Chapter 2 -- The Design of Educational Reform

2.0 Emergent Design

In this chapter we look closely at the commonality of the activities of organizational and educational change. The less traditional intellectual base in which my work has roots is an area that has not played a significant role in guiding educational thinking. This is the remarkable evolution in the past few decades of thinking about management of businesses and other organizations and specifically about the management of organizational change. My own career has woven between work directed at helping young people learn and work directed at helping organizations change. But even on the most superficial level the two kinds of activity have never felt to me as different as they might appear from the outside. In education one is constantly up against the organization of schools and in managing organizational change one is constantly up against processes of learning. This chapter is an attempt to look at the commonality of the fields in a less superficial way.

I use the concept of *design* to provide a conceptual framework for the endeavor. The driving form of the questions I shall be asking is: “How does one design X?” X might be a new structure for a business or a new curriculum for a school. In such cases the question of designing the new thing must be followed by questions about how to implement the design. But this question brings in more issues about design. Determining a strategy of intervention is itself a process of design.

Thus design rests on design. And if we pursue the line of questioning we come to a view reminiscent of a famous explanation in Hindu mythology. In that tradition is written that a turtle supports the earth. When the student asks what supports the turtle the sage answers: "Another turtle." And what supports that turtle? "Why, another turtle … it is turtles all the way down." In the same spirit I suggest that we have to think recursively about design resting on design resting on design … "all the way down."

2.1 Design All The Way Down.

The recursive image also captures another aspect of the possible role of *design* as a concept in the discourse of education theory. My emphasis in the previous section was on the *educator* or even the *education policy-maker* as a designer. In following chapters a closer look at my own work will show *students* also doing work that is well described as design. Some authors such as Idit Harel, David Perkins, Janet Kolodner, and Yasmin Kafai among others, emphasize the role of design in student activities [Harel, 1991, Perkins, 1986, Kolodner, et.al. 1998, Kafai, 1995]. Louis Gomez and others have begun to advocate the role of teachers as curriculum designers. People who create curriculum or propose education reform are designers by definition. While the benefits of practicing design are evident within each, there are inherent limits when either the possibilities for real design creativity and decision-making are restricted (for example when students are coerced to design only by selecting parameter values or in highly constrained pre-determined scenarios or when teachers are charged with designing particular curriculum units with little room to innovate due to limited time, resources, or freedom).

The relationship between children as designers and educators as designers is not simply one of ends and means. I see an element of contradiction in the concept of an imposed, pre-designed design-based curriculum. If the children can be entrusted with the design of their products why should the teacher not be entrusted with the design of the classroom activity? This question takes us one layer down in the structure of "the turtles." And yet another layer down leads us to ask where the very idea of the design-based curriculum comes from – whether or not it has the teacher-as-designer twist. In the end we are led to a conception of the entire educational enterprise from the leading-edge visionaries and researchers to the youngest student as a complex interactive whole.

This conception is radically different from the way in which education reforms are usually carried out. Some set of people decides there is a problem needing addressing (such as low math and science scores) or a change deserving implementation (such as the introduction of a new item like ethics to the curriculum). A group convenes. They call in the various experts, stakeholders, practitioners, and other usual suspects. They design a blueprint for their reform. The blueprint contains a curriculum, materials, texts, assessment, teacher training, and so on.

Educational reform efforts, over a long period of time, have offered very different blueprints. Yet none have had the substantial effect for which they were designed. Why is this the case?

This thesis presents the view that these blueprints have failed simply because they are blueprints. Many analysts researching this situation, most recently David Tyack and

Larry Cuban, have shown how the process fails [Tyack and Cuban, 1995]. Whatever blueprint is proposed, it is inevitably going to be transformed in the course of appropriation, ending more in conformance with what the designers originally hoped to reform. The institution tends to reform the reform, perhaps retaining the rhetoric but rendering it toothless. Tyack and Cuban brilliantly term the overriding mindset the "grammar of school" [page 85]. Like a grammar, they describe a deeply-held organizing system that only allows certain expressions (or actions) as legitimate and renders some expressions nonsensical if they deviate from the underlying system

What Tyack and Cuban made clear was whether reforms are big or small, from the right or from the left, national or local in scope, they do not work. Some might deserve to fail because of the nature of their content. But while content may or may not be a limiting factor, they fail because of the form in which they were designed.

What is needed is an alternative approach that is not a blueprint. This naturally raises the question that having no blueprint mean we are abrogating all design and planning so that anything goes.

2.3 Problem-solving versus Emergent Design

The major objection to the view of things that is projected by the previous paragraph could run like this:

> Of course you are right. Of course "education" taken as a whole is a complex interactive process. Of course breaking it into parts loses some of its wholeness. But it also gains something vitally important: the possibility of action! The description of "the way education reforms are usually carried out" is not something special to education reforms: it is a description of good practice in problem solving! The way to solve problems, the way to get anything done, is to divide the work into tasks and sub-tasks, problems and sub-problems.

