, "please help me, no doctors!" Her frantic plea did not stem from labor pains; she had just been told that as a charity case she might be sent to the wing attended by the hospital's medical interns instead of the midwives. Most charity patients endured a similar lot. Elizabeth knew the direction her gurney turned could determine life or death. The medical interns' ward suffered some 25 to 30% deaths in childbirth while the midwives ward managed barely 10% of that.

Where in the numbers would Elizabeth fall?

Shortly after the intern attended her delivery, Elizabeth died from puerperal (childbed) fever. Staggered by the high death rate, a young Hungarian obstetrician, Ignaz Philips Semmelweis (1818-1865), offered to the medical community in 1848 the hypothesis that physicians carried puerperal fever from cadavers or infected patients to others by physical contact. Observation of the system itself provided the clues: Physicians worked on cadavers and attended many patients sequentially; midwives did not. Semmelweis, then in charge of interns, changed the system, requiring his charges to wash their hands in chlorinated lime between contacts with each patient. His order resulted in reduced instances of puerperal fever mortality by an astounding rate.

Although Semmelweis' research provided a procedure that caused dramatic results, his peers still rejected him. By challenging the hospital's professional practice community, he was viewed as a threat. His boss fired him because his reasoning was inconsistent with existing practice, and his colleagues complained that washing their hands was insulting. The death rate from their existing practices had been stable at 25 to 30% for many years and they considered that figure to be inevitable.

LEARNING FROM THE PAST

The 1840s' philosophical view held that the cause of disease was spontaneous generation—disease was the result of miasma, a seemingly poisonous atmosphere then thought to rise from putrid matter and invade patients. Physicians believed that puerperal fever was unavoidable and just one of the natural hazards of childbirth. Particularly relevant to our concerns is the trap of the status quo, the attitude of acceptance rather than raising questions.

Semmelweis' colleagues and interns assured him that they would not knowingly harm patients. Surely the death rate could not come from their hands or their traditional system of treating a patient. After Semmelweis was fired, he returned to Budapest where he implemented similar aseptic procedures in St. Rochus Hospital and reduced the substantial childbed fever death rate to 0.8% . In Vienna, it remained at 1%. He knew statistically that his theory was correct, but he had not seen the organism that caused the problem; he could not offer proof that would overcome traditional medical thought.

Louis Pasteur (1822-1895) discovered *why* Semmelweis was right. In Paris, Pasteur won a prize from the French Academy of Science in 1859 for showing that disease was caused by the transmittal of microorganisms from one person or source to another. His work was significant in establishing the germ theory of disease.

Next, Joseph Lister (1827-1912), the British surgeon who discovered antiseptics, greatly reduced deaths due to operating room infections from 50% to 15%. After adopting Pasteur's germ theory in the 1860s, Lister applied a carbolic acid antiseptic directly to instruments, wounds, and dressings. This major breakthrough could then be followed by systematic and continuous incremental improvements.

Significantly, while each man lowered the death rate, their professions rewarded them in drastically different ways: Semmelweis was ostracized, Pasteur was prized, and Lister was baronized.

Overcoming such costly traditions in conservative professional practice requires substantial effort, usually following a significant discovery or from outside influence. It took more than 40 years to disseminate the knowledge of germ theory and antiseptics and incorporate this knowledge widely into practice. In medicine, practitioners like Semmelweis and faculty members like Pasteur could do credible research in the basic issues; such research can usually fit under a microscope. Such research is less likely in schools.

Because the case for sterile procedures has been well established by research, physicians today who fail to employ careful antiseptic methods could be quickly disciplined, discharged, or involved in malpractice litigation.

Are Hospitals and Schools Alike?

"No! No!" screamed Elizabeth White to her father as she opened her senior class schedule. "They gave me Mr. Johnson in physics. He is awful. I won't go. They can't make me take him! Please, make them change it!" Elizabeth did not scream from fear of hard work; rather, she did not want her hard work to be useless and ineffective in the system of Mr. Johnson's teaching. She needed physics knowledge to score high on college entrance examinations.

In schools as in medicine, practitioners and professionals are a tightly knit social group with specific norms and strongly held belief systems. All physicians had been previously warned to “least ways do no harm.” Semmelweis’ peers interpreted this caveat to mean that they would do no harm if they *intended* to do no harm. And so out of ignorance, the practicing physicians in the hospital managed to achieve a 35% death rate from childbed fever even though they had the highest of motives, the best intentions, and the complete support of their colleagues. Fraulein Elizabeth Weiss died in the hospital and, for similar reasons, Elizabeth White learned little physics in school.

A Closed System

Semmelweis, as head of interns in the hospital, faced problems that resemble those faced by principals or directors of instruction in public school districts. The regeneration of the workplace most often works as a closed system. To be an assistant principal, then a principal, and then a director of curriculum or instruction, one must have first been a classroom teacher. Furthermore, most teachers interned with an experienced teacher. Educators begin as practitioners and are socialized with those views and beliefs. One is ingrained with the procedures before becoming responsible for the results. Few principals are hired directly from other occupations from which they might bring fresh ideas and experience. The system is self-contained, perhaps to its own harm.

