Technological Fluency and the Art of Motorcycle Maintenance:

Emergent Design of Learning Environments

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M.S. Media Technology, Massachusetts Institute of Technology, 1996

Submitted to the Program in Media Arts and Sciences
School of Architecture and Planning
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
at the
Massachusetts Institute of Technology

June, 2000

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ABSTRACT

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Abstract

The empirical basis of this thesis is a two-year project to bring new learning environments and methodologies to rural Thailand. Five theoretical and practical innovations are emphasized:

1. A new methodology of merging education with the actual use of technology to improve the economy and quality of life of community is demonstrated.
2. A practice of "*applied epistemological anthropology*," which consists of probing for skills and knowledge resident in a community and using these as bridges to new content, is developed. For example, analysis of learning behaviors led me to identify an "engine culture" in rural Thailand as an unrecognized source of "latent learning potential." This theory has already begun to spawn a theoretical enquiry with significant promise for assessment of the learning potential of developing countries.
3. Pilot projects were mounted outside of the education system with the specific purpose of breaking "educational mindsets" that have been identified as blocks to educational reform. A salient example is the assumption that the population and teachers of rural areas lack the cognitive foundations for modern technological education. The engine culture is an existence proof for the theory of unrecognized foundational elements.
4. The work required a flexible approach to the design of digital-based educational interventions. Analysis of these design issues has led to a theoretical framework, "Emergent Design," for investigating how choice of design methodology contributes to the success or failure of education reforms.
5. The concept of Emergent Design exposes parallels with developments in the restructuring of non-educational organizations. To help explicate this, I draw from my own experience in reforming a healthcare organization.

The work suggests a conclusion with a very broad sweep:

The latent learning potential of the world population has been grossly underestimated as a result of prevailing mindsets that limit the design of interventions to improve the evolution of the global learning environment.

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Acknowledgments

I am truly and deeply indebted to so many people that there is no way to acknowledge them all, or even any of them properly. I sincerely hope that everyone who knows that they have influenced me feels satisfaction that they have helped such a poor soul along and does not feel remorse that either I did not get it right or then ungratefully omitted them from explicit mention. I offer my sincerest apologies to anyone in the latter category. The nature of this work is firmly in the Blanche DuBois "relying on the kindness of strangers" camp, and without the efforts and kindness of all the people involved in this project, the previous projects, as well as those who have profoundly influenced me and helped me get to this point, this work would not and could not have been done and I certainly would not have been in the position to do it. I extend my deepest gratitude to all.

The first person I have to thank is my advisor, Seymour Papert. Properly describing Seymour's influence is like trying to define intelligence -- no matter what you come up with it only seems to capture half the story. Seymour has had the most formative influence on my adult life. I truly think, look at, and act in the world differently due to Seymour's influence. Among other things, Seymour is famous for saying "You can't think about thinking without thinking about thinking about something." I cannot think about thinking or learning without Seymour's influence. When I think about it well it is when I try to think about how Seymour would think about that something. Although we often shy away from the word, Seymour is the ultimate educator. He can find the goodness and intelligence in anyone and then help build upon that always in such a way that the growth

always belongs to that person. Our popular conception of a good teacher may evoke images of someone who is a good talker. Seymour may be one of the most scintillating speakers I have ever heard, but even more impressive is that he is perhaps the best listener I have ever met. By listening, and concentrating, on what someone is saying, and then engaging them through that person's viewpoint, one learns in ways that one cannot quite imagine.

While researching this thesis, I reviewed some old writings of Seymour's. I was amazed at the currency and relevance of so many of those ideas. Seymour created a new field and laid groundwork that not only still is valid but also still is misunderstood or poorly understood by so many. However, Seymour's contribution did not end there. He continues to work and to add to the theory and practice in the field.

How Seymour does this is most impressive. He does not sit back and pontificate. Rather, he is there creating new projects and working with all the children, whether it is kids in the juvenile jail, kids in poor rural areas, kids in his neighborhood, or kids anywhere. He not only is a proponent of "kid power," he also is an enabler and admirer of that power. I have been fortunate enough to be with Seymour with kids as well as with presidents, ministers, governors, corporate executives. He treats all of them with the utmost respect and it is to this that people respond.

Seymour has been so much more than just the best advisor that he is beyond categorization. He has been the best friend, mentor, teacher, companion, and confidant. I

am truly fortunate to have been able to enjoy and benefit from such a relationship with him and the best way to show this is for me to extend these qualities to others. I can only try. Thanks, Seymour!

Perhaps the best work I did in the course of this thesis was to choose an incredible committee. To Henry Jenkins, Edith Ackermann, and Brian Smith I also extend my deepest gratitude. Henry is an MIT treasure, opening new areas, new ideas, and new ways of looking at things. Henry opened the world of critical theory not only to traditional areas but also to new computational media, while bringing a strong sense of justice and values. His classes are scintillating and conversations with him are always a learning experience.

Through Edith I have come to know not just Piaget, although that would have been enough, but also many other areas. Her breadth and depth are amazing. Only her modesty and the blindness of others prevents her from being recognized for the genius she is. I look forward to years of collaborating with her.

Brian's wit makes him a fantastic companion, but his intelligence and deeply critical and analytical way of looking at ideas make him a fantastic colleague. He sees the value in and enjoys working with real kids in real settings. Again, I look forward to years of collaboration.

I also benefited from the work of my unofficial committee. Shep White, Walter Bender, Gloriana Davenport, Andre Boder, Ron MacNeil, John Maeda and Jack Driscoll all helped me work through ideas. I benefited tremendously from Shep White's classes, and also enjoyed many lunches and conversations. I benefited from Gloriana's talks about her work within Project Lighthouse, and she also gave excellent comments on earlier drafts. Walter not only discussed ideas, he also read and helped edit the entire document. Where I still manage to fracture the language and create a document difficult to traverse is due to my stubbornness and not his qualities as an editor. Andre not only helped me learn so much about learning and development, but has become one of my best friends.

Howard Austin has been and continues to be an inspiration, source of ideas, and excellent discussant. More than anything, he is a fantastic friend. His generosity is boundless. As his friend Noubar says, Howard is the pre-eminent "knowledge-seeking missile." His intelligence is overwhelming and I am honored and deeply indebted to be his friend.

Without Jacqueline Karaaslanian I never would have met Seymour and certainly would not have finished anything. I tease Seymour that Jacqueline understands the ideas as well as or better than any student and perhaps he should just hire people rather than take students. That she can manage the group's, Seymour's, and even my affairs is testimony to her capabilities as an administrator.

I have to thank Nicholas Negroponte and the other founders for creating such a place as the Media Lab that empowers graduate students to take on large projects no matter how

weird or far out. The creative environment, people associated, and resources available combine to make the place stimulating, exciting, convivial, and productive. The lab could not function without many people creating this environment and I am indebted to them. The people behind the scenes do a tremendous and often thankless job to make the place run and we all benefit from their hard work. In particular, among them I would like to thank Dennis Irving, Greg Tucker, the Necsys group, and especially Linda Peterson. Linda has an impossible job and manages to carry it off gracefully, kindly, and fairly. Without Linda I probably would not have graduated.

I have benefited from the work of the groups around Seymour over the years. The Epistemology and Learning Group at MIT has produced tremendous work and a wealth of ideas from which I have gained considerably. I have been fortunate enough to have had contact since 1984 and have enjoyed the friendship and collegiality of the students, staff, and others who collaborated in the group's projects during this time. In particular, Seymour's students in the years since I have been at MIT (Paula Hooper, Alan Shaw, Aaron Brandes, Michelle Evard, and David Williamson Schaffer) were an interesting and fun group. I learned very much from many discussion with Paula in particular and wish to thank her for her generosity and kindness. Alan's influence on this work is obvious. I benefitted greatly from discussions with Aaron, Michelle, and David. Seymour's current group of students, Marina Umaschi Bers, Savalai Vaikakul, and Claudia Urrea, are a wonderful and exciting group. They all contributed greatly to this work as well as to setting an invigorating intellectual climate at the lab. Mitchel Resnick and his students continue the tradition of the E&L group and provide a basis for the continuing

development of the ideas. Although it is unfair, I particularly want to thank Bakhtiar Mikhak (and his family) and Rick Borovoy for their kindness, conversation, and support. I have been extremely fortunate to share offices with some of the best people at the lab. I have to thank my officemates Amy Bruckman and Marina Bers not only for benefiting from their intelligence, wit, humanity, and companionship, but also for all the patience and generosity to put up with my messiness, tardiness, and disorganization, as well as with the rudeness or lack of tact shown by the many people calling to look for me when I was often elsewhere. Prior E&L students from whom I have learned a lot and who have assisted me greatly include Carol Strohecker, Aaron Falbel, Kevin McGee. Carol's work and character are outstanding and I always enjoy our too infrequent talks over coffee. Aaron is a moral compass. Kevin is a joy. Although they were not in E&L per se contributed much to the ideas, Mike Travers and Marc Davis.

I also want to thank the many people who undertook the difficult, often thankless, and certainly poorly paying tasks of putting the ideas about learning environments into practice in very difficult places. Without their work and sacrifice the work at MIT could not exist. I especially want to thank Carol Sperry and Michael Tempel for their friendship and thank them for how much I have learned and gained from them. Carol and Michael are both excellent teachers, primarily because of their ability to develop strong relationships with us all. Cynthia Solomon not only contributed to Project Lighthouse and our work on vocational education, her depth of understanding of the basis for Logo makes her the best discussant. Her insights are always deep and invaluable.

Jose and Ann Valente have also been not just wonderful friends but also wonderful teachers. Their development of the NIED group at Unicamp in Campinas, Brasil, provided another wonderful group of researchers from whom I have learned much. They, more than anyone, understand how one can do excellent work and still provide a warm, friendly, and convivial atmosphere. I thank all of them for hosting me on several trips there. I also want to thank Rodolfo Baccarelli and Tadao Takahashi for their support and friendship.

It is obvious how much I learned, gained, and enjoyed from the work in Thailand. Without all the people there, it would not have been possible. There are so many people involved that I cannot thank all of them. But I am tremendously indebted to all of the participants and I wish they could have gained even a small percentage of what I have gained from the experience. I hope no one will be disappointed that I could not mention everyone by name. All the people at all of the sites mentioned in the dissertation have been wonderful. The legendary friendliness of the Thai people is not mere tourist propaganda. It has been a wonderful place to work not merely because of its beauty, but overwhelmingly because of the people. However, I would be remiss if I did not mention at least some by name.

Without the passion, compassion, diligence, and energy of Anita Horton we at MIT would never have been contacted to help in this effort. Without the intelligence and support of Dr. Dumrong, this project could not have begun. Khun Paron worked incredibly hard over incredibly long hours even at tremendous personal sacrifice to help

make the project successful. His intelligence, ethics, and diligence are inspiring to us all. He opened so many doors, convinced so many people, organized and administered so much work, and did more than anyone could imagine that any success in this project is directly attributable to him. We have all gained from knowing him. Khun Bangkok likewise has put in so many hours that it is mind-boggling. He has worked so hard, again at personal sacrifice, to help make the project successful that we are all indebted to him. His friendship and good cheer, plus his knowledge of restaurants and food, enriched my life. I enjoyed our many conversations both in Thailand as well as on the phone. I miss them now that they are less frequent.

The original group of supporters and advisors provided a strong basis upon which to begin work. Their friendliness made the project enticing. Among them in particular are Dr. Sippanonda, Dr. Krissanapong, Dr. Harit, Khun Adul, Dr. Chaianan, and Ajarn Bupphachart.

I have particular fondness for the original participants. Dr. Suchin, Paw Ackachai, and Ajarn Jirachai created a wonderful environment in which to work. I learned so much from them. Their hospitality was stupendous. Their staffs exceptional in their work and wonderful in their kindness. The NFE teachers at Chiang Rai, Lampang, and Mae Fah Luang did wonderful work under difficult circumstances. Again, although it is unfair, I want to thank Nong, Nine, Toi, Tik, Neung, Bom, June, Narawan, Fam, Nok, Tookta, Pramote, Pom, Jo, Nan, and La (and apologize for using nicknames as well as missing a few whose names I did not have). I would be remiss if I did not give special mention to

Ae and Denchai who inspired us all. Pom, formerly of the Suksapattana Foundation, did so much for us even though we made things difficult by constantly changing plans at the last minute. All of the people from PDA made it easy for us to begin work in Nang Rong. Khun Meechai is an inspiration to millions of people. His top staff at PDA are deep and tremendously committed people. Khun Booncherd's dedication and hard work made the Cbird center successful in the eyes of the villagers which gave us immediate legitimacy that otherwise we may never have earned, or at least would have taken many years. Khun Gaensri and her family were a tremendous help. Of course all the Thai MIT students who participated in the project contributed so much to its success. Helping to localize Logo for Thai language was difficult but extremely important. Translating is always a difficult job, but it is even more difficult when having to translate unfamiliar concepts in real time. Atchicha, Peng, and Piyada did fantastic work and it is an honor to know them. Roger (Arnan) also provided so much to the project and it is wonderful to have him at MIT as a student now, even though the project suffers from his absence. Thanks also to Roger for taking the photos I used in this thesis. I am indebted to the other MIT participants, Deb Roy, Michael Best, Arjan Schutte, Philip Tiongson, Janet Cahn, and Vanessa Collela, not only for their work but also for their friendship.