The objection is true to this extent: the approach to designing educational interventions being advocated here challenges much more than traditional educational practice – it challenges paradigm of thinking that are of vastly greater scope. This might seem to imply that this view, if true, would imply that a hard – some would say impossible – task is even harder than it seemed. But I will argue that, on the contrary, it makes it easier in some very essential ways by allowing educators to draw on the larger body of experience and analysis that has been accumulating from other manifestations of the same paradigm shift.

My central argument is that there has been emerging in many areas something I propose here to call *Emergent Design*. The principal thrust of this thesis is to offer concrete experiences that show emergent design as a viable alternative in education. But the educational strategy will be far more fully appreciated in the context of realized strategies in other fields. So in this chapter I first describe one of my own experiences in emergent design of organizational change outside of education and then survey briefly some of the

other manifestations of the shift towards emergence of paradigm for understanding and influencing change in complex systems.

The experience I choose as the centerpiece for the chapter is taken from the field of healthcare organization. I choose the example for at least three reasons. First, the relationship between healthcare and education happen to be particularly transparent in certain key respects. Second, I can speak from personal experience of having played the lead role in the operation I describe. Third, this particular experience played a key role in the emergence of my own conviction that this is the correct approach and in the formulation of a conceptualization that bridges education and fields (such as business) that have had more attention from modern organization theorists.[1]

2.4 An Example of Emergent Design

Healthcare shares a number of similarities with education. Primary among them is that there is not yet a complete, robust theory of how the system works.[2] That is, we fully understand neither the mind for learning nor the body for health. Both fields have to rely upon empirical results to determine probable causes and courses of action. In both there are many hidden factors, where a current action may only have results, either positive or negative, after a considerable amount of time. Both deal with highly complex, open,

[1] In my conclusions I shall speculate on why education has received less probing attention from this community.

[2] The late Dr. Mark Weinstein, who at the time of this work was the Chief of Surgery at the Harvard University Health Services and a professor of surgery at Harvard Medical School, told me that he used to open his lectures to beginning surgery students by telling them that "Fifty-one per cent of what I am going to tell you is wrong, and I do not know which fifty-one per cent it is." His goal was to firmly implant in their minds that they have to be open to being wrong but still to practice in the best manner possible, while always open to re-learning even some of their most fundamental assumptions.

dynamic systems where attempting to produce a positive result in one sphere may simultaneously have detrimental side-effects in another sphere. Lastly, in the United States in particular but also in virtually all of the rest of the world, they are practiced in relatively conservative, hierarchical institutions. One result of this is that although for many years there has been the specter of radical change through the introduction of intelligent and innovative use of computational technology, for the most part neither healthcare or educational institutions have been able to avail themselves of the potential benefits.[3] This section details a design and implementation effort to pioneer a radical change in the healthcare field that the author led. This example will shed light on the effort in learning environments described in subsequent sections.

Although medical care in the United States is considered extremely high tech, the technology is almost exclusively used in diagnostics and treatment. The fundamental operation of the encounter between people and healthcare providers has remained relatively constant over decades, for both good and bad reasons. The primary exception to this is the push for "productivity," which has resulted in many fewer encounters between the parties with much less time spent in each encounter. Critically important to note, is that in this context productivity only means the number of bodies seen by the

[3] Claiming that medicine in the United States does not fully utilize advanced technology may seem counter-intuitive at first. Many aspects of medical practice are extremely high tech. However, the use of computational technology, for the keeping of medical records, for the guidance of practice, for use by practitioners and patients, for communication, and so on, are extremely rudimentary. One study detailed how more than ten percent of prescriptions for senior citizens are mistaken. One can visit a specialist who will have no idea of one's records, tests, or medical history. The fault is not in the potential of the technology but in its lack of use in various aspects of healthcare.

provider, and is not any measure of the health of the people, which clearly should be the only consideration.[4]

2.4.2 Background

This example comes from the effort to dramatically reform the Harvard University Health Services (UHS). UHS provided medical care to not only the entire student population, but also provided services and insurance to a large majority of the university employees and their families. The health services suffered from the same difficulties from which other healthcare providers and insurers suffer. This includes:

- high level of demand for quality
- rapidly spiraling costs
- reduced revenues
- high demand for service
- reliance upon expensive equipment and practitioners
- increasing demand from the public and regulators to document outcomes of practice

To the credit of this particular institution, management and the chiefs of medicine and the specialties had an internal drive for consistently providing the best possible healthcare and moving the practice of medicine forwards by a careful study of its own activities.

[4] I do not mean to imply that this is a choice of the doctors, nurses, or healthcare providers. Rather, it is an outgrowth of the design of the system where the pressure on cost is primarily dealt with by decreasing services and increasing the flow of people.

My role was initially defined as leading the design and development of new computer systems to support the practice and management of healthcare. However, it soon expanded to be much more than this. Upper management originally looked at this as purely a technical question. Determine the best system to purchase and install it. However, my examination of medical informatics systems found no suitable system to fit the organization's needs and goals. More importantly, as the following discussion will illustrate, no off-the-shelf system could meet these needs and goals. The particular culture of the organization combined with the various practice patterns of the healthcare providers and the open, uncertain nature of medical knowledge makes finding an ideal system developed elsewhere an impossible task. Once this was clear to management, my role expanded beyond designing the system to a more integrated role in the management, practice, and reform of the entire organization.