In Budapest’s St. Rochas hospital, Semmelweis was a hero for implementing the same practices that caused his dismissal from Vienna. The Vienna hospital had an atmosphere that disallowed new procedures. Since that time, hospitals have made limitless advances in patient care and professional practice. Some educators (see Lieberman, 1992, and Miles and Darling-Hammond, 1998) believe that professional practice communities will be the answer to improving schools, although they offer little evidence to support this view.

Can anything be done? In public education, authority is distributed among many stakeholders and government units. Strong professional networks may stymie changes they do not embrace. Widely held beliefs about how schools should operate can limit the introduction of new approaches (see Lieberman, 1992). No public agency is charged with implementing processes based on new knowledge.

The Stakeholders

A plethora of vocal stakeholders is engaged in the discussion: students, parents, teachers, unions, employers, school boards, professional associations, universities, local governments, university researchers, individual legislators, and religious pressure groups. Public schools often appear rudderless in a sea of many winds. A huge majority of the stakeholders attended 12 years of virtually identical public schooling. This shared schooling experience reduces the potential for genuine educational improvement, because it imprints a vivid *implicit mental model* of what school should be. Those stakeholders who lack training and experience in systematic analytic problem solving will remain chained to their prior experiences. Because stakeholders who are limited in their information base rarely come up with demonstrably effective solutions, the schools do not improve (see Hanushek, 1997).

Incremental Reform

Traditional and easily understood changes advocated by education reform commissions, school improvement plans, and the popular press involve standard tweaking—trying to repair, stimulate, and improve the existing educational establishment, including more teacher training, raising published standards, and requiring more credits to graduate. These single issue interventions can be reduced to short phrases such as class size, longer school year, teacher pay, raising standards, national certification, vouchers, and many others. The failure of these programs to improve educational results effectively continues to frustrate policy makers who seek global solutions (see Cuban, 1988; 1990). Even increasing teacher pay appears to produce few improvements (Ballou and Podgursky, 1997)

A recent summary in *U. S. News and World Report* (Walsh, 1999, p. 24) addressed the issue of single-issue reforms. The article summarized discussion on the issues of class size, universal preschools, and testing and accountability. On the class size issue, California limited classes to 20 at an annual additional cost of $4 billion. For that investment they improved three percentile points in mathematics and two percentile points in reading over students in the larger classes. Similar meager improvements were found for the other programs. To achieve these modest gains nationally will require an estimated annual *recurring* expenditure of from $2 billion to $10 billion (Brewer, Krop, Gill, and Reichhardt, 1999).

Other widely quoted studies on class size have reported modest but slightly higher gains than in California. In the Tennessee STAR program, class size was cut almost in half to 14 students to achieve small gains (Finn and Achilles, 1999). Clearly, the cost effectiveness of these programs is questionable at best. Is that modest gain really worth the price, considering alternative uses of the money?

In the 1980s, a strong movement was initiated to begin choice, charter schools, and vouchers for students to use at schools of their choice. Many passionate arguments were used to support these proposed changes, but their efficacy has yet to be documented (Chubb and Moe, 1990; Gerstner, Semerad, Doyle, and Johnston, 1994; Hanushek, 1994).

Why Traditional Changes Provide Little Improvement

In 1983 the National Commission on Excellence in Education issued a scathing report on the quality of education in the United States, entitled *A Nation at Risk*. It offered numerous standard proposals such as lengthening the school day and year, training teachers better, and setting higher standards for students. The defining characteristic of the recommendations was that schools should do more of the same.

In making those proposals, it left the *teaching-centered* model of schooling intact. That model in which teachers “impart knowledge,” “cover material,” and “present information” has been with us since before the Romans first put teachers on the public payroll. To be sure, new requirements such as certification, additional training, and passing more tests have been implemented¸ but the benefits of these additions have been difficult to value.

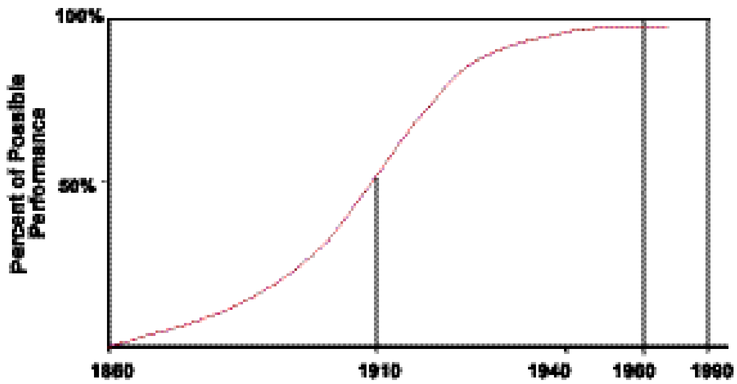
Teaching was well entrenched in the world centuries before there was a science of learning, systems knowledge, and modern concepts of organization and development, and other significant discoveries about human behavior. The Romans had no computers, no electronic data sources, no empirical understanding of cognitive processing, and, by the way, no notion of the germ theory of disease. Their choices were limited by how far the human voice could carry. We could speculate that valid knowledge in education and medicine was about equal in the year 400 — even 1400, since neither group made significant advances in that millennium.