I want to thank all the people at Harvard University Health Services. It was a wonderful place to work and they are very dedicated people. I gained so much from it. In particular I want to thank Marc Pollack who had the impossible task of being my boss. He was the best. I also want to thank Noly Williams, Marge Fisher, and Audrey Sallese of the IS and medical records staff for their collaboration and friendship. Howard Austin, David Tan,

Dean Scharnhorst, Richard Wells, and Charlie Munitz were great to work with and contributed immensely to the ideas and did all of the development work on the system development.

I spent many formative years in Cleveland and gained so much from so many. I want to thank Allen Siegal, Mike Franyin, Ted Dostal, Eric Mumford, Abdul Shakur, and Idris Abdul Latif in particular. All of my extended family, Howard, Gertrude, Sandra, and Damon Bagley and the whole McCulley clan, have provided warmth and love for many years.

Family is extremely important to me in all likelihood because I am blessed to have such a wonderful one. It is a pity my Mom passed away in 1998 and did not see this day. At least she lived long enough to know I would get here. Her intelligence, compassion and love of books are deep within me and provide a lifelong inspiration. I miss her.

My brother Michael helped raise me. He is the best strategic thinker I have ever met. His family, wife Leah, and children Jacob, Bren, and Gideon, are all wonderful to be with. He has helped me in so many ways that there is no way I can repay him.

Without my Aunt Susan I would not have gone to, or been able to survive, Rutgers. Susan is an inspiration and my role model for how to be an academic. I cannot say how many of her students and colleagues have gushed to me about how influential she has been in their lives. My cousins Eric and Paul are also wonderful companions and friends.

I have learned and gained more from my children, Uthman, Malik, Kareema, and Aiury, than I could ever hope they could get from me. I am so proud of them it is ridiculous. So many people tell me how wonderful they are that it must be true and not just my subjective opinion. When people compliment them and ask how I managed it, I like to joke that if you set a bad enough example, then your kids act right saying "you don't want to grow up like Dad." I am afraid it might be more a truth than a joke. It is strange to say that one's children are an inspiration, but in my case it is true. I love them more than anything. Now that they (excepting Aiury for a while and Malik at least for now) have begun their own families I am learning from how well they are raising their children. Susan Hart Cavallo is a joy and just a spectacular person. Her family is warm and wonderful. My grandchildren, Amina, Justin, Rameses, David, and Julian, are brilliant. I look forward to learning more from them than from my kids.

Without the love and support of my wife Alice I would be nowhere. It was her suggestion to go to MIT. It was her support that enabled me to go. It was her sacrifice to enable me to succeed. It is her love of life, joy, and kind-heartedness that is a daily reminder of why anyone does anything. I am so indebted to her there is no way to repay it. Thank you, Alice, for everything.

I also want to thank the whole Fonseca family of Brasil for their warmth and kindness. I would be remiss if I did not single out my mother-in-law, Dona Alice Mello da Fonseca.

Muito obrigado, Dona Alice, pelo seu carinho, atencao, e dengo. A senhora e a pessoa mais doce que eu ja conheci. Sem a sua ajuda (e cafezinho) eu nao poderia ter terminado.

Last, but certainly not least, I want to thank my dear friend Greg Gargarian. At his funeral the priest said that everyone felt Greg was his or her best friend. It was the most apt description. Greg was so unassuming and humble that people underestimated him. His insight, thoughtfulness, and generosity helped so many people. I am fortunate enough to be one of the ones Greg helped. If it were not for Greg, I would not have kept in such close contact with the ideas and work of the E&L group and the Media Lab. I would not much without ever thinking of what he might get in return. Thank you , Greg, for everything. The world is much richer for your having been here, and much poorer for your leaving it so soon.

Introduction

The central thrust of this thesis is the presentation of a new strategy for educational intervention. The approach to the design of the educational intervention I describe here resembles that of architecture, not only in the diversity of the sources of knowledge it uses but in another aspect as well – the practice of letting the design emerge from an interaction with the client. The outcome is determined by the interplay between the understanding and goals of the client, the expertise, experience, and aesthetics of the architect, and the environmental and situational constraints of the design space. Unlike architecture where the outcome is complete with the artifact, the design of educational interventions is strengthened when it is applied iteratively. The basis for action and outcome is through the construction of understanding by the participants. I call this process *Emergent Design*.

It is not for me to judge whether there are circumstances in which it is appropriate for an architect to design a building in the isolation of an office without interaction with the people who will use it and be affected by it. It is not even necessary for me in order to make my point here to argue that there are no circumstances in which it might be appropriate for a new educational system to be designed by specialists in their offices and laboratories. My point is that there is another way. And the way to make such a point is by providing what mathematicians would call an existence proof: by showing one example.

The intellectual roots of this thesis are in two soils: one that is traditional for educators and one that ought to be. The less traditional area, the design and implementation of technologically-enabled organizational change, has not played a significant role in guiding educational thinking. The more traditional area, design by specialists in educational theory, has played a significant role in thinking about educational change, but is used here in an unusual way, that of being subordinated to the guidance of emergent forms.

The traditional soil is the set of theories about learning. In this respect my proclivity is for the role of activity emphasized by Jean Piaget, the role of dialog emphasized by Lev Vygotksy, the role of intentionality and social consciousness emphasized by Paulo Freire, the role of context emphasized by Jean Lave, and the role of construction emphasized by Seymour Papert. My own work is presented as a "theory in action" through which these sources are seen not as rival theories but as complementary themes.

The feature that might strike a reader most forcefully is that I cross many of the lines of theoretical division. There is a narrow would-be rigorously "scientific" approach that sees Piaget and Vygostky, for example, as defenders of rival theories. In this perspective endless debate can be generated about who is "right." From the point of view of a designer, the appropriate questions are more pragmatic: how can their ideas be used? From the point of view of Emergent Design the possibility of both of these approaches being useful is particularly large: an emergent process may well veer more in a Piagetian

or more in a Vygostkian direction. These great thinkers take on the role of beacons that guide navigation in many directions rather than single destinations.

This does not mean that my approach is eclectic. It is far from meaning "anything goes." Emergent Design does have direction. It requires discipline. However, its holistic and pragmatic nature allows it to find a place for a variety of insights without having to decide which is "fundamentally right."

To make the point let us look more closely three views of the mind: Piaget's structuralism, Vygotsky's functionalism, and Freire's activism. Given any manifestation of intelligence, the three look at different aspects: Piaget at the "deep structures" that underlie it and make it possible; Vygotsky at the process of the thinking; and Freire at the larger social view that gives it meaning.

Piaget was among the first to demonstrate that learning was not simply a matter of layering new information onto a blank slate. Rather, Piaget believed that people construct new knowledge as a function of their unique experience and ways of knowing. In the context of this work, the Piagetian influence entails delving down into what people know in order to facilitate connection to and construction of new knowledge.

Vygotsky emphasized the role of language and social collaboration in the construction of knowledge. In the context of this work, this appears in the design of the learning environments, the interactions, the tools, and the activities. Rather than working in

traditional schools, a large portion of the work described in this thesis took place in rural technology centers. This liberated us to work in different ways. For example, children were not grouped by age but rather we worked with everyone, children and adults alike, who chose to participate. We used technology in a constructionist, expressive manner. People with expertise in and passion for various knowledge domains worked closely on projects with the local participants and through their discourse and interactions each developed new relationships with each other and with the fields of study.

Freire emphasized the role of critical engagement with one's world. He disparaged the "banking view" of knowledge where learners are made to store facts away for possible later use as though it were money in a bank [Freire, 1972]. Rather, he advocated engagement with the issues of primary importance to the learners, determined by group discussion. Addressing these issues became the basis not merely for study but also for action. In this way people could learn about these issues, their causes, and their potential remedies. More importantly, this critical engagement could bring about a change of agency among the participants, where they develop into knowing and capable actors on their environment. Development along the lines of agency, critical questioning, collaboration, and the integration of knowing and learning into interaction with one's environment take precedence over the banking of facts.

This work employs the above and other influences in the emergent design and implementation of new learning environments. We use Piaget to dig for the *roots* of knowledge. We use Vygotsky and Freire to create *shoots* of meaningful projects in the

domains of interest to the participants. The *fruits* appear as the knowledge gained and the agency changed.

In this thesis I have adopted a certain style of writing which is closer to a narrative than to the style followed by many writers in the field of education theory, which consists of formulating a theoretical statement and then providing evidence to verify it. My choice is not simply a literary preference. In fact the style itself is an assertion of one aspect of the underlying theory. I believe (and others such as David Tyack and Larry Cuban have shown) that effective educational reform cannot come about though the incremental application, one by one, of principles each of which can be verified by experiments in which the relevant factor is changed while everything else is kept constant [Tyack and Cuban, 1995].

The work of an educational innovator is more like that of the designer of a complex entity, for example an architect designing a building who draws on knowledge of different kinds ranging from quantitatively precise principles of structural engineering to holistic considerations of quality of life, impact on community and visual integrity. The advantage of one architect over another cannot be reduced to a verifiable proposition in any of these specific kinds of knowledge. Although the architect needs to draw correctly on all of them his skill lies in being able to put them together. The work described in this thesis also draws on many different areas of relevant knowledge and in return offers some contribution to several of them. But what is most unique about it is a style of design.

Since what I want to exemplify is a process of design through interactions, telling the story of that process seems to me to be the proper style of exposition. The point is strengthened by giving it a name and I have chosen the label *Emergent Design*. It is also strengthened by relating it to other similar processes. Architecture could have been a choice. But I have preferred another field in which I have worked myself and which has particularly close analogies with education. This is the field of restructuring organizations and in particular the restructuring of business organizations precipitated by the opportunities offered by the advent of digital technology. The example I shall use is a reorganization of a health service for which I was given responsibility. I will devote the second chapter of this thesis to describing my experience and providing pointers to considerable body of literature on the remarkable evolution in the past few decades of thinking about management of businesses and other organizations and specifically about the management of change in organizations. Some readers, impatient to get to the "educational meat," might see the chapter as a digression. They are invited to skip it; the later chapters will still be readable. However I see the chapter as an assertion of a principle: the general study of design for change, including organizational change, should be as important a part of the education of an educator as the study of such topics as child development and cognitive psychology. 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.

Chapter one provides a description of the initial conditions and some activities in an engagement for educational intervention in order to provide a basis for the discussion on design that follows. Chapter two looks closely at the commonality of the activities of organizational and educational change. Chapters three and four go deeply into activities within the intervention. Chapters five and six draw the conclusions from this work.

Chapter One – Scenes from Thailand

The context of this thesis is Project Lighthouse, a bold intervention to initiate radical change in the educational processes in Thailand. As its name suggests, Project Lighthouse is not a blueprint for education or education reform. Rather, it attempts to highlight actual possibilities for powerful learning environments in Thailand, particularly in settings where traditional education has not succeeded. A primary goal is to *break mindsets* about what education must be by providing concrete examples. The following is a sample of activities from Project Lighthouse over a seventeen-month period. The scenes provide a concrete basis for the discussion that follows.

1.1 Scene: Bangkok, March 1997

Seymour Papert and I are meeting with leaders of the Suksapattana Foundation. We are designing a proposed intervention intended to provoke a radical reform of the educational system in Thailand. The meeting came about because a group of industry leaders and government officials had come to believe that unless they achieved a total transformation of their educational system Thailand would not merely stagnate economically, but also that they would lose all the gains of the previous decade. More critically, they worried that there was a growing and more intractable divide between rich and poor that would destroy the fabric of Thai society. They further believed that in the absence of an educated, thoughtful, literate populace, it would be impossible to support their nascent democracy and prevent a return to autocratic, and corrupt, military rule.