The systems for keeping medical records at UHS were hopelessly obsolete. There were many pressures to upgrade the system. However, since management desired to upgrade the practice, they decided to use the change in technology as a lever to create a broad, dramatic change in practice throughout the organization. Thus, the idea was not merely to get the same type of system on new, faster hardware, but rather to change everything; practice, systems, process, and management.

The management of the institution, the head of which was also a medical doctor, presented me with a number of goals and constraints for the design of the technology.

The primary consideration was to improve the care provided to the people.[5] Part of the most cost-effective method of providing improved care was the better use of information and computational technology. The director of the health services told me that, "We have twenty primary-care physicians and if someone comes in for a diagnosis, we could give them twenty different answers. Such uneven care is unconscionable. Worse, as our systems are now, we would not even know if this were the case."

The design challenge, then, was far from simple. Our plan was to use the design and development of the new technology as a catalyst for change within the entire organization. We wanted to do much more than automate existing practices. Rather, we hoped to enable new ways of working through a more supportive, more flexible, more intelligent application of computational technology. This required totally different systems, processes, and behaviors, with the change occurring without an interruption in care delivery, and with a minimum of resources. The design question became: How does one design and implement for mega-change?

2.4.3 Design Tensions

[5] Although it may be somewhat clumsy, I will not refer to the population using the more popular terms of either patients, which puts them in a position of sickness needing treatment, or as consumers, which puts them in another subservient position. Although this may be typical in the field, another view is that this is part of the problem in that it divorces people from the responsible management of their own health and well-being.

In our work we identified a number of tensions where factors pulled in different directions so that hard design decisions had to be made. These are described here in ways that will bring out their similarity to educational problems. It must be remembered, however, that this project was not an exercise to make points about education. These were the real issues that faced us in dealing with the health care organization. The following shows how we dealt with these tensions.

1. Top-Down Goal Setting versus Emergent Collaborative Goals

An immediate conflict arises about the level on which goals are set. It is easy to fall into the trap of listing all the improvements that anyone wants to see happen. This would result in unrealistic and unrealizable expectations, and thus a chaotic approach trying to balance competing interests. Besides, since there always are so many ambitious goals and the existing practice and environment had so much room for improvement, we knew beforehand that success is precluded.

Instead of thinking of our goal as list of improvements we saw it as producing a change of *mindset* by the providers and other employees of the health service. A change of mindset would be the optimal enabler of any subsequent change. To change the mindsets would involve reflection on existing practice, new visions of possible future practice, discussion, concrete examples of new and better ways of practice, a belief that the reforms would be in everyone's best interest, and some early successes in change. The overarching goal for establishing different mindsets is establishing the belief that things

can be better, they can be dramatically different than the current situation, and that each person can contribute to this improvement.

At UHS we decided to entwine the system development with the broader changes. These changes were for both the clinics and the administration. We set sweeping overall goals for improved clinical practice, reduced costs, and better services to members. I designed a systems architecture that could create a new environment to support new practice and new functions while simultaneously supporting existing practice and draw from years of accumulation of medical records. The design had a comprehensive, coherent architecture so that it could grow and support emergent, evolving applications. It was also sufficiently modular to support applications developed for particular purposes as well as applications developed outside of UHS.

For example, we created pathways into the existing, proprietary, hierarchical medical-records database to support new applications by various departments. This streamlined reporting and adding of new members. This also resulted in cost savings by eliminating enrollment busywork and improved personalized treatment by enabling management and practitioners to view practice patterns. Since the new architecture was open, it also enabled the use of medication software created and donated by outside vendors.

2. Centralized versus De-centralized Control

Upper-management created the initial push for change at UHS. However, it is misleading to think that a desire for change did not exist at every level. But even though the desire

for change may have existed at every level, it is highly unlikely that all levels would agree on what needed to be changed, how to change, the priorities for implementing change, and so on. Upper management may try to insist upon change, but if the other levels of the organization do not buy into the changes, they will resist, ignore, or subvert implementation. If the lower levels of an organization feel a sense of ownership of the changes, perhaps having designed some of them, and feels a sense of benefit resulting from the changes, this naturally increases the likelihood of acceptance, cooperation, and initiative. However, a design tension can arise if the changes proposed on the initiative of the lower levels do not fit with the overall goals. This situation requires re-framing the problem or negotiation of a solution amenable to all levels.

For example, the insurance office was able to realize savings and simultaneous gains in productivity by advocating for and helping to design applications to review, manage and pay for outside services. As this was both a goal for management and the insurance office, both sides gained through this initiative funded by that department.

3. Adaptive versus Strict Planning

Results are not fully predictable in open, dynamic systems. When trying to mobilize the intelligence and talents of an organization, one cannot predict what new ideas will arise. When they are suggested and are demonstrated to be valuable, it behooves the organization to take advantage of the situation. This will not strictly be in the active plan, but to ignore the benefit would be obviously foolhardy. Thus, the plan must be adaptive. However, there must be a coherent enough philosophy and development plan or else the

organization will just bounce from place to place, idea to idea, without building and maintaining its progress.