In 1984, researchers at Florida State University (FSU) began study of the *Nation at Risk* recommendations and continued for about three years. We examined the recommendations and interpreted them in the context of other research results. We concluded that even if the states could implement all recommendations, and few had, the changes proposed would be expensive and would cause little improvement in results (see Firestone, Fuhrman, and Kirst, 1989).

To seek an understanding about why traditional changes and funding increases have resulted in so little improvement, we studied the work of C. S. Smith (1981) at Massachusetts Institute of Technology, who plotted the life cycles of many technologies. We believed that these same general life cycles applied to school operations (Branson, 1987, 1998). From those studies and many other analyses, we concluded that the current teaching-centered model of schooling had reached the upper limit of its potential capability. Through dedication and years of hard work the teachers and principals have obtained from this technology about all it will yield.

The upper limit relationship as applied to schools is presented in Figure 1. Smith held that any technology goes through a similar cycle, from early development, through a period of rapid improvement, finally reaching the point of diminishing returns. To improve results at the point where the current technology has reached its upper limit requires a change in paradigm with subsequent changes in the processes used. To reduce the death rate from puerperal fever below 35% requires completely new practices.

Figure 1
Hypothetical Upper Limit of Productivity of the Teaching-centered Model As a Function of Time (Adapted from C. S. Smith, 1981)



Teaching is, by Smith's definition, a technology. It is a set of common processes governed by rules and concepts applied similarly by a large number of practitioners. From Figure 1, we can infer that by about 1960, the teaching-centered model had achieved 96 to 97% of the effectiveness that it could ever reach.

For example, in an analogous arena, each of us will reach the point where we run or swim as fast as we ever will: We realize our personal best. Some will have a personal best that qualifies them for the Olympics; the rest of us will simply notice that we aren't getting faster. Beyond that, no amount of dedication or hard work will add to our qualifying times.

Evidence Supporting the Upper Limit Hypothesis

Other than the anecdote about running and swimming, three kinds of evidence support the upper limit hypothesis. If a technology were still in Smith's rapid growth stage (say, at 1910 on the figure), then increases in resources should enable steadily improving results. Second, if results are improving over time, there should be good empirical evidence showing the improvements. Third, direct observation of the practitioners should reveal opportunities for process improvements leading to additional incremental gains.

Data from Herrington (1995) and Hanushek (1994, 1997) and many others, including Boulding as early as 1972, have reported dramatic increases in school funding. That the increases in school funding have been substantial seems to be well accepted in the policy community. Few measurable improvements have been reasonably attributed to increased funding.

Two strong public education advocates have published data indicating that performance has not improved during the past 25 years. Data published by Berliner and Biddle (1995) provided compelling evidence supporting the upper limit hypothesis. They concluded that student performance had remained unchanged for the previous 20 years. In doing annual surveys for the *Phi Delta Kappan*, a widely read educator's magazine that defends the interests of public schools, Bracey (1991, 1997) reported data generally congruent with Berliner and Biddle. In a keenly dramatic conclusion, Bracey (1991) said, "The lines on a graph of average student performance are as flat as the surface of a frozen lake. Nowhere is there any evidence of a decline" (p.109).

Based on job observation and job analyses of key public school positions, we discovered people working very hard within the structure of the system. Few process improvements within that model were discovered for classroom activities. Other administrative processes were significantly improved using benchmarking techniques from quality systems (see Johnson, 1993).

Teaching Performance

Sanders and his colleagues (Wright, Horn, and Sanders, 1997) carefully documented that the upper 20% of teachers could produce as much as 50 percentile points higher test scores than the lower 20%. He also calculated that of all children who have a lower quartile teacher one year, 25% would have trouble the next year. If they draw a lower quartile teacher the second year, their deficit will be virtually unrecoverable in the third year. Out of 100 children, about six or seven (6.25%) will have a lower quartile teacher two years in a row. Further, having a lower quartile teacher once does not reduce a child's chances of repeating that experience in later years. Sanders' work provides clear evidence of a *system failure* (see Scerbo and Mouloua, 1999).

Based on the evidence provided in all these analyses, the upper limit hypothesis appears to account for the lack of improved results: The current model of schooling is unlikely to produce better results than it already has. The traditional fixes mentioned earlier have already made their contributions to improvement. Instead of accepting the status quo as the Vienna hospital accepted the mortality rate, it seems that the time is right to develop another strategy (Branson, 1998).

DEVELOPING THE SOLUTION STRATEGY

Between 1910 and now, other sectors of the society and economy have not been idle. Science and technology have grown by leaps and bounds. Performance and productivity in virtually all economic and service sectors are not as flat as the surface of a frozen lake. Gains were made in organizations that used the kinds of people they could reasonably expect to hire—not heroes.

Three key elements must be in place to provide the basis for major education improvements. First, there must be a base of valid knowledge of the kind developed by Semmelweis and Pasteur. Second, there must be an organizing process to convert basic knowledge to theory and identify the causes and effects. Third, the knowledge and theory must be incorporated in a learnable technology and disseminated to practitioners for implementation (see Perelman, 1989).