The Thai leaders believed that the existing school was not a hospitable medium for developing alternative forms of learning. Moreover, they felt that to change it directly would cost too much and take too long. They believed the existing schools to be too rigid, too reliant on rote instruction, and staffed by too many barely educated themselves.

They had set bold and ambitious goals for their educational system. They had developed a new national education plan as an essential part of their national development plan. This education plan, combined with a special commission from the Office of the Prime Minister devoted to education reform (ONEC), specified the new goals. The goals were thoughtful and admirable. They included:

- becoming learner-centered
- developing critical-thinking ability
- fostering innovation and creativity
- developing collaborative spirit and skills
- learning how to learn
- providing familiarity, ability and comfort with working with technology
- developing "happy" learning, that is, a joy for learning

However, none of the plans specified how to achieve such a system. They did not discuss how to operate in this new paradigm or how to make the transformation. Thus, while the goals were lofty, the implementation of both the new system and the method of reforming the current one, were mired in the existing, undesirable paradigm.

The goal behind our endeavor, Project Lighthouse, was to break mindsets by creating technologically rich learning environments that would demonstrate the "out of the box" yet practical possibilities for children in Thailand.

However, it was not clear what to do. Moreover, there was little agreement on or acceptance of our proposal. Some believed that we should focus on gaining the acceptance of the national curriculum developers as the current system moved only through the curriculum. Others believed we from MIT should train the trainers who would then train the teachers who would then work with the students. Others felt we should place computer labs in more schools and train teachers to work there. Finally, there was near unanimous agreement that the existing teacher corps was incapable of working in a new, learner-centered, project-based, technologically rich environment. Virtually everyone told us that the teachers were barely educated themselves and might not be able to learn to use the technology let alone teach with it.

We proposed creating four pilot projects where we could quickly demonstrate significant results in some of the most critical areas of need[1]. These were:

- create an alternative environment within non-formal education
- create rural village learning centers
- teacher training
- projects with at-risk youth such as street children in urban areas and girls at risk for or exiting prostitution

[1] The thesis will go into considerably more detail regarding the decisions and the rationale behind them. This section is merely to serve as an introduction.

Our idea was to go deeply into particular areas to show concrete examples of dramatic results through employing a different educational methodology and tools. This was as opposed to doing something broadly, but as would be inevitable in early experiments, shallowly. If, as hoped, the pilot projects succeeded, the idea was to further deepen the existing projects, add new ones for new target areas, and to take the best practices and ideas into other educational projects in Thailand. To achieve this, we proposed a new fellowship program to begin concurrently with Project Lighthouse. The Lighthouse Fellows would mentor and monitor the pilot projects, research the activities, publish and discuss the results, and help to bring them into broader practice.

There were two major objections to our proposal. First, commentators argued that our proposal did not fit the prototype five-year plan, which spells out all activities over that time period. How could people know what to do if we did not provide such a plan? People wondered if perhaps either we were not serious or did not know what we were doing. Second, people told us that the quality of the teacher corps was so low that they would be incapable of carrying out an ambitious endeavor such as ours.

However, we argued that it would be counter-productive, if not impossible, to develop any specific plan. It was not merely that we were not familiar enough with Thailand to know what would be the right things to do. More profoundly, what was needed was a philosophy of design based upon recognizing that nobody could know beforehand what would resonate, how people would appropriate new learning technologies and

methodologies, what learners would choose as projects, how villagers would react to the intervention, and so on.

At the meetings we tried to show that there is a fundamental contradiction between having learning environments that function through connecting to, building upon, developing, and deepening the interests of the learners, and planning everything centrally in a top-down manner where all activities are pre-determined for all learners and all locations. What is needed is a philosophy of design for educational innovation as different from traditional ideas of reform as the content of the new innovation would be from traditional educational content.

Our Thai hosts agreed to let us proceed. This thesis describes how some very general initial ideas developed concretely in practice. It explores the theoretical framework for such a philosophy of design in the context of ideas from the management of business and of research as well as ideas about education.

The phrase "Emergent Design" in the title of this thesis puts a spotlight on the need (which has not been recognized by education policymakers) to study the conceptual space where the purposeful stance implied by the word design mates with the openness implied by the word emergent. This mating underlies modern approaches to organizational practice. It also underlies modern approaches to organizational practice. My work in Thailand and the thesis itself bring together my own experience in these two areas.

The emphasis on *emergence* as the guiding principle does not imply that this is an anything goes environment reacting to the whims of the participant teachers and learners. We brought a very disciplined set of principles, methodologies, tools, activities, models, and exemplars for learning environments. However, to deliver a pre-set curriculum with pre-chosen problems, explanations, and sequence of events would be not only antithetical to the underlying learning philosophy but also it would be incapable of taking advantage of the very benefits that the technology affords.

Designing for this dialectical tension requires something vastly different than previous design methodologies. In this case one is designing where human use and appropriation is the critical element and is unpredictable. Thus, the design must enable a wide range of possibilities, must be able to adapt to the situation, must be appropriable, and must deal with dynamic change. This thesis will describe this project and begin to delineate such an emergent design methodology.

1.2 Scene: Non-Formal Education Department, Education Ministry, Bangkok, March, 1997

Seymour Papert and I are conducting a short, introductory workshop. The goal is to introduce the ideas about learning and the technologies we will employ in Project Lighthouse. The audience is composed of people from the education ministry, formal and non-formal education sites, university professors, and a few business people.

A high-level member of the education ministry is supposed to inaugurate the workshop. Unfortunately, he is late. People tell us he is arguing in front of parliament for the restoration of the education budget, which is being severely cut. We are unsure when to begin, as our hosts are reminding us of the importance of protocol, and, since he is the highest-ranking attendee, must be the first one to speak. This sets the workshop off on an uncertain footing.

After more than an hour delay, the deputy director arrives and convenes the proceedings. After some introductions, Seymour begins an introduction to the project, the idea of Constructionism, and then begins to demonstrate Logo. Not wanting to make everyone listen to a long lecture, we invite the participants to begin programming small projects based upon what they have seen and heard so far.

Everyone is hesitant. No one dives into a project. No one is even exploring the possibilities in the environment. Seymour and I go to as many people as we can to get them started, but since there are so many of them and so few of us, we can only manage to get a few started. People tell us they want explicit instructions and clear tasks to attempt.

Mercifully, we break for lunch after about an hour of lab time. Seymour remarks to me that this is perhaps the worst workshop he has ever done. I think that by now he might have done thousands of them, so that is a pretty strong statement. We wonder if what

people told us about the inappropriate fit between an open, learner-centered approach and Thai culture could be accurate and too difficult to overcome. We all go to lunch.

I decided to return to the lab early to think through what we might be able to do. When I arrive, one person is working on a computer, building a project. He is not a workshop participant. Rather, he is the driver for one of the staff from the Suksapattana Foundation.

He had been sitting to the side all morning, observing the workshop. By watching the demonstrations and going from computer to computer to look at what each person had put together, he took what he felt were the most engaging aspects of their projects and combined them into his own. This is even more amazing given that he did not understand English and thus could not have understood anything that had been said since the workshop was not translated. He created an animation with birds flying to trees filled with apples. Through a translator he asked me how he could program it so that the birds would go from apple to apple, eating them, so that the birds would grow and the apples would disappear. Although simple, this is fairly impressive for the first day.

The spirit that the driver demonstrated was what we were hoping to see from the other participants. He had an idea of something he wanted to express. He explored ways to do it. He took in what was possible and let his imagination carry him from there. We related the story and demonstrated his project when the others returned. This helped liberate the rest of them from their anxieties, clarify what we were expecting, and cleared the path for a very exciting and enjoyable workshop.

The driver went on to take an active teaching role within Project Lighthouse for some time. He now teaches at a private computer school, although he also devotes significant amounts of time to many other projects. In subsequent interviews he told me that as a child he spent a tremendous amount of time in a neighborhood motorcycle shop. He went because they had a racing bike and he hoped to ride it some day. While there, he would watch the repairs and listen to the interactions between customers and the owner of the shop. He eventually did get to ride the racing cycle, but, ironically, on the first try he had an accident and hurt his knee.

1.3 Scene: outside Chiang Rai, northern Thailand, March, 1997

On my first visit to Thailand my hosts took me to a Non-Formal Education (NFE) site in a Buddhist temple. I saw a computer class held at the NFE temple school. A child was being taught DOS commands. The logic behind such an introduction to computers, following the typical school curriculum grammar of sequential building blocks of knowledge, is that it provides the requisite basis for later, more difficult learning. However, the useful learning never comes! And in the meantime, the formalistic nature of the beginning work confuses and frustrates the novice.

His teacher assigned four commands for him to learn and practice. The first was *dir*, to get a listing of files in his directory. The second was *copy*, to copy a file from one location to another. The third was *format*, to format his A drive (fortunately it was not the C drive). I do not remember the fourth but it was made irrelevant by the re-formatting of his disk.

This confounding situation led the student to stop me with a plaintive "what was the problem here? It worked before but now it no longer works. I am following my teacher's instructions but this is not working properly." On the first iteration of practicing his commands by rote, everything was fine. Subsequently, however, none of the commands were giving the specified results. His directory was now empty. He could not copy his file. I explained to him that the result of using the format command is that it re-formats the entire disk, meaning it wipes what was on it clean and sets it for the computer's operating system. Thus, there were no more files in his directory to list or to copy. Despite several attempts at various ways of explaining it, including re-creating the example on the computer and showing how *dir*, *copy* and *format* work with a newly created set of files, I am not sure he understood my explanations. One reason for this is that my explanations meant that what his teacher had said, done, and assigned no longer made sense, which would be quite disorienting. Another possibility is that no matter what the explanations and examples, learning commands this way is too decontextualized to make sense. One is merely learning by rote what someone else says is important without any conception of why or how it might be used.

In any case, learning to use office automation software, even if valuable for the types of applications for which it is designed, does not embody the deep computational ideas, which, as this thesis will demonstrate, can become powerful tools for thinking about real-world situations. My central goal is to show how such ideas can be accessible without many years of preparation, including to villagers with only a rudimentary formal education. Simply being an end-user of office-automation or web-browsing tools does not

provide leverage for learning other domains of interest. Working with computationally powerful ideas from the outset by building projects allows learners to appropriate not only the deeper ideas, but also mundane (and often arcane) operating-system commands.[2]

The split between conventional "School thinking" and cultural learning was shown vividly in the contrast between the computer class at the temple and how the monks themselves teach flower gardening.[3] Beautiful flowers are grown and displayed at all the Buddhist temples in Thailand. They are impressive, colorful, and fragrant. After my visit and the experience with DOS teaching run amok, I inquired about how people learned to cultivate such gorgeous gardens. The monk explained that when initiate monks enter the temple, they work alongside more experienced ones and learn by demonstration, by asking questions, in the best sense of learning by doing. I mischievously asked whether any classroom instruction was involved. The monk looked at me askance, but politely answered no, they felt there was no need. I tried to explain that this was the approach we also preferred for learning computational ideas. That is, that new learners work on projects of their own, are in an environment with others working on similar, but perhaps more complex, projects, can observe and ask others, in essence are immersed in a culture of computing just as the monks are immersed in their culture.

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[2] While terms used such as "project-based" or "learner-centered" and concepts such as an emphasis on design appear in other writings on learning, the formulation within this work is distinguished from those others both by the method of practice and the development of a holistic approach outside of the grammar of school that enables a different practice. The differences are made evident in the descriptions of work in chapters one, three, and four, and discussed in the two concluding chapters.

[3] I am adopting the convention of capitalizing the word "School" when referring to School as an institution containing the prevailing mindset around organization, process, learning, and teaching.

The depth of resistance to these ideas was illustrated by the way the teacher who was translating my remarks into Thai misrepresented the explanation, creating an initial misunderstanding between the monk and me. After listening to my translator, the monk politely responded that they would never do what I suggested. Considering that I had just suggested that we create environments for learning computational ideas in the same manner that the monks learn gardening, I could not understand how he disagreed. So I inquired again about what was said. The teacher told me that she told the monk I had suggested that they teach gardening in a classroom just as we teach computers in a classroom. When I re-explained what I had really intended, the teacher could not believe I meant it. Rather than immediately re-translating, she passionately protested. Surely classrooms were the modern and most effective means of teaching. How could I, from a modern western university, suggest that the monk's method could be better? It took quite a while to get her to tell the monk what I thought. In retrospect, this was a powerful learning moment for my translator, although thoroughly and necessarily unplanned.