4. Concrete versus Abstract

Not surprisingly, envisioning dramatic change in healthcare practice at first is abstract. How can we know what it will look like before hand? Even if we buy into the conception of the problems of the present and the vision for the future and the supporting philosophy, we may not know how to act in the new environment. Moreover, we may not know how to design it fully beforehand.

In engineering practice, we use rapid prototyping to augment the design process. Building a rapid prototype provides a concrete artifact upon which to work out many of the more complex, hard to plan elements. We can use the same technique in organizational change to see what works, what does not work, and what elements are different than what we imagined. This helps provide proof of concept.

Rapid prototyping also provides a second, important benefit by providing quickly realizable tangible benefits. This helps create confidence in and acceptance of the proposed changes. Of course, there is a new design tension inherent in this process in that if some changes take longer to implement and longer to realize benefits, people accustomed to easier, rapid projects may become disillusioned.

5. New Modes of Operation versus the Familiarity of Legacy Systems

Software systems comprise a major element of the processes and culture of an organization. People become accustomed to the role and function of the computational systems. They utilize what they like and find ways to work around what is cumbersome. Unfortunately, so much of systems design still is rigid, difficult, and unfriendly [Landauer, 1996, Norman, 1990]. While systems design is evolving, the art is still far behind what people like and need. This deficiency is not merely confined to user-friendliness. Rather, important functions go unmet or poorly performed due to systems limitations. For example, the medical director and the chief pharmacist informed me of one study that demonstrated that more than ten percent of medications given to senior citizens are prescribed incorrectly and potentially harmfully.[6] The reason is due primarily to doctors not knowing what medications a person is taking, and prescribing something that interacts badly with another medication, food, or an allergy.

A primary reason for this lack of capability does not lie in any inherent weakness of the technology. Many other, less critical, institutions than healthcare are quite proficient at mining data, finding patterns, and dynamically responding to situations in real time. Ironically, a major factor in this computational deficiency is that healthcare institutions were among the first to adopt the use of information technology.

Thus, they designed their systems when computer science was still in its infancy, computers were slow, expensive, and had little memory. Healthcare institutions led by a joint effort between the Massachusetts General Hospital and MIT, made an early, and wise choice to automate patient records. They designed a new, and in its way brilliant for

[6] Personal communication

its time, language called MUMPS to store the records. The designers considered the nature of medical records as large amounts of text not consistently applied on every entry across all possible fields. They combined that with the existing practice of how doctors maintained medical records and their need for as rapid recall and access as possible. They then molded that to the state of computational technology of the time and created a language that facilitated the storage and retrieval of text kept in sparse matrices within a hierarchical database. This early design took hold and became entrenched. While MUMPS was successful, because of the importance of maintaining records, the difficulty in re-training staff, and the inertia of large organizations and their ability to resist change as computational technology and computer science advanced, healthcare systems, for the most part, remained stuck in the technologies of the nineteen-sixties. Looking across many records via relations to determine outcomes, practice patterns, disease states and so on, having more useful interfaces, communicating and coordinating across various systems, as well as other needed features, were virtually impossible to implement within the framework of MUMPS.

7. Make It versus Buy It

The hope of the management was to purchase a commercial system that would provide the features they desired. Unfortunately, at the time such a system did not exist, and if it did, the cost would have been prohibitive. Even if one were available, it would not just fit since health care is idiosyncratic, cultural, and open-ended. Thus, we set about designing the system that would fit the needs of the existing institution, fit the culture, but also help to begin to change mindsets and reform the practice in the institution.

Adapting to the local culture is a critical element in emergent design. In the past, when the technology was bigger and more costly, people attempted to adapt cultures to the needs of the technology. Naturally, this left most people frustrated with the technology. We now have the capability to *adapt the technology to the culture*, and, not surprisingly, this is producing far better results.

Rather than purchasing a system that had its method of practice set in concrete, we worked with practitioners to tailor the system to their needs. Indeed, as many doctors do not practice in the same manner, we had to support everyone's mode of work while still ensuring that they adhered to the proper guidelines previously set by their committees. For example, as each doctor has had both a different educational and practice history, they use different terminology to refer to diseases, symptoms, and syndromes. Rather than enforcing a particular vocabulary, I designed the system to accept their particular terminology so long as they related it to established, accepted vocabulary and defined the differences. We also designed their patient encounter screens to support different paths, questioning, terminology, and so on, so long as the documentation was complete. If it was not complete we prompted the provider to ensure the patient's visit was thorough.

8. The Ultimate Tension: Dealing with the Grammar Paradox

There is an inherent contradiction in the design of such a reform effort. On one end the chance for success is slight without the willing participation of the practitioners on whose intelligent efforts the system depends. The new systems and change must therefore fit with the needs, desires, and aesthetics of the practitioners.