People or Systems?

In U. S. culture, as in many others, those who try to improve schools have identified the problem as deficiencies in staff, students, and society. When school results do not meet expectations, most people assume that the *system* is OK, but the teachers, students, and administrators are failing. The endless cycle begins: Find the faulty people and replace them. Try to get people to work harder and longer. This view is reinforced by the nightly news. When a hard-working hero principal turns around one school in Georgia or Brooklyn, it shows on ABC or is the subject of an article in a popular magazine (Wolkomir and Wolkomir, 1999). However, the cameras aren't around three years later when the hero moves and the school returns to the level of the frozen lake.

As school performance in the U. S. reached the point of diminishing returns, in another part of the world W. Edwards Deming was introducing the quality movement to the Japanese. The recovery of the devastated Japanese industry following World War II was a tribute to his teaching. He introduced the quality sciences to the Japanese manufacturing industry and within fifteen years, "Made in Japan" became a source of admiration rather than a pejorative. Deming discovered that in organizations having significant performance deficiencies, faulty work processes, not defective people, caused about 85% of the problems. Organizations that focus only on staffing issues limit their scope to this 15% —even if they solved them all, it would not cause major system improvements (Deming, 1986).

Unfortunately, the emphasis remains on staff: Hire great principals, train teachers better, fire bad teachers, develop tests for master teachers, and similar plans. To be sure, I do not urge retaining incompetents in any position, but the vast majority of teachers and principals are *not incompetent*. They perform reasonably and adequately in an obsolete system. The current cohort of teachers and principals are as competent as we can reasonably expect to hire.

One R&D-Based Approach

In the early 1990s, the legislature originated a state-sponsored R&D program entitled the Florida Schoolyear 2000 Initiative (SY2000). The mission of the initiative was to redesign public education in Florida. The focus of the redesign was to move to a learning-centered model that was based on years of research on human learning. It set out to design environments in which learning could be increased by using modern tools and procedures. The legislature supported the program by providing resources to nine collaborating districts that were the field test sites for the new model.

To begin, we used standard procedures from industrial psychology, operations analysis, and systems analysis to analyze the jobs of teachers, counselors, and others. We analyzed jobs, workflow, and planning processes in a sample of Florida schools. Based on these analyses, we reported that about 95% of the staff—the teachers, counselors, and principals—were working about as hard as they could. They were faithfully applying the existing processes and expressed continuing frustration about their inability to accomplish what needed to be done (Bruskiewicz and Hanson, 1996).

One major goal of SY2000 was to integrate available technologies into overall operations, including computers, Internet connectivity, and administrative applications (see Gery, 1991). Integrated technology-supported processes are vastly different from those that involve merely adding computers to a traditional classroom or learning laboratory (see Cuban, 1992).

During the initial planning and analysis, we documented a large number of planning disconnects, process inefficiencies, and process failures. Based on these analyses, we came to believe that we could achieve no significant performance increments through training, motivational changes, or incentive manipulations. Our only hope for significant improvements was through major process reengineering, job redesign, and organizational change (Johnson, 1993). All SY2000 work was done in the context of a *systems approach.* An overview of the systems perspective and methodology is presented next.

Systems Thinking

Although systems thinking is a topic of much greater depth and breadth than can be included here, a brief overview should be useful. One significant and basic difference between traditional *solution selling* and *systems thinking* is in the method used to address problems. Solution selling occurs when an advocate urges the adoption of some policy, program, or configuration without taking into account the possible effects on other departments or functions. Frequently, the fix lies within the budget authority of the adopting entity, but not always. Solution selling most often defines the cost as the initial purchase price, such as the operating capital outlay required to buy computers or Internet connections (see Ackoff, 1999; Salisbury, 1996).

Systems thinking, on the other hand, uses a total cost of ownership model applied in the context of a cost-benefit trade-off analysis. Further, a systems approach invests an adequate effort in problem definition before advocating a solution. Systems practitioners virtually always require the "whole system" to be in the room at the time the problem is defined and the solution strategy adopted. In a systems approach, all appropriate stakeholders must participate in the orderly processes of analysis, design, and implementation (Gharajedaghi, 1999).

Providing food relief to starving children serves as an example to highlight the difference between the two. When the nightly news shows emaciated children in some remote and destitute country, the most immediate and seemingly compassionate response is to give them food. Viewer spirits rise when the TV next shows the United Nations or other donor agency, airlifting food. Spirits sag when we next see the donor's futile attempt to distribute the food. Then the TV scenes show conflicts between donors and the owners of the normal food distribution channels who steal the food. The hapless donors then plead for the UN to send troops to force the donor distribution efforts. Spirits rise when the troops unload from the helicopters, but then the resistance kills some UN troops. Spirits plummet and public outrage leads to a strong demand to withdraw the troops.

Notice that the process is *reactive* at every step. Donors react by sending food that cannot be equitably distributed. The UN reacts by sending troops to protect donors. Sons are killed and the public demands a withdrawal of the troops. All the while, the needy people are still starving. The process involves only a forced push from the outside in. How might a systems model differ?