This example illustrates the mindset we hoped to change. A culture of doing, i.e., to have people learn not by typical classroom instruction but rather by performing activities in conjunction with others, was such an anathema to the teacher's way of thinking that she could not even translate my words properly (although she was extremely accurate otherwise). The incident is significant because it is not an isolated exception. Examples of successful learning environments that do not rely on classroom and formal instruction abound in Thailand. People are well aware of them. But the grammar of school has captured the mindset when people think about education.

The deeper goal of Project Lighthouse was to change this mindset by providing powerful examples of alternative learning environments. The reasons we could hope to be more effective in this than the presence of examples such as monk flower growing are twofold. First, we were also tackling typical school subjects such as math, science, and history. Second, we intended to make the discussion explicit by researching the projects, reflecting upon the results, and having a broad-based group of influential Thai citizens discuss, publicize, and try to disseminate the ideas. So far, the results of this strategy have been mixed, with some important aspects of progress in learning and learning environments wildly exceeding our expectations and other aspects, also critical, barely moving forward at all. I will discuss these issues in depth later in this work.

1.4 Scene: Nong Baot village, BuriRam province, northeastern Thailand, January 1998

I am conducting an introductory Logo immersion workshop to develop technological fluency. Unlike most projects trying to bring technology to remote or impoverished areas, our goal is to have the attendees quickly build projects and create programs.

There is a mix of participants; villagers, teachers, and a few local economic development workers from the NGO that is hosting us, the Population and Development Agency (PDA). I begin the workshop by showing what a computer is, how you turn one on and off, and how you operate one, as this is the first time that the villagers have ever personally seen one, except for viewing one on television.

In the evening we hold discussions with the villagers to get to know them and their situation. I ask why the villagers say they want us to place computers and internet connections in their village. They tell us that water is very scarce in this region. Worse, there is either too much of it during the two month rainy season or there is none of it during the rest of the year. In fact, one could describe the area as having two seasons each year, flood and drought.

They describe two problems they are having. They feel that the problems are related, but do not know how to determine if it is the case. The first problem is that they have a spoiled reservoir and do not know how the water became unusable.

The second problem was that the cattle developed a swelling around their hindquarters. They did not know what was causing this. They believed it was related to the spoiled water supply but did not know how to make the diagnosis.

When I asked whether they asked for help from local agencies, the village headman[4] told us they used to call in the government agricultural experts but they stopped doing so. When I asked why, he explained to me that they used to do so but gave up for two reasons. The first was that they found it frustrating and demeaning whenever they called in agency help because the people that came never went through the diagnostic thought process with them. Rather, they just told them their conclusion and solution, which was

[4] That is the literal translation of the Thai word for the person holding this, now elected, office. The word though is traditional and reflects traditional views. It is possible, and is the case in some villages where we work, that the village "headman" is a woman. I maintain the literal translation as it is their term and in actuality carries the connotation and contradiction.

often to put some chemical in the soil. This led to the second problem. They worried that previous chemical treatments had contaminated their water causing the current reservoir and cattle problem.

Thus, they told me they wanted access to the internet so that they could find out for themselves what the problems were and what they could do about it. The wanted access to expert knowledge, but most importantly they wanted to be in control of what to do with the knowledge. Technology could provide them the access and the control.

As the week progresses, we develop a relationship. Everyone is building their own projects, first in Logo, then adding robotics with Lego-Logo. What at first was foreign and somewhat intimidating technology is now a source of fun and pride in product. A mixture of people collaborate on their projects, always working in groups, since we did not have enough machines for everyone. The villagers, in particular, work in multi-generational groups, from young children to the elders in their seventies and eighties. While the youngsters do more of the programming, all decisions are made jointly. They are doing programming and engineering, while working on projects of their own choosing.

1.5 Scene: Nong Baot, August 1998

When I returned in August, the situation was quite different. This time our discussion moved quickly to how to calculate the potential and the reality of building a dam. In each of the past two years the villagers tried to construct a dam to create a reservoir. The idea

was that the dam would retain water at the end of the rainy season that could be use for agriculture in the dry season. In each of the past two years the project failed, since the reservoir did not contain the water. Both the villagers and the rural teachers developed the project together. I took a supporting, mentoring role. I did not take a direct role in the project myself, believing that the only sustainable benefit would be for them to develop the package of skills themselves.

They had not previously calculated the potential benefit from the dam. When we engaged in brainstorming about this topic with them, together we calculated that the villagers would more than double their yearly income if they could harvest a second vegetable crop. We walked through the flood plain and took some digital photographs.

Then, a remarkable thing happened! Using the computer led naturally to mapping the terrain. To my surprise this was a totally new experience not merely for the villagers but also for the teachers. While the fact that the villagers could not do this might not be surprising, the teachers could not do so either. They had certainly taken school courses and passed school exams on this type of knowledge, yet in practice they could not make a map. Together, the teachers and villagers created accurate computer representations of the areas, preserving distances, maintaining relationships and ratios as they created various views at different scales, and calculated the relevant distances between important objects.

Immediately upon creating the maps, we discovered a mistake repeated each of the past two years. They had been building the dam in the wrong place! The original location benefited from natural terrain to create the reservoir. However, it was about two kilometers from the village water pump used for irrigation. Once they constructed their own map of the area, they realized they could not create a reservoir large enough to cover the distance to the pump. Even if the dam had functioned properly, it would not have provided the expected benefit as it was prohibitively expensive to re-locate the pump and the irrigation hoses.

As the design project continued, we observed how the efforts of one of the participants was exceptional. He told me that he had not had any success in school and left as soon as it was legal. He primarily helped his family with the farming. We had only introduced computers to the village within the current year. He spent this time working on programming – not by taking classes, but by programming his own projects.

What was so striking was that he had quickly become quite an adept software hacker.[5] Atypical of many of our experiences with more educated people, he, as well as others in other parts of Thailand, dived in and figured out how to build the projects he wanted. If something did not work, he was not daunted. Rather, he debugged the system and worked until it was satisfactory.

We discovered that he spent considerable time working with engines. By learning how to build and repair engines and by working on the farm with few resources, he developed a

bricolage spirit. That is, he would make what they need with what little he had. If something did not work, he fixed it. If he did not have the right tool or material, he improvised. He took this spirit and applied it to computational technology.

As this skill and experience became apparent, he and others took me to visit their farms. At the farms, everyone who could used a small Kubota diesel engine to power a wide variety of local technological contraptions. They used the little motors to power rice mills, well-water pumps, irrigation pumps, one-person tractors, field vehicles, and even lightweight trucks. The barns contained little pulley systems for lifting the motor from one device to another. The logic of each machine was open and obvious. The innovation and creativity were remarkable. The utility was tremendous. They had taken objects for other, often quite specific, purposes and combined them in a general-purpose melange particular to their needs, resources, and budgets. The experience and expertise of those who worked with these engines and devices was quite impressive.

1.6 Thai Combustion-Engine Culture

Virtually all commentators on Thai education and on the Project Lighthouse proposal believed that the quality of rural teachers was extremely poor and that they would be unable to work successfully in the proposed technologically rich, learner-centered environment. These same commentators bemoan the problems and capabilities of the overwhelming majority of rural students as well. Lack of faith in the intelligence and capability among economically disadvantaged children is an unfortunately universal belief that is all too difficult to dislodge.

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[5] That is, in the positive sense of hacking.

Contrary to these perceptions that rural and impoverished students are not capable learners, rural teachers are not competent technologists, and that Thai culture is not amenable to innovation, collaboration, deep learning, and technical expertise, we discovered that there are deep intellectual roots and significant innovation practiced and learned over at least many decades, and presumably much longer. Indeed, although not written about in academic circles, there is a strong tradition of "peasant technology," particularly using and adapting the internal-combustion engine to satisfy local concerns and constraints.

Perhaps the best example of this innovation is the creation of the long-tailed boat. There are many areas throughout the country where waterways are the principal means of travel. Significantly, this is also the case on the rivers and canals of Bangkok. As people desired to transport more and heavier goods, human-powered boats became more problematic. In the north, one innovator decided to experiment with placing motors onto the boats. After several attempts with various types of inboard and outboard motors, he settled upon using an automobile engine with long drive-shaft so that the propeller was far from the boat. Typical outboard motors did not work well as they churned too much water into the long canoes that everyone used. The many reeds in the rivers also jammed the propellers too often, negating their benefit. The drive-shaft, the long-tail of the name, not only solved the churning problem, but also served as a rudder for steering and enabled the pilot to lift the shaft from the water to avoid entanglement with the reeds. The use of an auto engine leveraged existing knowledge about repairs and benefited from not

requiring parts not manufactured in Thailand and therefore difficult and expensive to obtain. People quickly adopted this technological innovation throughout the country [Phongsupasamit, 1989].

Tuk-tuks are another similarly inspired innovation. Small motorcycle engines are placed onto the pedicabs, again to alleviate human stress and increase speed. Other rural innovators have also adapted engines to create low-cost one-person mechanical plows, irrigation pumps (including one ingenious invention to pump over roadways, since the native soil had the tendency to crumble into irrigation tunnels), and devices to help operate wells in drought-stricken areas.

Figure 1 -- Long-tail boat

Figure 2 - engine on long-tail boat

Figure 3 - Kubota-powered 1-person tractor

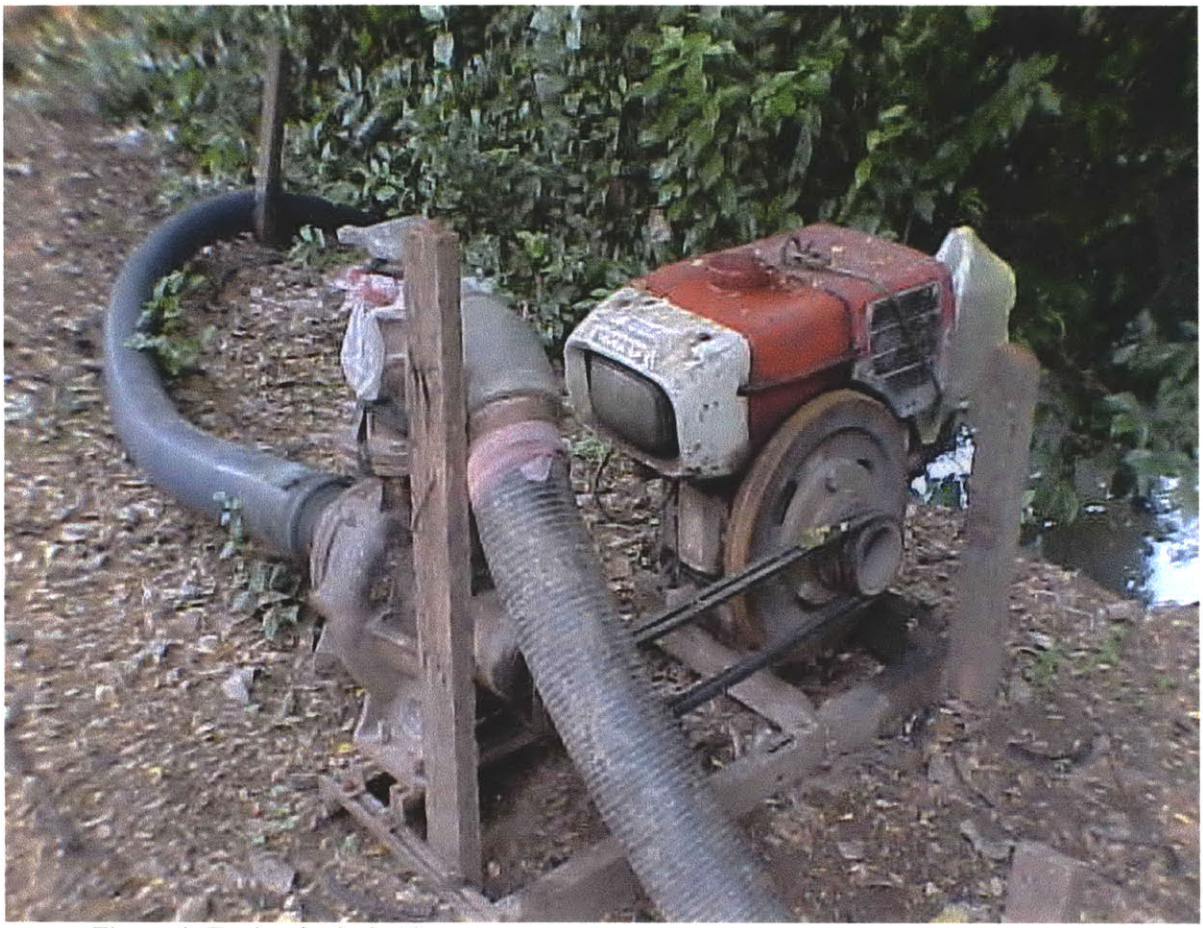

Figure 4--Engine for irrigation pump

Figure 5 - Kubota-powered farm vehicle

Figure 6 - Mechanic working on motorbike at repair shop

For the most part, not only did these innovations not occur in universities, research labs, or corporate departments, these circles barely took notice of them. Rather, they were a grassroots effort, based in the interests, needs, and practices of Thai culture. People created and adapted new technologies to alleviate their burdens and to create new opportunities.