On the other hand, since one is designing for a major reform, if the designer only provides an environment to which people are already accustomed and familiar, then one will merely reproduce the existing practice and also not achieve the desired reformed results. The contradiction is that one must break the existing grammar of practice while simultaneously constructing a new grammar that remains resonant with the existing ideas of the practitioners. In this case, as in learning environments, since there is no one correct way to practice but rather there are many variations, it is essential that there must be room for individual styles and preferences. Moreover, since one is transforming practice into something which does not yet exist, and depends upon the meaning that the practitioners will make of it and within it, then the design cannot be planned completely in advance. Rather, one must design for a system and environment that is evocative of and facilitates the various types of preferred practice while diminishing the likelihood for types that are discouraged. Thus, the designer operates within a dialectic between acceptance by the practicing community and transformation of that practice.

Thus, at UHS we began with providing applications that created new value and function to the providers and administrators. We provided on-line access to clinic notes that previously were lost or hard to obtain, particularly for follow-up visits by patients who had been to the emergency room the previous night. The notes looked exactly like the paper notes, except that they were always available, shareable, and encoded. We provided other functions such as referral closure, automated test ordering and reporting, prescription writing, on-line access to medical journals and databases, and so on to

providers to get them to accept the system. This allowed us to add other functions that were necessary to move their practice forward. We also enabled information and access to the subscriber population that enabled them to be better informed and take more control of their health even though some providers did not desire this. However, this was part of moving practice forward and providing better care, even if it meant that some providers felt others were usurping their authority.

9. Pace Of Change of Computational Technology versus Other Technologies

Another delicate design consideration is the rapid pace of change of the technology. Whereas in the past designers functioned as if the system should remain in place for the foreseeable future, now that is no longer possible. Major environmental changes in computer technology, also for the most part unknowable in advance, occur every few years. Thus, here is another constraint-filled decision point. If one makes a major investment in a particular environment, then in a few years one may be stuck at a point where the rest of the market is developing for a totally different environment. As described above, when computer systems went away from large, proprietary mainframe systems to smaller, open networks of personal computers and servers, the healthcare industry became stuck in a costly and less functional environment. If one does not take any action, then one is stuck anyway. A key design issue is how to resolve this dilemma.

The factors for making choices also have changed rapidly, and are different from what is in the popular mindset. Previously, the limiting factors were cost, computing speed, and memory. Cost will always be a factor, but now the primary costs are in software

engineers and time to delivery, not in the hardware itself. Computing speed and memory, once the driving force behind technical and managerial decisions, are now non-issues. Since the health services could not, and should not, create a large staff of engineers, we made the decision to open the architecture, create a path to use the existing medical record data, migrate this to a new, evolving, open, secure, relational database, enable communication within the organization, create connections to partner healthcare providers such as teaching hospitals and laboratories, connect to desirable third-party applications, and, primarily, provide new, intelligent computing applications to the providers and people served by the health services.

10. Modern Rate of Technology Change versus Past Mindset

In order to roll the new architecture and system out successfully, change practice habits, eliminate errors and redundancies, and reduce operational costs, we focused first in two areas. First, we needed to open the existing system to use the data and build new applications. Because this is a long-term proposition, however, with little visible results in the near term, we decided to build some small applications to give the providers functionality they truly wanted. For example, by putting clinic notes on-line immediately, they were now able to function much better in a collaborative environment. Previously, if someone had come to the clinic at night for a problem and the clinician at night recommended that the person return the following day to see the primary care provider, the primary care provider would not have a record of the previous night's visit. By indexing to previous visits and complaints, and connecting across the network to various clinical databases from the National Institute of Health and the Center for Disease

Control, as well as many electronic publications as they wanted, they were able to do better research on cases more easily. We enabled electronic prescription writing and review. We also connected them electronically to other collaborating clinics, we were able to close the information loop when patients were referred to specialists or for tests. In each of these cases, the providers were happy, and thus were more apt to put up with other changes with which they were not so happy such as having a peer review of referrals.[7]

11. Ability to Change in Large versus Small Organizations

As management was purchasing a new phone system, they looked to the culture and the primary issues to solve, rather than believing that any system should solve all problems. The CIO of one of the cooperating teaching hospitals said he would have loved to use our system but felt he could not since they had too many employees, with too high a turnover rate, to get the technological fluency necessary to work well with the system. This is an example of the need for mindset change referred to earlier. The CIO knew that practice and results would improve with our system. Yet, he did not choose to use it (we were not trying to sell it to him. Indeed, we would have gladly given it to them for free where his staff could augment the system substantially) because he did not feel his staff was capable enough with the technology and with the responsibility for action, and that the costs of training the staff to have that capability was prohibitive. This lack of confidence on the abilities of low-wage staff is similar to the lack of confidence in rural teachers.

[7] This was initiated not only for cost reasons, but also to ensure quality of care.

This mindset also holds that developing technological fluency is a long, costly, difficult, stepwise process. As we shall see, the lack of confidence in rural teachers and their potential to work with advanced technology was unwarranted. The staff, though considerably smaller than the staff at the hospital, at UHS not only managed to learn but actually began to thrive and to suggest and design system and process enhancements.