First, to solve the problem, one would include *all credible stakeholders* in the problem analysis from the beginning. Then a careful documentation of the problem is done after data collection and receiving input from all those affected. In the starvation problem, the simplest of all solutions according to C. West Churchman (1979) is to give the starving people enough money to buy food and let the market solve the problem. Based on the established fact that a *market will always supply demand at some price*, the people who have money will get food. Of course, if you send families real money, some will buy booze and others will be robbed. Perhaps food stamps would work. Perhaps issue a special scrip currency. Many possibilities should be considered.

The critical factor is the consideration of credible alternatives by the stakeholders and a listing of the pros and cons of each. Had the food distributors been at the planning table in the beginning, they could have told donors what to expect if they chose the give-away method enforced by troops. Giving food away eliminates the merchants' normal revenue. People with power will resist threats to their incomes.

One possible arrangement might assign the traditional distributors to deliver the donated food, the citizens to have coupons or credits, and the distributors agree that they will not black market the credits. The point is not to claim that we can solve the problem before we have the information, but to adopt a problem solving methodology that can yield an effective and lasting solution, one that feeds the children at the lowest sensible cost, and minimizes human suffering.

COMPARING INVESTMENTS IN R&D

A systems approach virtually always incorporates the results of programmatic research and development. The Semmelweis to Pasteur to Lister story has been repeated hundreds of times in many different fields of endeavor. Rapidly advancing organizations, both public and private, depend on programmatic research and development to achieve major improvements—the kind of research and development that produces better defense systems, better medicine, better fabrics, and better computers. Traditional companies with fully mature product lines also invest to keep abreast. These organizations invest dollars that would otherwise go immediately to the bottom line. Eliminating R&D would free these funds to make profits higher or taxes lower. But, history has taught them that the benefits of the long-term investment radically outweigh the costs.

Table 1 shows the average percentage of gross revenues invested in R&D for several economic sectors. The most optimistic estimate for education R&D nationwide is 0.025% (Perelman, 1989). In Florida, it is less than that. To preserve the state's most significant resource, the students of today and workers of tomorrow, a true commitment to programmatic R&D is essential now.

We could speculate that the category "Drugs and Medicines" is more like education than certain machinery and equipment. There a massive 10.4% of total sales is invested annually and that percentage increased by 109% between 1985 and 1995 (Murphy and Topel, 2000).

Regardless of the quality of R&D in the medical community, they too can fall into Deming's "15% faulty people" trap. Congress worked on the Medical Error Reduction Act of 2000 as a means to reduce medical errors, currently the eighth ranking cause of death in the United States. The initial drafts focused solely on finding the malpractitioners and punishing them. Subsequent testimony by the human factors, ergonomics, and human error research communities provided for a more informed inquiry into the complex causes of medical error and the application of a systems approach to reduce errors and accidental deaths (Mumford, 2000). Adequate R&D and a systems approach to design are both required to realize the necessary and sufficient conditions for improvement.

Table 1
R&D Investment As a Percentage of Sales for Selected Industries

Drugs and Medicine	10.4%
Office and Computing Equipment	8.1%
Communications Equipment	8.0%
Electronic Components	8.0%
Optical, Surgical, and Photographic	8.0%
Scientific Instruments	6.6%
Industrial Chemicals	4.7%
Motor Vehicles	3.0%
Non-electrical Machinery	2.4%

Source: Murphy and Topel (2000), p. 30

Competent R&D requires hard and demanding work that rarely proceeds rapidly and consistently toward an easy goal. Unfortunately, not only is R&D hard and time-consuming work, the R&D approach is a tough sell to legislators and the general public. Few educators have an R&D background; parents feel they have enough personal experience to supplant research; and political solutions continue to have quick fix appeal.

Granting that advancing knowledge and practice is critical to improvement in competitive enterprises, it would be fair to conclude that no large societal sector will improve without substantial R&D investment. Having studied the problem for a number of years, we concluded that to improve significantly, the education sector must also conduct the hard, persistent, and deliberate R&D work that everyone else has to do.

Part of the Solution: Contemporary Educational Research

No matter how costly marginal literacy becomes in adult life and how limited the opportunities of the victims, society has accepted the damaging illiteracy rate just as Semmelweis' peers believed that the incidence of childbed fever could not be reduced and accepted the deaths (see Kozol, 1985; Mathews, 1998). Even today, some effective remedies are available to improve student learning, but the routine mechanisms for incorporating new procedures into practice must still be developed.

Two examples, selected from a large number of others, demonstrate the high payoff from effective educational research. The first documents an improved *process* of instruction. In the early 1970s, the American Institutes for Research issued a report on peer tutoring (Klaus, 1973) that reviewed numerous research studies and programs throughout the world, virtually all of which produced positive results across a number of subject matter areas. Greenwood, Delquardi, and Hall (1989) reviewed the peer tutoring literature 16 years later and reached similar conclusions. Other researchers summarized the conclusions:

> A consistent set of findings has convinced us that peer tutoring is one of the least costly, most effective teaching methods known. But we rarely see tutoring programs in the schools we visit. (Berliner and Casanova, 1993, p. 52)

Because peer tutoring does not increase costs and requires no additional technology, it could be compared to hand washing in Vienna. It is cheap, available, and effective. Unlike the spread of hand washing, peer tutoring is making no headway. To benefit from new knowledge requires starting a continuing effort to use it.