These innovations could not have achieved such widespread use if a culture of practice and knowledge had not also developed to spread and support them. In order to use engines widely, a group of people capable of maintaining them had to exist. This group did not do well in school and did not receive its training in school. Rather, almost exclusively they learned to diagnose and repair engines in informal learning cultures. Making this diagnosis and repair more difficult is the fact that among this social stratum in Thailand, there are not a lot of materials, parts, diagnostic equipment, or written manuals. These mechanics have to become *bricoleurs* [Levi-Strauss, 1966, Papert, 1980, Turkle and Papert, 1992], that is, they must adapt materials at hand to satisfy their goals, even if it is not the accepted way to accomplish the goal nor the proper materials for the task.

What makes this story compelling is that these mechanics, while respected for their mechanical abilities, were not regarded as academically capable. Conventional wisdom stated that this group may be good with their hands but they were not good with their heads. Moreover, the belief in the dichotomy that different people with different skills are required to be good with their heads remains.

However, in the context of Project Lighthouse, the capability of these motorcycle and engine mechanics was immediately evident. Not only did they learn the new computational technology quickly, they were also quite adept at adapting it and applying it to solve local problems. This was the case with designing dams, improving irrigation, and devising alternative methods of cultivation of rice and other crops in BuriRam.

Still, moving from one technology, engines, to another, computing devices, while impressive, would not necessarily be remarkable except that in order to accomplish the tasks with computational technology they had to competently handle some sophisticated mathematics, biology, engineering, physics, and computer science. What is remarkable then is that:

- they accomplished projects requiring competence in these recognized bodies of knowledge
- they accomplished this in extremely short timeframes
- they leveraged their mechanical expertise and "hacking" spirit to build a computational technological fluency
- they then utilized the technological fluency to gain competence in these bodies of knowledge previously inaccessible to them

Moreover, the dam design is but one example from one site. Other sites also had similar results. The point is not that everyone should design a dam, but rather that at each site the learners could work within the same methodology and same set of tools on projects of

interest and import to them. That each site developed uniquely is an important result of this work.

The significant accomplishment in this work is demonstrating a significant gain in accomplishment among a population that had not previously exhibited such competence in educational institutions. This work demonstrates how to build upon and enhance local knowledge. Within the design of this learning environment, the learners:

- work from local knowledge and interests
- bridge to other knowledge domains
- liberate their local knowledge from its specific situated embodiment

The role of the computer in this process is to draw on a set of skills so that they can transfer it onto something different. Through computational tools, learners design and construct and thereby make the forms of knowledge they have more general. Developing technological fluency enables them to break out of the specific context and represent their knowledge in forms they can draw on in many contexts.

1.7 Thesis: The Design of Technologically-Rich Learning Environments and the Reform of Education

Discovering the engineering expertise and hacking spirit among so many Thais who had previously not succeeded in school is a major benefit from the Emergent-Design approach utilized within this project. Not only had School not build upon this talent and intelligence, it did not even recognize it. The typical school reforms, despite their

intention to promote creativity, problem solving, technological capability, and so on, also are generally incapable of discovering and leveraging such local knowledge. This is due to their top-down, pre-planned, standardized, curricular approach.

There was no way to know beforehand for every site what will resonate and what local concerns and local knowledge exist. What one does know is that there always is something, and, if one uses Emergent Design combined with the principles of learning environments and open, programmable, technological tools, then this something can be built upon and leveraged.

This thesis will spell out concepts in Emergent Design as a methodology for broad institutional change and for learning environments. This work will also detail the accomplishments and the disappointments in Project Lighthouse. I will investigate what it was about their background, what it was about the activities within Project Lighthouse, and what it is about the nature of the technologies within the project that facilitated the results. This further understanding of technological fluency and new learning environments will help guide principles for the development of other technologies for use in these environments.

It bears noting that this is a work in progress. Project Lighthouse is still developing and we continue to study, reflect, and modify the activities and tools. We only have minimal resources in this project. Primarily, there is a lack of people who have had the opportunity to develop expertise in learning and technology. This more than anything limits the possibilities. In the stories below, in some ways the parts are greater than their

sum. The individual stories demonstrate the possibilities of what could be achieved. The thesis examines in detail how this evolved and how this could be further developed.

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

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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

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[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.

Chapter 3 – Cases from Project Lighthouse

3.0 Project Lighthouse in northeast Thailand

This chapter details the activities in a number of Project Lighthouse sites in Thailand as they relate to my thesis of Emergent Design. I choose to focus primarily on one site, Nang Rong, for a number of reasons. The foremost reasons are that I spent a considerable amount of time there, thus am most familiar with it, and I have influenced the work there considerably. Regardless of my personal involvement, as will be shown in Chapter 4, the work in Nang Rong is indicative of Project Lighthouse as a whole. In the following chapter, I also include short sections on some of the other Project Lighthouse sites. Rather than describe each site in detail, I choose to highlight only those aspects important to this thesis.

3.1 Nong Baot village, BuriRam province, northeastern Thailand, January 1998[1]

Nong Baot is in the northeast of Thailand, the poorest region of the country. It is approximately one-hundred kilometers from the Cambodian border. The New York Times described it as having "two harsh seasons, flood and drought" [New York Times, "Nang Rong Journal," January, 1997]. The economy is based upon agriculture but, due to the harsh weather, little can be grown. Nong Baot survives on cultivating one rice crop per season. There are some small vegetable plots used primarily for subsistence as there is not enough water to grow enough crops to sell. Lately, some groups of villagers have tried to cultivate fish farms by creating small reservoirs during rainy season. This, too, provides food for them only for a brief time, as the water is gone within a few months.

Nong Baot is an area that suffers from logistical problems that stifled the potential for economic development [Sachs, 1998]. It is tropical and does not have ready access by water to the rest of the world. These factors inhibit the development of industry. The soil is poor and there are no mineral deposits. Thus, it has remained an area of minimal means and wealth.

Education in this area likewise has been minimal. There is little incentive to remain in School. Many people leave school as soon as they are legally eligible, claiming that School has no relevance to their lives. Children need to work in the fields or in other occupations to help their families. Few people go on to attend university.

In this region of Thailand, Project Lighthouse collaborated closely with the Population Development Agency (PDA)[2]. PDA is a non-governmental organization (NGO)

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[1] This material was briefly introduced in Chapter 1. That description served to set a context for the overall work. I go into significantly more detail in this chapter although some of the material will already be slightly familiar to the reader. I extend my apologies and request patience.

[2] PDA was formed by Khun Mechai Viravaidya. Its original goal was to work on reducing the extremely high birth rate in Thailand by increasing awareness about family planning encouraging the use of condoms. Khun Mechai became know affectionately as "Mr. Condom" through his quite successful efforts. Khun Mechai demonstrated what a tremendous educator he is in this work. He tells of how he would initially introduce condom use in villages. Thai society is quite polite and reserved, and is quite taboo to talk openly in public gatherings about sex. Khun Mechai would gather the villagers together and hold up a condom and ask if the villagers knew what that was. He said no one would ever answer except there was always an audible gasp. He then asked if they knew what they are for. He received a louder gasp. He then asked if they knew how to use one. An even louder gasp resulted. Finally, he said he would show them. At this point people were shouting at him. He then would blow on up like a balloon and let it loose to fly around the gathering. He then would blow up another and paint a face on it. He would fill another with water and create a water bomb. At this point everyone was greatly relieved, laughing and participating. Without saying another word, or preaching at them, he would leave a large supply of condoms and move on to the next village. He relates that without fail, the birthrate immediately declined in each of these areas. This is true education and highlights the possibilities of what one can accomplish not merely without explicit lecturing but perhaps because he did no lecturing. PDA now focuses on economic and social development of rural areas. Due to their success and the villagers' trust in PDA, we were welcomed warmly and did not

developed by Khun Mechai Viravaidya[3] of Thailand. PDA's first mission was to combat over-population and high birth rates, which in the nineteen seventies was a major problem for the health and well-being of Thailand. After successfully addressing that problem, PDA turned its attention to matters of sustainable rural development, including changing farming methods to environmentally friendly, sustainable ones, and to support development of clean industry in the rural areas. PDA has tried to make rural areas more economically viable in order to help keep the rural families intact – adult wage-earners leave the villages to go to the cities, leaving only the children and elderly.

Before the economic crisis of 1997, many adult villagers would leave the area to work in industry as laborers in and around Bangkok, except during rice planting and harvest time. While this provided some income, the practice was not without costs. Village populations were mainly reduced to children in the care of their grandparents. Family life was ripped apart and the local economy was seriously compromised.

For many of the villagers the life in the city was also not easy. Unscrupulous middlemen exploited the migrant workers. These middlemen would promise work, good wages, and housing in the city. Upon arrival the reality was quite different. The housing, if there was any, was unsanitary and unhealthy. The wages for the job, if there was a job, were inadequate. The slum areas where they lived are rife with violence and drugs. The

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need to spend the usual amount of time, often years, building trust in the local area. Our association with PDA and their support and cooperation were strong factors in any success that we achieved in this region.

[3] The Thai word "Khun" has several meanings. I use it throughout this document as it is the polite term of address for both men and women, like Mr. or Ms. I also refer to the Thai participants in manner in which we referred to them during the project, and the other participants form other countries in the way we referred to them.

middlemen charged exorbitant fees for job placement and support and often the villagers would expend great effort only to wind up in debt. The life of the villagers is harsh and fraught with inadequate resources whether they remain in the village or migrate to the city for work.

It is in areas such as Nong Baot where the government hopes to improve education as the path to development. For example, the education reform act recently approved by the Thai parliament extends the period of compulsory education from four to nine years. But this in itself cannot be a solution. The villagers hold school in low esteem. If they believed that school is beneficial, they would remain, rendering the extension of compulsory education superfluous. They drop out not only to work on the farm or to earn money or help support their families. They also leave because they feel school as it is provides no value to them and is an irrelevant waste of time. Moreover, many teachers are quite harsh, inflicting corporal punishment on the students. Obviously, the goal of an educated public is worthwhile. However, whether extending the number of years of poor schooling in a country with few resources for education is as useful as fewer years of higher-quality education is an open and important question.

Of course, the assumption underlying standard educational design is the hope that quality as well as quantity can be improved. The view projected by this thesis is that this definition of the problem expresses an in-the-box mindset. *Policy makers have rarely seriously considered fundamentally different alternatives.* My goal is not to provide an

"alternative solution" in the form of a prescription, but rather to break the mindset that impedes the emergence of truly diverse alternatives.

Before diving into detail, I must however concede one way that education in Thai society has been unusually successful. Thais have an amazingly high literacy rate. Administrators in Non-Formal Education told me that the literacy rate is over ninety-five percent.[4] This fact clearly facilitated so much of our work as we did not have to simultaneously introduce reading and writing along with the computational ideas. How the methods described here might fare in a less literate context will be discussed in the concluding chapter.

3.2 Initial Work in Nang Rong

I began our work in the area by conducting an introductory Microworlds-Logo immersion workshop to develop technological fluency. A major goal was to have the attendees quickly build projects and create programs, often very different from anything we might have imagined in advance. At their best, these workshops permit quite dramatically surprising expressions of the thinking and interests of the participants, illustrating an integral part of the Logo philosophy "low threshold, high ceiling" [Papert, 1980]. The slogan means there should be as low as possible a barrier on entry to doing real things but as few limits as possible to what can be done. In this way the learner does not spend inordinate amounts of time preparing before being able to do something meaningful. One is building projects that feel "real" right away.

[4] Personal communication.