The system continues to evolve with new functions being written and purchased. This has enabled the organization to remain small and independent, and thereby to provide more personalized care, even at a time of huge losses for competing healthcare providers in the area. Every area of the health services, including not just primary care but also the dental clinic, mental health clinic, pharmacy, laboratories, and administrative departments such as insurance and billing now take active roles in the system development and process operations. They help decide goals, needs, and priorities, help to determine the interfaces and functions, and suggest what new applications we should create. They decide, in collaboration with the systems team and upper management, what to do.

By making the process participatory, it facilitates cooperation and utility, and provides a sense of ownership and responsibility over the operation. This more open and inclusive decision-making process prevents the possibility of top-down planning. However, the benefits from the participation far outweigh the uncertainties from not having a rigid, a priori plan. The important point is that since we had an open, coherent, fundamentally sound architectural basis we could afford to have an open-ended emergent design process. If we remained consistent then we could maximize the benefits from engagement.

12. Assessment and Measurement in New Organizations versus Old

Assessment of medical practice can not yet, if ever, be absolutely objective and accurate, as there is no exact measurement for how healthy one is.[8] Still, there are patterns and events for which one can look to provide guidance on the direction of care. Surprisingly, however, the information technology that healthcare institutions use does not facilitate this analysis of actual practice.

Several events pointed to how the approach was working. Most importantly, verifiable quality of care improved even while costs were reduced. We enabled new reporting functions, important both internally as well as for review organizations, for the first time ever. The mindsets we hoped to change did begin to change, although some people did choose to leave the organization. Providers willingly participated and took time from extremely busy schedules to help design the system, request third-party applications, and suggest new functions. We then were able to rationalize and democratize the development of the system by including all of the user community, both providers and the service population, in participating in the determination of development priorities.

The biggest changes were twofold. There was a change in mindset by the practitioners and administrators of the health services. This was evidenced by the change in practice. What helped facilitate this was treating the computational system not as a final, highly structured, restrictive entity, but *rather the treating the medical and business software as a learning environment*. We wanted the providers, subscribers, and administrators to

learn and grow, and the system to learn and grow with them. Rather than a final destination, the system was an enabling and evolving tool, never finished.

2.5 Educational Environments and New Paradigm in Management of Organizations

Why have educational institutions not achieved the remarkable gains most other institutions have through new practices enabled by computational technology? Although we think of School as the institution for learning, a tremendous amount of learning occurs outside of School. Moreover, much of the practice in School is derived from paradigms across other boundaries. The organization and process of School draws from organizational paradigms. The hierarchy in School and the organization of the processes resemble the hierarchy and processes of mass production factories. Yet, we would never want to think of our children as widgets being acted upon as they are moved along an assembly line. The technological paradigm of the printing press drives the practice of, even the existence of, the classroom. New technologies are introduced and used not for their own unique affordances, but rather to mimic the dissemination of information. Not surprisingly, people often deem the new technologies more costly but no better than text. In the existing epistemological paradigm, knowledge is treated as information. Knowledgeable people are those that recall information in the approved language.

However, the advent of new digital technologies has enabled dramatic change throughout multiple paradigms. We view knowledge and learning fundamentally differently. New organizational paradigms are developing. Rather than being the "one best system" as

[8] We *Star Trek* viewers hold out hope.

envisaged by Frederick Taylor, groups are free to invent the organization that fits the particular culture and people [Taylor, 1998, Malone, et. al. 1998]. Indeed, the work of Richard Lester demonstrates the change in institutional structures where in the previous paradigm, managers and researchers would attempt to isolate each new method and study its effect on the overall organization [Lester, 1998]. The implicit assumptions were that:

- the existing system was at a local maximum
- each addition could be studied and assessed in isolation
- each addition, if positive, would incrementally improve the system
- each addition could be studied in isolation with all other properties held equal
- the particulars of the people, the culture, and the local context did not matter

We see the same experimental methodology applied in education. This methodology suffers from the same faults in each domain.

Lester demonstrated that this did not fit the current case of business practice. Each organization operated in a more holistic fashion. The parts could not be separated from the whole, and the whole was more than the sum of the parts. Methods that improved the situation in one place did not in another. Moreover, in business people at least agree on some important set of objective measures, such as profit, quality, time to market, time of product development, inventory turns, and so on.

Firms that were clearly more successful did not all follow the exact same practices. Other firms that attempted to adopt single practices without transforming an overall culture did not improve even when adopting successful isolated practices from successful

companies. Each successful firm one developed their own core practices, fitting their own culture.

Even though School draws from other paradigms, when looking for its own reform School is amazingly inward looking. That is, education reforms for the most part only look at education. This thesis expresses the view that when we design the reform of learning environments we also need to examine design itself, as well as how design and practice has evolved in other domains besides education.

This thesis describes a form of intervention in learning very different from the model of reform studied by Tyack and Cuban, and more in line with reform efforts in other institutions. It offers hope of addressing the great educational needs created by the digital age by drawing on two of its important innovations:

(1) digital technology

(2) the approach to management of organization and of organizational change that has come in the wake of the technology

More precisely, this work draws on the combination of these two innovations. A distinction must be made because, as I shall show, the temptation to use either of them alone has led to failure. It is the combination that offers an optimistic vision for the future of learning. The combination of these two products of the digital age along with a theoretical framework based on pre-digital-age thinkers who knew what to do but did not have the means to do it. Among these the most central is Paulo Freire, but also

represented are John Dewey, and although he did not focus on education per se, Jean Piaget.