The second is a product example. One advantage of a combined product and process change is that it can be continuously improved. One program that relies on new instructional materials and procedures is Success for All, developed by Robert Slavin and his colleagues at Johns Hopkins (see Slavin, 1999). Based on solid R&D, this program combined materials and procedures to promote more effective learning in groups and spans the pre-K to 12 curricula. Fortunately, other technology-supported programs that are demonstrably effective have been developed to provide intense instruction and feedback. The old model of individuals teaching as they please, regardless of outcome, resembles the practice of medicine before the germ theory.

Although the R&D solution has proved effective in many other disciplines, the problem of implementation in education approaches being an insurmountable opportunity. To improve requires a new paradigm. To implement a major redesign requires a transformation of immense proportions. To make a change of that magnitude will require resources and consensus of the stakeholders. To enable the practitioners to adopt the change and implement the new processes will require time to learn and to adjust to new procedures. Paying teachers to learn new roles and procedures is costly —as NASA learned when they trained aircraft pilots to be astronauts.

That the proposed redesign of education will be daunting for a period of years and will require a massive effort—a Manhattan Project—in no way relieves our obligation to begin. Fraulein Elizabeth Weiss must not die in childbirth. Elizabeth White must learn physics.

Active Independent Learning

Recent popular and professional articles and treatises urge developing a new kind of active and independent learner for the information age. Advocates argue that society is changing at a faster pace than ever. People will change jobs and careers much more frequently. To survive and thrive, graduates will require knowledge- and skill-gaining strategies that do not depend on sitting in class. The U. S. Department of Labor (1999) and other organizations assert that these skills are still lacking in recent graduates and that a large percentage of high school graduates require remedial training to profit from college-level instruction or technical training (Barton, 1999; Carnevale, 1999).

Active and independent learners, who can take charge of their own learning, contrast with passive and obedient students who are rewarded for cooperation and compliance. Traditional schooling served and rewarded the latter group. Creating a learning system to enable students to flourish in the future will require a major effort by the best designers available (Scardamalia, Bereiter, McLean, Swallow, and Woodruff, 1989).

Processes Cause Results

If Dr. Deming is right that processes cause results, then if different results are necessary, new processes must be adopted. There is a huge body of literature in the quality sciences that documents the importance of process changes. To establish higher standards and hope for better results while using the old processes is irrational. In Florida, one can applaud the Sunshine State Standards and the development of testing programs to measure them, such as the Florida Comprehensive Assessment Test (FCAT). Setting standards and measuring them well are critical elements of success. What remains to be done, however, is the adoption of new educational processes to cause the increases in achievement demanded by the standards.

It makes little sense to expect students to develop vastly different capabilities without experiencing vastly different educational practices. To realize different results requires the following stages: *analyzing* the requirements, *defining* the outcomes, and *planning* interventions that will cause the new outcomes. Although we might be able to design new interventions based on existing knowledge, these stages still require a new research base.

The NASA View

In 1961, President John F. Kennedy challenged the National Aeronautics and Space Administration (NASA) to send a man to the moon and return him safely to the earth before the decade was out. At the time, NASA did not know how to do that. It was also clear that the existing fleet of aircraft would not be up to the job. The Boeing 707, the leading aircraft of the day, had reached its upper limit in terms of speed, range, and payload. Although it served a previous mission admirably, it was not going to the moon. The aircraft was not, but the pilots could be trained to the new mission.

To meet the challenge, scientists at NASA adopted a knowledge classification system that could be used in education. They recognized that there were critical scientific areas that were *known to be known*. Astronomy, physics, propulsion, work environments, navigation, and many other areas had well developed knowledge bases. Within these disciplines and others, NASA identified problem areas that were *known to be unknown*. The known unknowns became the research agenda of the day. Without hesitation, they set out to learn what they did not know. They invested in R&D because they had to; they could not achieve the mission without new knowledge. As more of the unknowns were addressed and solved, they made an incredible discovery along the way. With a healthy respect for their own ignorance, they took a giant step in solution theory when they realized that there were vast areas that were *unknown to be unknown*. They could not discover these unknown mysteries until they solved some of the known mysteries. Semmelweis did not know that he did not know about germs.

NASA’s approach represents a clear divergence between education and the research and technology community. In education, many urge that schools should adopt “best practices” used by others within the existing system. Clearinghouses and diffusion efforts among those who appear to be doing the same kinds of work can be effective for some purposes. The 707 flight crew community always shared experiences and problem solutions to their own benefit. Their sharing of existing knowledge did not increase the speed, payload, or range of the aircraft. Sharing knowledge is useful only in the same context; it is not a method to accomplish dramatic new results.

The valid knowledge base for education—what is known to be known—continues to be limited. An organized knowledge inventory of the known unknowns has not been systematically developed. Any program that focuses primarily on people almost certainly has a massive, but unidentified, inventory of the unknown unknowns.