Thus, our goal in introducing computational technology is very far from the more common one of teaching rudimentary computer usage, under the misnomer of literacy, thereby devaluing the term. Papert has noted that a person whose knowledge of literature was comparable in extent to the goals of computer literacy would be considered thoroughly illiterate [Papert, 1997]. While the cultural capital attached to computational technology often provides a boost to the initial phase of learning even the rudiments of Windows[TM] and Office Automation "Productivity Software," without fail the students soon hit a plateau and progress halts. The learners become bored, as there is nowhere further to go and no way to leverage such rudimentary knowledge into a greater gain. The initial empowering effect, in the end, has a deadening effect not merely on learning the technology, but also on the students' senses of themselves as competent learners and performers.

3.3 A First Workshop

Our first workshop at the PDA CBird Center in Nong Baot, BuriRam province, had a mix of participants. Some were local villagers. Others were teachers from the local district of the national Ministry of Education Non-Formal Education (NFE) department. A few were local economic-development workers from PDA. The remaining participants were some professors and students from the teachers college of the province.

It was in the discussion after this workshop (previously summarized in Chapter 1, Section 4) that the village leader expressed the need to gain more control over their lives and the

belief that certain uses of the technology could help them. They described much of their problems as economic, caused by the harsh climate where there was either too much or too little water. They wanted access to expert knowledge, but most importantly they wanted to be in control of gaining the access and the decision about what to do with the knowledge. They felt that the local authorities did not involve them in the thought-process and decision-making whenever the villagers asked for assistance. This left the villagers feeling dependent and without the hope for their own progress. To make matters worse, due to the appearance of new problems with the cattle and the water, the villagers believed the advice and proposed remedies to be harmful rather than helpful.

They believed that the technology could provide them the access and the control. They wanted to end this cycle of dependency and lack of control by gaining access to information and gaining control of the situation. Even though I had to introduce the workshop by demonstrating what a computer is including how to turn one off and on, through the symbolic value of the computer they viewed competency with the technology as a plausible path to this control.

As the week progresses, we begin to develop good working and personal relationships. Despite language difficulties, through the valiant efforts of our translators, they began to know me as a person and I them. Through this relationship, they came to understand why I would come to their village. I began to understand their individual interests and personalities. I tried to be as open as possible about our motivation for working there.

I told them that our effort was part of a broader national effort to improve the educational system. I explained that my colleagues and I would introduce computer technology for learning and attempt to initiate new methods for learning environments that the technology potentially facilitated. We wanted to focus on local issues as the basis for study. We would work together on these projects. The primary goal, however, was not for us to teach any particular curriculum, but for them to appropriate the technology and apply it on whatever they deemed most important. I believed that rather than pre-determining what exactly was important for them to learn, how they should learn, and to build from one step to the next, the important, powerful ideas would emerge from their working on real projects. The powerful ideas are powerful because they help people to understand the knowledge domains. These would appear through working on real projects and thus would have context and facilitate connections.

I told them our choices of tools were based upon our experiences and that we believed these tools were best to help build a fluency quickly. However, the language would still be applicable on harder problems. We also promised that they would have access to other tools and languages and we would jointly decide directions initially. We also told them it was our intention to "work ourselves out of a job," by helping them and the teachers and local community workers learn and understand our role so that they could take it over as soon as possible.

It is important to note that the philosophy expressed above is not merely practiced but is also an object of discussion and reflection. Making the rationale and choices explicit and

discussing them, helps recast reasoning, decision making, and control into a cooperative effort. This project does not belong to us, where we have total control and the process is hidden from the villagers. We are not, however, mere passive observers without input either. We have a role – in our manner of working we take it as our obligation to offer a set of experiences – and a viewpoint, while any actions and decisions are taken as collaboratively as possible. This is true for the overall project and is true in the interaction with individual learners in the course of their projects. In this way the endeavor forms a more coherent whole.

In Nong Baot we were able to achieve rapid acceptance because of our connection with PDA. PDA had been working in this area for more than fifteen years and the villagers had come to trust them. They extended an initial trust to us based upon PDA's presentation of us and our role. It was easy for the villagers to see that our methodology was similar in approach to that which PDA successfully used. That is, we introduced new technologies and methodologies for their appropriation, under their control, and applied to what they desired. They could understand that our goal was to help them develop technological fluency to enable them to use powerful computational tools in the same way that textual literacy provides a powerful set of tools, for their own purposes. Their familiarity with PDA's approach and their knowledge of the potential long-term benefits enabled them to understand quickly how to work with us.

In short, the villagers were able to experience what we did in the spirit of "cultural leverage." As a result, the participants were soon building their own projects, first in

Microworlds Logo, then adding robotics with Lego-Logo. What at first was a foreign and potentially intimidating technology, now is a source of fun and pride in product. The villagers worked in multi-generational groups, from young children to the elders in their seventies and eighties. The teenagers and children did more of the programming, being more open to new technologies. The adults contributed their wisdom, maturity, and experience. They made all of the decisions jointly. They were doing programming and engineering, working on projects of their own design.

I introduced several types of initial activities in Microworlds Logo. Since the participants did not know English, we used a beta copy of the Thai language version.[5] Doing so raised an issue that comes up often in discussions about computer use in developing countries. A common idea is to "do it in English so that the students can learn the language and you can achieve two purposes at once." But this goal goes against our philosophy of "cultural rootedness," where the native culture is a powerful source of learning. The web of connections from the deeply rooted and intuitive sense of one's native language extends a rich set of meanings to things we approach with our language. In Logo, many commands and conventions are based upon this web of understanding. Ideas of *forward*, *back*, *right*, *set*, *shape*, *color*, and so on, are not merely formal commands but inherit from their meanings to English speakers. Treating them only as technical commands debases them and loses the rich web of connections.

[5] We did not know it before we began the localization effort with LCSI, the vendor, but this was the first programming language translated into Thai.

Moreover, programming not in one's native language makes learning the programming much more difficult. The error messages, help text, examples, and support materials are important for understanding learning to program. If one cannot make use of these materials, the task is much more difficult. Thus, I felt that the positive features of "learning English as well" were minimal and perhaps not positive at all. The negatives were strong. Still, as it was our goal in the design of the overall project that our Thai partners not merely follow our directives but construct and develop their own understanding and make decisions accordingly, we decided to leave it open to each site to use whichever version of the software they wanted. How the paths differed based upon the choice would be an interesting research question.[6]

In working with the villagers, I did not want to spend much time with preliminaries thereby delaying the moment when people could begin to perform meaningful work. All too often people helping beginners take long amounts of time showing every little step of using the computer. Even when well-intentioned by not wanting to overwhelm people with something daunting, this too often has the effect of losing people's interest because the relevance of the tool becomes obscured in details of use. It begins to feel like another meaningless school task where the potential joys and utility are deferred too far into the future for people to maintain the faith to continue. We knew from discussions that many in this workshop had left school after only a few years because they did not feel it added

[6] Xxx and yyy in Israel related their results in working with a Hebrew langauge version of Logo. The results were dramatic across the board in terms of types of students. The students who programmed in the Hebrew version performed much better, wrote more and more sophisticated code, accomplished many more projects, and even had better mathematics and science results. They are now in the process of writing these results and they should be published soon. They related this during the EuroLogo conferernce in Sofia, Bulgaria in August, 1999.

anything to their lives. We did not want to lose them as well by taking days to show arcane aspects like files, directories, DOS commands, etc.

Microworlds is designed according to the Logo principle so as to allow a learner to construct something real and satisfying as soon as possible. Creating animations or pretty designs with turtle geometry might not be directly useful but was sufficiently captivating to enable people to begin and continue to work. That Logo is, to at least some degree, personally expressive helped to engage the learners, as each one could make something of their own choosing, reflecting their own aesthetics. However, the pervasiveness in their school experience of following instructions presented an obstacle. It was necessary to continually remind the learners that when we gave examples they were not meant to be "commands" for everyone to follow by rote.

People did manage to build their own programs during the first day. There was considerable joy and satisfaction among the participants over having created their own projects, primarily aesthetically pleasing designs from geometric commands and the use of colors. Especially salient was the feeling of mastery over a high-technology device, the computer. This was particularly empowering and liberating in that many aspects of school and modern life left many of these people feeling powerless and alienated. That they could program and control this device gave a feeling of accomplishment. With this spirit they moved on to attempting to use the technology under their control for projects to their benefit. Moreover, accomplishing this quickly, without months of prerequisites, was critical so that they were not further alienated.

I began with two types of Logo activities, turtle geometry and creating simple animations. My goal was to introduce the language in a manner comparable to the *in vivo* learning of a natural language. Children learn new words by using them in meaningful situations. A typical way people introduce programming languages is to list the most elementary commands, provide an example, and have the learners memorize the commands. Once they have memorized an initial set, they are given a simple programming task such as organizing a list of elements, or placing a message on the screen, or performing a simple calculation and outputting the answer. The underlying paradigm again is of contained building blocks, introduced out of context of use or only within the context of the curriculum designer. The learners are expected to collect the building blocks, which they can subsequently apply when they finally are allowed to program on their own.

Rather than listing commands for people to memorize, I demonstrate how to make things happen within the Microworlds environment. I know that the participants do not have any familiarity either with the environment or with programming, so I cannot expect them to know what is possible. Thus, I have to show some things. However, I try to make this familiar, interactive, and enjoyable.

I introduce turtle geometry. Through this they will see how to program and manipulate objects in the environment. I have concurrent goals for the teachers. I want them to learn the language but also to think about their learning while we do this. Since our objective

of technological fluency is not just to have someone learn any particular programming language, but rather to learn how to think and express themselves using computational ideas, reflecting on how this is possible is paramount. However, it cannot work well in the abstract and needs to be embedded in some concrete activity. This is the role for the programming language.

I begin with moving the turtle with FORWARD and RIGHT commands. I use PD to put the pen down so that the movement of the turtle leaves a trace so they can see better what is happening. Initially, even though FORWARD and RIGHT have abbreviations that work (FD and RT, respectively), I spell the commands out completely so people can understand their meaning and the command itself is not so cryptic. Soon, I switch to using the abbreviations.

I move the turtle forward and show how it rotates in the same spot with the RIGHT command. I then suggest we make a square and ask how much we should turn. In this situation, people typically suggest ninety as the right amount. If they do not suggest ninety, I take whatever suggestion they give. In these situations, although they may not describe it this way, people can quickly see that the turtle has not made a right angle and will not make a square. I show how to undo a command and move the turtle back to its previous location. If this situation occurs, I always make certain to make explicit that making a *mistake* is not bad and usually leads to a better understanding later. On the computer we can typically rectify what went wrong so there is very little cost. The bigger cost is in being afraid to make a mistake and therefore not trying things. I encourage them

to try, see if it is what they want or not, and try something different if it is not. I want make this spirit of experimentation, of trying, hacking, guessing, reflecting, explicit and alive in our learning culture.

This is just the opposite of typical Thai School culture. People are not encouraged to guess. Indeed, for the most part they are not encouraged to participate. Having the wrong answer leads to the shame of "losing face." It is better to keep quiet than participate. This situation, of course, is not conducive to a good learning environment. Nor is it conducive to helping people develop the skills desired in the new education plan. Changing this attitude is a key goal of Project Lighthouse.

3.4 Nong Baot, February-July, 1998

Both the Suksapattana Foundation staff and the MIT group felt that the work in collaboration with PDA was important. This site enabled us to work in a non-school, community-center-based site. Although we would have preferred to be in the villages themselves, working from the CBird center had advantages also. There were already on-going activities there. PDA had developed a strong relationship with and trust among the villagers. There was technical, logistical, and staff support for the computer room. The electricity and phone lines were stable.

However, unlike locating in the villages, rather than being an integrated aspect to village life, coming to the computer room was an extra effort. Indeed, it often detracted from

village life and was difficult in rainy, planting, or harvest seasons. Still, this was better than nothing.

Unfortunately, at this point the funding for the foundation was badly hit by the Asian financial crisis. Thus, rather than having Foundation staff that could help develop the project at the Nang Rong site, combined with not having a group of Fellows to mentor, monitor, and guide the project, the Nang Rong site was left primarily to its own devices.

One PDA staff member, Khun Saithong, devoted part of his time to supporting Project Lighthouse. He had been hired to provide technical support. He is very pleasant and likes children, so he volunteered to work with the children who came to the computer center. He had participated in one Logo workshop, but that was the extent of his experience with our methods. Moreover, his computer training was quite rudimentary.[7] He had never really thought about learning or education. He helped out because he liked the project, liked the technology, liked children, and was generally supportive and helpful person. However, the burden placed upon him was clearly too large.

The Foundation did try to send some people from outside the area to support the Nang Rong site. Ae, the driver, came for several periods, working individually with people. Several students and young faculty came from KMUTT to run a Lego/Logo workshop.