A focus solely on technology leads to technocentrism, that is, a view that it is the technology and not what we do with it that has impact [Papert, 1986]. Such a focus also leads to a narrowness of vision. In other words, we simply place the technology into the existing structure and thus are not able to see the possibilities that extend beyond the existing organization. Lastly, merely adding technology reinforces an experimental paradigm out of place. This paradigm tries to modify one element at a time holding the others constant. When using such an approach when introducing technology, what one holds constant, rather than maintaining experimental purity, merely serves to neuter the potential for educational change catalyzed by the technology. Thus, an erroneous view of the technological and learning potential results.

Likewise, the reform of management, usually in form of administrative decentralization, does not break the stranglehold of the grammar and ends up with reversion to type. By themselves, ideas such as decentralization of control and decision-making or intra-district competition do not generate new content and methods. On the contrary, they merely push the same practices down the hierarchy without fundamentally changing practice.

One of the most revolutionary affordances of computational technology is the democratization of learning, information, access, and finance [Friedman, 1999]. School, chartered with developing citizens for democracy, ironically is one of our most autocratic

and hierarchical institutions. In order to remove the dissonance, both the processes of the learning environment and the process of changing the learning environment need to reflect the philosophy and the practice desired. In this way, a top-down, autocratic approach is hopelessly contradictory and doomed to failure.

Another irony is that even the canonical example of standardization, the production assembly line, is now freed to function in a dynamic environment enabling customization on a mass scale. This has evolved from a hierarchical control mindset, where Henry Ford, a pioneer and innovator in creating the mass production assembly line proclaimed that "Tell them they can have any color they want so long as it is black."

2.6 Emergent View of Scientific Knowledge and Paradigm Blindness

The inability to use computational technology in its most powerful ways can be viewed as a classical case of paradigm blindness. That is, there is slowness of adaptation to paradigmatically new possibilities since meaning is created through the functioning of the existing paradigm [Kuhn, 1970]. The mindset engrained in the working of an existing paradigm not only does not know how to utilize the findings of the new paradigm but also totally misunderstands the data. In the case of computational technology, educational institutions have primarily used the technology not for the constructive properties, but rather for their information delivery capabilities similar to existing print materials. While this use in itself is not bad, it does not take advantage of the unique and powerful new possibilities.

No matter how ridiculous or obvious it may seem in hindsight, effecting paradigmatic change in complex social systems is not a simple matter. Despite the current hype about paradigm change, the deep point about paradigms is that they are relatively stable and do not change easily. After a paradigm change is complete, it can be not merely hard to imagine how it was difficult to change, but past viewpoints can appear so nonsensical that it is hard to imagine how anyone could have thought in such a way. Thomas Kuhn describes reflecting upon some of Aristotle's views in this way. How could the same Aristotle, who laid the foundation for formal logic so brilliantly, also have so held beliefs about motion that anyone today would think a sign of silliness? Kuhn's explanation is the paradigm that supplied the underlying logic to the system makes looking back from an existing worldview incommensurable with the former. [Kuhn, 1987].

Change does not merely follow from showing the inaccuracy of some point or belief. Paradigms do not change merely through strength of argument or reason. Even when experiments demonstrate clear results, it does not automatically follow that everyone willingly changes and adapts [Latour and Woolgar, 1986, Kuhn, 1970]. Neither does it work that each new innovation or advance is simply incorporated into the existing system. This cannot happen if the advance is paradigmatically different.

Change needs to proceed at multiple levels simultaneously. On one level a different language and set of models must be developed to provide a framework. On another level, exemplars are needed to provide a concrete basis for understanding and developing practice. This thesis describes an effort that consciously attempts to facilitate a true

paradigmatic change by working at both micro and macro levels concurrently and consistently so that the two may provide feedback and benefit to each other.

There is another aspect to the work of Kuhn, Latour, Feyerabend, and others, that is particularly relevant in this study. Prior to Kuhn the popular belief was that scientific knowledge was additive, that each bit of knowledge added onto another into one corpus. The practice by which this occurred was *the* scientific method, as though there could only be one. Scientific knowledge could be divided into discrete chunks, with individual scientists working away to add to this body of knowledge. While this view of science has changed and broadened, School, and particularly science and mathematics education, still functions according to the old, discredited view.

2.9 Emergent Design for Dynamic Change

The above examples demonstrate that large-scale, technologically enabled changes are not trivial to implement. Still, there is a fundamental difference between prior changes and those involving computational technology. Prior technological advances for the most automated existing activities. New machines made existing work faster, cheaper, and better. Electric power generation was a more efficient means of supplying power. Tractors were more efficient than horses. Internal combustion engines facilitated the faster and more efficient movement of more and heavier goods. None of these advances fundamentally altered the nature of the work being automated.