In the new design, another issue requires attention. Now, a large amount of valid research comprises the known-to-be-known category. But, known valid knowledge is not universally applied. Many research discoveries have not been used. To change that requires a new methodology and an approach to problem solving that has worked in numerous other complex situations—adopting a programmatic R&D model. Those who do not apply what is known are unlikely to value discovering the unknowns. Without a major redesign, the chances for making substantial gains in school performance are minimal.

The Mission Context

Significant educational improvement requires a coherent mission from consensus. The Sunshine State Standards could serve as the core of the mission. Reasonable operational objectives can be derived from the mission. When that mission is set forth clearly, systematic analysis will reveal the interim steps and attributes *necessary* and *sufficient* to achieve it.

For example, to find out what high school graduates needed to know and be able to do to progress to their chosen next step, the SY2000 surveyed 625 job experts employed in 183 Florida organizations to find out the necessary entry skills for these jobs (Peterson and Sager, 1993). Universities and colleges were included in the survey sample to ascertain their required entry skills. These documented entry requirements can be incorporated into new operational objectives.

If the teaching-centered model has topped out, and the evidence supports that conclusion, if new levels of performance are required, the paradigm—the set of core processes—must be changed. An aggressive R&D program will discover new and improved processes. As more known unknowns are converted into useful knowledge, new approaches will appear.

As a means to reach the higher standards, one of the objectives might lead us to change from the teaching-centered model to a learning-centered model. That requires a complete list of characteristics and defining attributes of a new model. These might be elaborated in the form of design requirements. Perhaps two of these design requirements would be horizontal and vertical integration of services and processes. Integration means the development of seamless boundaries between levels and locations of service areas. Research programs would assist in providing answers that would improve overall system performance (see, for example, Scardamalia et al., 1989).

Who Should Initiate the R&D Program?

Given the need for a research and development program, who should initiate this research? The federal and state governments and local school districts are the obvious candidates. The federal government has traditionally identified educational research as an appropriate responsibility but in practice has failed to meet that responsibility. The federal government's investment in disciplined inquiry and research-driven experimentation is small, particularly as compared to its research investments in other public sector areas such as defense, health care, energy, and agriculture.

Further, no other group at the national level is picking up the responsibility. Foundations tend to fund demonstration projects with limited research on comparative effectiveness and affordability. State governments have no tradition of funding basic research and little tradition of funding applied research. State efforts have generally been limited to data collection, replication and dissemination, and evaluations of existing programs or monitoring of small-scale pilot projects. School districts remain the third possibility. However, school districts, on the whole, lack the capacity. Central staff is often small and overwhelmed with operational responsibilities. The larger districts, which presumably have greater capacity because of scale, are often highly troubled districts due to the host of problems besetting urban America (Herrington, 1995).

As a practical matter of survival, whoever funds an R&D program should benefit from the results. Who stands to gain the most from increased effectiveness and efficiency in public schools? In Florida, the state stands to gain the most from more effective schools and can realize cost avoidance with more efficient systems. The state has both the incentive and the capacity to initiate the R&D program. In fact, it may be more costly not to make the investment.

Properly implemented, the real benefit from a solid R&D-based educational system will be in increased knowledge and performance of students. Information age requirements and the internationalization of many traditional commercial enterprises provide those states with the most capable population the opportunity to realize many quality of life benefits. International comparisons suggest that the U. S. and Florida have a challenge to catch up in mathematics (see Geary, 1996). The knowledge industry is unique in that it requires the employees to define and discover the nature of the business from the beginning. The traditional idea of attracting industry by offering training to potential manufacturing or service employees is gradually being replaced. In many cases, the information age employer does not know in advance what the employees should do to add real value to their product or service.

As a case in point, Ireland has traditionally been economically challenged. In the past 20 years, with a 98% literacy rate and an educated population, the economic growth has been just short of miraculous. High tech industry, information technology firms, and others requiring advanced personnel competence have located there. Companies opened plants in Ireland initially for low-cost labor and the high education level. The international market will, of course, close the gap on the cost of labor. Ireland's economic marvel can be substantially credited to the emphasis on education.

Does R&D *Really* Pay?

One look at the return on investment (ROI) for medical R&D programs could show by comparison what might be accomplished in education R&D. Murphy and Topel (2000) attributed investment in medical research to increases in life expectancy. Then, they calculated the economic value of life expectancy increases to be between $2.4 -$2.8 trillion annually, based on an R&D investment amounting to less than 3.2% of healthcare expenditures. Perhaps more importantly, these expenditures that increased life expectancy also resulted in spectacular improvements in the reported quality of life. The widespread application of the results created through R&D investment caused both increased longevity and increased economic payoff to the society.

As the data from the medical sciences indicate, through programmatic R&D, it should be possible to gain an increase in student achievement and to reduce the rate of growth in per pupil costs at the same time.

Education Funding

State governments often dedicate over 50% of their general revenues to schools. Because of funding formulas and other restrictions brought about by the Florida Educational Finance Program, it will be necessary to reserve money to support R&D before the remainder is distributed to the districts.

How much money will be required?