[7] The problems with printing when we upgraded the computers highlights the rudimentary nature of his training, and the lack of adventurous spirit that inspired many of our supporters from the private sector to initiate Project Lighthouse in the first place. We upgraded the four computers already at PDA and had a dozen more donated. The new and upgraded computers ran the Thai version of Windows95. When they upgraded the existing computers, the printer attached to them stopped working. Rather than connecting the two events, or trying to diagnose the problem where the cause seems fairly obvious, or even just hacking

Still, while helpful, this type of sporadic, unsustained effort was not sufficient for the people at this site to develop the technological fluency needed to create interesting, meaningful, varied, and complex projects. Saithong himself had only participated in one week-long workshop. Thus, for these seven months the Nang Rong site did not develop much at all.

Still, and quite amazingly, when I arrived at Nang Rong in August, the children ran to the computer room every day after school. In fact, on my first day back we held a meeting in the computer room. I noticed the children arriving at the window, peering in, but not entering the room. They kept returning to the window to look at us. It appeared to me that they were becoming angry. Someone told me that they normally used the computers at this time, but would not enter out of respect while we were meeting. They were bothered because here we were, preventing them from entering, and we were not even using the machines. Once we realized the situation, we held our meeting outside so that they could work.

Rather than play games, they worked on Logo projects. The staff told me, and I witnessed this during my time there, that this was the usual state of affairs. They made many animated stories, added music and images, and also played with creating and programming fanciful and artistic geometric shapes. That this continued for so long is impressive, and a tribute to Saithong's efforts.

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through the debugging process, they decided to stop using the four computers and just use the new ones so

3.5 Nong Baot, August 1998

We enlist the help of the director of the PDA Nang Rong Center, Khun Booncherd, and Khun Gaensri, who manages some of PDA's projects with the villagers. We invite residents from the Ampur (an official term meaning district) to a brainstorming session about what projects we will undertake in the technology center. There are about fourteen villages in each Ampur and we are fortunate that at least two villagers come from each village. We have a session in the morning for one Ampur, and another in the afternoon for the other.

Khun Gaensri addresses the morning group first, explaining our goals, the activities we hope to do, and what we hope to accomplish during this meeting. Khun Booncherd does this for the afternoon group. Khun Bangkok and I add some more detailed information about Project Lighthouse as a whole and what is possible and not possible with the technology. We then divide into small groups for brainstorming and discussion. Each village was one group, and someone from PDA, NFE, or from Project Lighthouse facilitated for the group. We asked them to think about what problems they had in the village, or what they would like to create, or what they would like to improve.

I was a little bit nervous about the participation of the local NFE teachers. In every other part of Thailand, we had conducted technological fluency immersion workshops for the local, participating NFE teachers. They had at least two weeks of introduction to the

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that they could print.

technology and the ideas about learning before they began working with children. In our proposal we had specified that they should have six weeks of workshops and another six weeks of working on their own projects. Despite our insistence on this, which was based upon our previous experience, no Project Lighthouse site in Thailand gave the teachers this much preparation time. The reason behind not providing the development was its cost. Yet, undoubtedly the project suffered from the lack of experience and development of the teachers and facilitators. This is a typical administrative decision that focuses on short term costs, and ignores the long term results.

We had two NFE teachers from Chiang Rai and two from Lampang assisting us in the project. Both the Chiang Rai teachers and one of the Lampang teachers had been involved in Project Lighthouse from its first workshops in Thailand. These teachers rode eighteen hours on the bus not only to help out in BuriRam, but also to learn how to work on such village projects. Rather than run a workshop about what we were going to do, we just planned our activities, did the activities, and then reflected upon and discussed how things went, looked for what the key ideas in the projects were, and then re-planned the subsequent activities.

The need for an emergent design is evidenced by situations in Project Lighthouse where even when people accepted and agreed with the ideas and principles, they often did not know what to do. They had no in practice examples for guidance. Part of this is a problem of running workshops. In workshops one can practice with the technology and discuss the ideas, but it is out of the context of the actual work. We therefore tried only to

use workshops for introduction to the technology and the ideas, but do as much *in situ* as possible.

Most importantly, no matter what one would do in the beginning, people would need time and practice to learn to function differently in a learning environment. Just as we expect learners to need time and practice to construct their own understandings, the teachers and administrators need time to develop their new understanding of learning environments. Just as learners construct their own theories based upon experience, style, and practice, and then further construct, develop, strengthen, or even discard these theories over time, the same would be true of the Project Lighthouse practitioners. We designed and planned as best we could at each step, but we still needed to observe, reflect, and react to the actuality of construction.

Still, I was worried about the burden we were placing upon the NFE teachers from BuriRam. They were all very young and inexperienced. Except for one, they had no experience working with computers. They did not have the benefit of participating in an immersion workshop. Not only did they now have to start working with the technology, they also had to work in an unfamiliar learning environment, and they had to work on real world projects. None of this is easy. I was worried that the pressure was too great and that they might quit. None of them did, and they all became active and very productive participants in Project Lighthouse. Indeed, one of them asked me when I was leaving if it would be okay to continue working with the villagers in this way after I left, or did he

have to return to the traditional way of teaching. I told him that the whole point was for them to continue.

3.6 Getting Down to Work

The majority of the project ideas that the villagers raised in discussion were about water or agriculture:

- create a reservoir to enable more farming
- create a decision support system to improve rice cultivation
- improve the layout of farmland for raising vegetables and rice
- find ways to obtain more drinking water
- create fish farms in reservoirs
- find new types of crops to grow
- find new uses for existing crops

At the end of the session, we re-grouped and discussed some of the more salient and common project ideas. One village did not have enough drinking water for the whole year. They had to ship in bottles of water for the final three months before the rainy season. Khun Bangkok led a session at the board, working out how much they might save if they did not have to truck in water. He asked them how much each bottle cost, how many bottles they needed per period, and how many they would need overall. He then worked through the calculations for the total cost.

At this point a villager stood up and interrupted. He said that he was just a simple villager and could not do such calculations and mathematics. He said he knew he spent twenty-seven thousand Thai Baht (then worth about six hundred U.S. dollars) on water for drinking and farming and that if he could reduce that cost to twenty thousand Baht (a savings of about one hundred fifty-five dollars), he would be very happy.

Of course, while he disparaged his mathematical ability, he had accurately calculated his yearly costs and knew how much savings would make an effective change in his family's lifestyle. We knew this because as we continued working with him we saw his bookkeeping and saw his mathematical ability. Yet, it was clear he had not yet developed a certain type of mathematical fluency. He was uncomfortable manipulating quantities in the way we had done on the board. His mathematical ability was accurate to the level he required to function in the way that he was comfortable. He was not mathematically inept as he claimed (although some of this could be typical Thai modesty), yet, he was not fully fluent with mathematics as a system or as a means of abstract expression.

More importantly, and we saw this repeatedly, the villagers often referred to themselves as "simple" or "not capable." Somehow, they had come to not value their own talents and expertise. Their category of "smart" and "capable" in things that require smarts did not include themselves.

It was this attitude as much as anything that we hoped to change in this project. However, we believed that we could not change attitudes in the abstract or by argument. The

change had to come from within the person. Moreover, this change could not come about unless the person accomplished things in areas that are experienced as difficult or requiring significant expertise. In other words, we believed that disempowering views of self would change through support and encouragement, but only if it is given in the context of accomplishing difficult tasks themselves.

Access to water was the major concern throughout all the villages of the Ampur. The people of Nong Baot wanted to construct a dam to create a reservoir. The idea was that the dam would retain water at the end of the rainy season that they could then use for agriculture. In each of the past two years, the project failed as the reservoir did not contain the water as it ran out.

They had not previously calculated the potential. When we engaged in this brainstorming with them, together we calculated that the villagers would more than double their yearly income if they could harvest a second vegetable crop. Again, Khun Bangkok led the way through the calculations. He had a very gentle, though also boisterous, way of leading the discussion. He made certain not to perform any step on his own, nor to continue before everyone said they were clear about what was the meaning of the step just taken.

We asked for the acreage (or number of *rai*, using the Thai measure, where one rai equals about four hundred square meters). He then asked what they would like to plant in this area if they could plant another crop after the rice harvest. There were several suggestions, but, as a group, they decided that growing cucumbers and cabbage would be

best. When asked their reasons behind this choice, they responded that the price was good. There did not seem to be much consideration of what might happen to the prices of these vegetables if they added to the supply. Indeed, this appeared to be a common trend. Decisions were rather immediate, without looking at the next steps that might occur based upon the initial decisions.

The villagers, seemingly without exception, knew by heart their acreage, the prices of crops, the cost of fertilizer, and their total costs and total revenues per growing season. As other work in other countries has demonstrated, they had the mathematics that they needed to work [Nunes and Bryant, 1996, Nunes, Schlieman, and Carraher,1993]. But the math did not seem to extend beyond the immediate needs. They were not familiar with working on hypothetical scenarios to calculate the relative benefits for decision making. The math needed to do this was not different from what they did to know their yearly situation.

One rather surprising point emerged in this discussion. The national government allocates a certain amount for the village to spend for the year's projects. The new constitution alters tambol governance (tambol, sounding like tam-bun in English, is a designation for village although what constitutes a village differs to the government and to the villagers). Currently there is the local headman and a village council (known by its acronym, OBT, pronounced aw-baw-taw) that should continue, although their selection process and national role changes.

The amazing point is that there did not seem to be any consideration of the results from projects other than having something concrete, in particular roads (although also things like telephone lines or dams), to show at the end. However, the budgeting process seemed overwhelmingly political in its determination of relative allocations. What project would receive money was a function of who it would help. Whether it would provide a greater benefit than some other project was never considered. Benefit was never considered in any project as a factor for making decisions. Cost-benefit analysis may have its shortcomings, but ignoring benefit completely also is not a good method for rational, equitable, and effective decision making.

There was also an emphasis on what people called *hardware*. That is, tangible objects made it appear that the government was providing real results to its constituents. However, this meant that many potentially important projects that would contribute to the social good, such as education, providing clean water, and so on, were ignored. There also were problems with corruption. We learned later that the headman of the village that trucked in water for three months of the year received a percentage of the payment from the company that provided the water. Thus, he had little incentive to solve this problem. Bringing transparency to the issues involved, making explicit the costs and benefits from alternatives, and providing open group discussion about problems, plans, alternatives, and then deciding collectively with as much data as possible, as we were doing in Project Lighthouse, potentially helps reduce such corruption.[8]

[8] Although, in the spirit of full disclosure, coincidentally the morning of the village meetings, I read in a Thai newspaper an article with the headline, "Body of Researcher Found in River." The river was in the province in which we were currently working. This made me less comfortable about attacking this problem first. The cause of the murder, apparently, was that the night before in a bar, the researcher had insulted

These considerations highlight the multiple, simultaneous aspects upon which we had to make decisions. Ours is a learning project, but we believed they would learn better when working on projects of real importance. We could not know in advance what their choices might be. Thus, here was another example of why we could not have provided the five-year curriculum for our project in advance. The projects would vary from time to time, place to place, and person to person. Our principles and mode of working, however, remain constant. We wanted the projects to be their choice, but also to be tractable, to not be too difficult initially so that they reasonable could solve them, to have connections to important bodies of knowledge, and so on.

The principle we applied here was to surface real projects collectively upon which to work. A fundamental component is that this had to be the villagers' choice. We knew they could not make such choices without our input because they did not yet know the affordances and constraints of the technology. They could not yet have knowledge about what was and was not feasible to attempt. Our role was to assist them in this, all the while making our choices as explicit as possible as it was also our aim to have them become self-sufficient in this role.

None of us assisting in the project truly knew beforehand how to solve any of the problems they chose to address. Rather than being a negative, we thought this was positive as we would all learn together. Another essential principle within Project

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some military officers. It did not seem to be connected to his research. Still, the potential for violence was an undercurrent as the project was potentially disrupting and altering the existing power relations.

Lighthouse, and indeed is also expressed in the goals for the future of Thai education, is to learn how to learn. With an ever-changing world changing at an increasingly rapid pace, no one knows what the future holds or what skills and knowledge will be useful. Thus, for everyone, learning to learn is crucial. Nowhere in typical School is this addressed, nor do typical students get the opportunity to see their teachers and leaders learn. In these projects we would all learn together. How we would go about learning serves as a strong, concrete exemplar for the learners.

Both the villagers and the rural teachers developed the project together. We formed groups so that an NFE teacher somewhat experienced with both Logo and the approach to learning in Project Lighthouse would team with an NFE teacher from BuriRam since they had no experience. Together, they would work with the villagers on the project of the villager's choosing.