Computational technology is quite different in this regard. The primary reasons for this are miniaturization of hardware and the malleability of software. Rather than automating an existing activity, computational enables a total re-thinking of the activity itself. Rather than having the *one best way* there can now be many possible ways.[9] Rather than adapting one's culture to the technology, one can adapt the technology to the culture.

However, because of the malleability and resulting variability combined with the hope that the future will continue developing and improving, the design process is distinctly different from processes for previous introductions of technology. Whereas in the past one designed for the attributes listed in the left column of the table below, the new design paradigm is for attributes listed on the right.

Old Paradigm	**Emerging Paradigm**
Primarily static system	Dynamic system
Certainty	Uncertainty
Standardization	Customization
Avoiding change	Encouraging positive change
Average case	Individual case
Hierarchy	Heterarchy
Centralized control	Decentralized control
Mass production	Customization for small groups
Eliminating surprise	Taking advantage of serendipity

[9] "The one best way" is the idea behind scientific management advocated and developed by Frederick Taylor. It has come to symbolize the hierarchical, bureaucratic, specialized, micro-managed process of

While the table refers to managerial change in business institutions, one can easily relate this to educational institutions. This type of design is for the situation when one can not know in advance what one needs and when one needs it. If it is the case that the key learning is now learning how to learn, then the most powerful moments and situations for individuals and groups are not predictable. Indeed, they never were! So, rather than design for the average case, delivering a standard curriculum in a standard manner to all in the hope that it reaches most, the goal is to design so that the situation, time, and resources optimize the environment for deep and powerful learning for all, accounting for individual and group styles and cultures.

The fundamental difference is between designing for a closed, simple, static environment versus designing for an open, complex, dynamic environment. Dynamic complex systems and design recognizes that there is not simple cause and effect. Rather, there will always be other unintended consequences and side-effects. Moreover, due to the complexity of the system, it is not possible to calculate or predict all such possible results in advance. A salient example is in economic policy, particularly now with open, global economies with multiple players due to the democratization of finance and access to information. Other examples, dealt with in this thesis, are human learning and learning environments. Because the system is evolving and dynamic, interventions are needed. These interventions as well will have intended and unintended consequences. Rarely will it be the case that any action will have only positive outcomes. Thus, not only must one weigh

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mass production.

the various consequences at the time, but also one must make the underlying reasoning determining the value judgments explicit, at least within the context of this work.

2.10 Change, Technology, and Learning Environments

The development of new computational technologies and their use in a Constructionist environment has been the catalyst not only for new learning but also for opening the possibility of systemic change. However, demonstrating the capabilities with the technology alone has been insufficient to effect the change needed to truly utilize the technological capabilities. In certain cases, isolated learners have succeeded in acquiring new knowledge or have succeeded where there had been little previous success. Yet we have not observed such new uses adopted systemically. Individual schools and learning centers have attempted to change and integrate new learning technologies. Yet again, we have either witnessed no change or isolated and often minimal long-term success. There have been many large-scale attempts at systemic reform, often well-conceived and well-intentioned, both in terms of curriculum and in process. However, results have been minimal with the goals of the reform rarely, if ever, met [Tyack and Cuban, 1995]. The grammar of school pervades and reforms the reforms. Change at any one level appears glacially slow or impossible.

This thesis investigates and explores effects when each element is in play simultaneously. That is, rather than focusing intra-level, only on researching new technologies with learners, or on change within one learning center, or attempts at systemic and policy change at a macro level, this thesis will review an activist intervention aimed at working

where the potential success at each of the above issues is enhanced by working on all together rather than any one in isolation.

2.11 Project Lighthouse

When Seymour Papert and his group, the Epistemology and Learning Group at the MIT Media Laboratory, were first approached to undertake the reform effort that was to become Project Lighthouse, it was expected that we would produce a top-down design plan to cover three to five years. One major figure in the reform effort advocated that we only train the curriculum developers, as the curriculum developers set the agenda for all education. By working exclusively with them over an extended period, this design idea advocated that they would then re-write a new curriculum, for which the administrators would set the environment, and the teachers would enact. And all this would be enacted, many years in the future on the children. While this example may be the most extreme of the design ideas, it highlights the top-down nature of the plans advocated. Ironically, most of the same benefactors and activists who recognized the moribund nature of the current system and the need to produce dramatic change, still possessed a mindset within the grammar of school reform.

We devised our plan according to the above principles in emergent design. Thailand was quite unfamiliar to us and thus it seemed ridiculous and impossibly presumptuous to believe that we could know enough to provide a detailed five-year plan. *Thailand was not unfamiliar to our sponsors and collaborators, yet it would as well have been ridiculous and impossibly presumptuous for them to propose a reform in this manner.* As the

following chapter will detail, there were many pleasant and unpleasant surprises in store for us all. Many deeply held assumptions were not true. Any design based upon such assumptions would be doomed to fail. Moreover, since the approach and the immersive use of technology was new to all, how it would be appropriated was unknowable. Indeed, a Constructionist approach by definition has to be open and non-prescriptive so as to enable appropriation. The following chapter details how the emergent design approach unfolded.