Currently, the education establishment resembles an endless fiscal sink. No amount of appropriated money would be adequate to raise teachers' salaries to the levels proposed by teacher organizations and bargaining units. Reducing class size consumes massive increases in funding. Seemingly limitless demands for buildings and infrastructure are requested annually. More money can always be spent on buildings, student resources, and new programs. With an expanding population, it could be beneficial to develop scalable programs to prevent costs from increasing linearly with population. Other sectors of the society have used technology creatively to enhance scalability (see also Salisbury, 1996).

The Proposed Education Formula

Suppose that the annual education budget is $10 billion to provide 180 days of schooling. Dividing $10 billion by 180 yields about $56 million per day. The R&D system should be funded at the annual level of at least one day's schooling. Although this is much less than 10% of operating funds invested in drugs and medicines, it is a gigantic improvement over the amount invested in educational R&D today. The first year's money, put in trust, would enable a research program of more than $8 million per year for seven years. Subsequent years would accumulate additional funds. If the money is not put in trust, the next legislature will reclaim it and all will be lost.

Research programs, too, can consume excessive amounts of money. However, a group of competent researchers working in collaboration with other stakeholders could provide a reasonable estimate of funds that could be wisely invested and a schedule that would permit gradual knowledge development. It would take several years for the education R&D institutes to consume prudently the suggested level of funding. Additionally, all government researchers know that trying to conform a research budget to the fiscal year funding cycle virtually always causes waste. That's why the money should be independent of the annual budget.

Who Should Do the R&D Work?

Because we have no direct history of programmatic R&D in education, it would be prudent to seek models from other sectors of the society. We could study institutes of research in medicine, military laboratories, corporate R&D centers, and many others. By taking a systems approach, we could locate the best models and combine the most efficacious aspects of each of them. Consequently, we should not adopt an answer until the question has been carefully analyzed.

Seeking Viable Models

Perhaps a good starting point would be a study of two R&D institutes with strikingly different missions. First is the Institute for Food and Agricultural Sciences (IFAS) at the University of Florida. IFAS is relevant because it addresses Florida problems directly, provides clear evidence of success, and is relatively independent of the University of Florida. State, federal, and local governments and industry fund it.

IFAS is a statewide organization dedicated to teaching, research, and extension and serves the agricultural, human, and natural resource needs for the state of Florida. IFAS has faculty located on the University of Florida campus and at 21 research and education centers, extension offices in 67 counties, and four demonstration units throughout the state. IFAS is a partnership in food, agriculture, natural- and renewable-resource research, and education. All of these IFAS functions are required in a good R&D program intended for dissemination. Ultimately, the Education R&D institute should establish a consortium of research centers, university departments, and collaborating school districts to ensure that the work is coordinated and managed to common goals.

The second institute is the Korean Educational Development Institute (KEDI). Careful examination of student performance in published international comparisons reveals that Korean students regularly perform at or near the top of the world. The KEDI was established in the early 1970s with the mission to improve education in Korea to meet the national economic development plan. Many consider KEDI to be the best organization of its kind in the world.

In addition to research coordinated through other Korean universities, KEDI also develops materials and instructional programs based on its own research. These materials are then provided to the schools and evaluated regularly. Thus, the Korean government decided that education was to be a national priority that would fuel future economic growth and established an organization to support the education system's movement to a new era. They set a national priority, established a means to achieve it, and have continued to support the R&D efforts for more than 25 years. On the basis of their high academic achievement compared to that of all other countries, it appears that they invested wisely (Morgan, 1979).

CONCLUSIONS AND RECOMMENDATIONS

Based on the analyses described in the report and on the studies of successful sectors of the society, the following conclusions and recommendations are offered:

Conclusions

- ♦ The existing teaching-centered model of schools is obsolete. In place since the time of the Romans, it reached its maximum level of effectiveness in Florida about 50 years ago.

- ♦ Numerous programs and costly initiatives have been tried in a continuing but unsuccessful attempt to revitalize the old system.

- ♦ Successful sectors of the society and economy, such as information technology, medicine, agriculture, and the military, have found that the only way to improve is through making substantial investment in R&D. These programs provide a large return on investment.

- ♦ If major improvements in educational outcomes are required, then an alternative model of schooling must be implemented. New models must focus on learning-centered processes and rely on research to make incremental improvements.

- ♦ The education sector invests only a minute percentage of total expenditures in R&D. Even when good research is available, implementation mechanisms are not in place to benefit from them.

- ♦ To the harm of schools, significant stakeholders in education appear to believe that they can improve results without doing the difficult and deliberate R&D work all advancing sectors have to do.

Recommendations

1. ***The state of Florida should establish an R&D program*** that would yield new processes to improve school performance. It is the proper role of the state to begin this work because of its interest, resources, and capabilities.

2. ***Initial funding should be set at investing one day's operating budget*** in such a way to ensure the continuation of the R&D effort for an initial period of eight years. ***Subsequent funding should***

increase proportionally as the needs are established and the results are found to be favorable.

3. ***Policy should be elaborated that requires the use of valid research knowledge obtained from the R&D efforts*** of Florida and elsewhere.

4. ***Models of successful R&D institutes all over the world should be studied*** to find the most efficacious organization to meet Florida's needs.

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