One quite wonderful and unusual aspect to this was the mixture of people working together on the projects. We not only had a mixture of teachers, NGO staff, and villagers, we also had a mixture of residents from different villages. We also had a mixture across generations. Wide ranges of villages, from grandparents to the young children who played with Logo after school, collaborated on building the projects. Often, the elders would not do so much on the computer, leaving that to the young adults, teenagers, and children. Still, they remained involved in the project, guiding the direction and helping to make decisions. Here again was a demonstration of a social-constructionist approach [Shaw, 1995]. We did not lecture them about the benefits of collaboration across

generations or among villages that often have less than harmonious relations. Rather, they came together to construct projects of value to all. The social benefits were subtly present, but real.

I chose to take a supporting, mentoring role. I decided not to just do the project myself, believing that the only sustainable benefit would be for them to develop the package of skills themselves. To me, this was a critical design point, where the choice of action is not exactly clear.

We had calculated that building a dam to create a reservoir would at least double the per-family income in the village. This is considerable. The dam project had failed each of the prior two years. Thus, it was not as if this was proceeding properly on its own. Clearly, there is a short-term advantage to building the dam. If either I, or any other outsider, designed it, contracted for it, and supervised its completion, a significant increase in resources to the villagers could occur.

On the other hand, there are some deeper issues than just the construction of the dam. The villagers initially wanted the technology to help them gain more control over their lives. They did not like how outside experts had treated them in assisting with other issues. The primary cause for the dislike was that the outsiders did not help the villagers gain knowledge about or control over their situation. Rather, the outsiders made a determination and took action, leaving the villagers disempowered. Moreover, even if an outsider solved this particular problem, where would they be when they faced the next,

and inevitable, problem? They would still be in the subservient position of having to rely on outsiders. This clearly is not in their long-term interest.

I also drew on the example of the World Bank study of the project the bank funded to install water pumps in extremely poor countries [Narayan, 1995]. The benefits of such a project are obvious. Clean water helps reduce disease. Having mechanical pumps would save the local people a considerable amount of time they otherwise would have had to spend walking to a stream and hauling the water. Still, in more than fifty percent of the sites where they installed pumps, within one year the pumps were no longer functional. The technology of water pumps is quite simple and well-understood, yet the failure rate is overwhelming. The World Bank surmised that the primary cause for failure was the lack of local involvement in initial decision making. When the planning, decisions and ownership of the project was held by outsiders, the pumps failed, were unused, were not maintained, or were vandalized. When the local people championed, owned, and helped make decisions about the project, then the project succeeded. This example provides a strong rationale for me and the other outsiders to take a supportive, not an ownership role.

In this case, and in the project as a whole, there is an issue of paternalism. We did not want to be in the position of placing the villagers in a subservient role, where we know better and only feign to let them make decisions. If the above reasoning were only carried out by me, without the involvement of the villagers, then this would still be a case of paternalism, and would still tend to disempower them. This is the case even if I firmly

believed my choice was in their best interests. However, we were working in Thailand, and the invitation of local people, because we had some expertise to which they wanted access. This expertise was in learning and technology. If we kept this expertise to ourselves and enable an *anything goes* atmosphere, then we would be neglectful in a different sense. My decision was to attempt to make every issue as explicit as possible through open discussion. As we were deciding as a group what projects to attempt, I expressed these thoughts about what role I should undertake.

As a group we decided to focus on a limited number of projects initially. We reasoned that we could not attack every problem simultaneously as there were not enough of us. In addition, August is the time to plant rice. The villagers needed to spend the bulk of their time preparing the fields, planting, and cultivating their rice crops, as this was the primary basis for their income for the year. The villagers and the participants from Project Lighthouse began devising ways to collect and maintain fresh water. PDA had already initiated a program with the villagers where they made large ceramic containers, placed metal sheets on their roofs, and directed the flow of rainwater over the metal sheets into the ceramic pots. This would hold the rainwater for later use.

We chose the following projects:

- design ways to create reservoirs to maintain the water to irrigate their fields
- design dams to harness the floodwaters and connect to pumping systems for irrigation
- re-design agricultural field layouts to take advantage of the topography of the terrain to better support multiple crops

- develop decision support systems to guide diagnosis and treatment of problems with pests and fungi in the cultivation of rice
- Design new ways of conserving water and delivering water to the houses more efficiently

As in other Logo projects, the goal of the decision support systems was not only for the benefit of the others, but to help the developers themselves formalize and make robust the knowledge required to accomplish the project. There are four important aspects to each of these projects.

The first is simply the accomplishment. Creating these projects will improve the lives of the people. The second is the knowledge required in order to accomplish the project. They can apply this knowledge on subsequent projects and efforts. This is truly the only sustainable development. The third is the process of deciding what issues to address collaboratively. The process of determining projects for the common good collaboratively puts them in an active agency with their environment and positive relationship with each other. Finally, there is the empowerment and satisfaction from accomplishing difficult real-world tasks. Such accomplishments, more than any verbal encouragement, go furthest towards developing positive self-esteem and role models.

Beginning with the dam project, we went out to inspect the area where the dam would be. They told me we were going to the river. As we were walking through a field, everyone stopped and began looking around and taking pictures with our digital camera. I asked

why we stopped. They told me we were at the river. Since this was the dry season, there was no river, just a flood plain. This highlighted the reality of their situation. It also made it much more difficult to envision how and where to place a dam. The locals told us how and where the water usually flowed. They pointed out to which point it usually stretched, although of course this varies depending upon the strength of that season's rains. We had decided to photograph the area, upload the images on to our computer's back at the CBird center, and begin our design there. We also inspected the locations for the other projects, questioning the villagers about problems, circumstances, past efforts at remediation and improvement, and so on.

As we showed people how to upload the images from the digital camera, we discussed possible paths for the software aspect to the project. We decided to create maps of the area, lay out potential solutions, simulate the different probable results, calculate which would choices be better, and then use that design as a guide to the construction.

Interestingly, neither the villagers nor the teachers knew how to create a map. When we asked which way was north, no one knew. So, we asked which was east, figuring that they would know that by the rising of the sun. Again, no one knew. I later found out this was even more surprising, as the word for east is literally sunrise. When we asked where the sun rose, everyone knew and pointed that way. We all laughed when the fact that sunrise and east were the same words, yet no one knew east but everyone knew where the sun rose. This was yet another example of not having access to a taught, but irrelevant fact, while all knowing the underlying concept.

While the fact that the villagers could not make a map might not be surprising, the teachers could not do so either. More importantly, knowledge of coordinate geometry was not at hand either. The powerful idea of drawing axes, marking units of length along the axes, and determining distances was not in their repertoire of ideas to use in representing the area. They had certainly taken school courses and passed school exams on this type of knowledge, yet in practice they could not do this. The impact of this is critical. It relates to the findings of Lave in other situations where people did not use their school math [Lave, 1988]. People legitimately question how we will determine the learning of students within our reform efforts. Yet, the other side of this question goes unexamined. There are many findings where despite passing school exams on the underlying knowledge, people could not or did not use it in real world situations. I will return to this theme briefly in discussion about the dam project.

Making this concrete, tangible, and manipulable was critical towards successful comprehension. Where the nature of the computational technology truly provided a benefit not possibly gained from other media was by enabling the proposed solutions to be shareable, dynamic, contextual, interactive, and easily alterable. Perhaps most important was that the solutions were a powerful expression of their own ideas.

Together, the teachers and villagers created accurate computer representations of the areas, preserving distances, maintaining relationships and ratios. For clarity, they created various views at different scales, providing views that zoom in and out. They calculated

the relevant distances between important objects. They used this to help determine situating the dam, determining the best methods of irrigation, and combining this with the projects for water flow for the entire village.

At the end of the first day, immediately upon creating the maps, we discovered a costly mistake repeated each of the past two years. They had been building the dam in the wrong place! The original location benefited from natural terrain to create the reservoir. However, it was about two kilometers from the village water pump used for irrigation. Once they constructed their own map of the area, they realized they could not create a reservoir large enough to cover the distance to the pump. Even if the dam had functioned properly, it would not have provided the expected benefit, as it was prohibitively expensive to re-locate the pump and the irrigation hoses.

One cannot underestimate the importance of this. In each of the past two years, they wasted a considerable amount of very scarce resources on a project that was doomed from the start. The villagers had not realized this. Even the experts who had tried to build the dam did not discover this. Yet, the villagers and the NFE teachers, both new to the problem type and the technological tools, learned this on the very first day.

Active collaboration among the residents was one of the essential lessons when the World Bank sponsored the introduction of water pumps into rural areas. The rationale behind their introduction was that the water pumps would not only help health matters, but would also leverage many other gains as people would spend less effort walking,

carrying and hand drawing water. This would free them for other more productive activities. However, although everyone needs and appreciates having clean water, the water pump project did not go smoothly or successfully in every area, and actually failed in a relatively large proportion of them. At some sites people refused to change routines to use the pumps, often because they were poorly located. At some sites they fell into permanent disrepair. At other sites people simply vandalized and cannibalized them for parts. While of course the situations are not exactly parallel, we are able to say that despite working in areas of poverty, there has not been a single incident of theft or willful destruction. Nor have people allowed the equipment to fall into disrepair despite difficult climate and infra-structural conditions.

Early in the morning of the second day working on the projects, the wife of the village leader and a friend came to see Khun Bangkok and me. They brought fried, sweet rice cakes with them for us. They were extremely dense and oily, and not the sort of thing that I, or Khun Bangkok, would normally eat. But since they had gone to the trouble of preparing them especially for us, we thought it might be insulting not to partake. So, we ate and listened to what they had to say.

They were very apologetic and asked for our indulgence. They said that they were just "simple villagers," and were not capable of attempting such ambitious projects as designing a dam. They thanked us for our concern and interest, but they felt this was beyond them.

After the seemingly successful meeting two days ago, combined with the discovery and progress of the previous day, this statement caught us by surprise. We had to decide on the spot what to do. On the one hand, we firmly believed that they had to provide direction about the project. We should not impose our wishes upon them. On the other hand, we believed that this oft-repeated view of themselves as "simple villagers," incapable of serious work was a symptom of many things, including the rural educational system. If our project was to succeed, then we hoped these self-images would change.

We continued our conversation, gently probing for reasons behind it. We told them why we thought it was important. We told them of our confidence in them and why we believed this was within their grasp. We pointed to the incredible progress made so quickly. We believe, and this belief is consistent with past work, that the best path to changing such negative images of self-intelligence is to work on projects that extend beyond what one thinks one can do [Cavallo, 1996a]. Only after successfully accomplishing more than one thought one could does this image change in a significant and solid way. Therefore, we hoped that they would try these difficult projects. We were dealing with a paradoxical situation. Insisting on continuing detracted from their control and initiative. Allowing the project to drop would lose important momentum and delete a potentially empowering project.

We also told them that we believed it would be essential at some point to call in experts in dam construction and water management to assist us. Considering how the project failed with experts previously, we wanted to be at a stage of knowledge and confidence,

so that these experts would consult to us, under our control, as opposed to dictate to us without our being an informed part of the decision making process. Given that at some point we would get experts to verify the practicality of the designs, would they consider allowing the project to proceed? They agreed, although we knew we were possibly losing the balance we desired between their control and our forcing them, no matter how gentle the manipulation might be. So, we continued.

As the design for the dam and reservoir progressed, it became apparent that a reconfiguration of the arable land was inevitable. This raised new issues. The villagers divided the village's farmland into family plots. Each family has a fair share acreage on which to grow their crops. Creating a reservoir would alter the configuration which has been in place for years. If nothing changed, a few families would lose their land for the benefit of others. How would they deal with this situation?

As was becoming customary, there was a discussion. After a period of time and a number of proposals, they settled on a monetary compensation plan for those who would lose their land. They also ensured that those that lost land would still have other land on which to farm. It appeared that everyone was satisfied not only with the plan, but also with the fact that they solved it relatively easily.

What was also changing was a new spirit of cooperation and activism. They were not waiting for and relying on outsiders to solve problems for them. They were taking charge themselves. They also were focusing more on the overall benefit rather than trying to

maximize one's own. This realization itself had a positive feedback effect. However, the changing of values, just as the changing of learning, was occurring not by lecture but rather through working on projects.

Another key element was the integration of various fields into the projects. A School approach is to separate the subjects into discrete units and then further separate the knowledge within the subjects. In this case, the work was on projects, both large and small in scale. To succeed at constructing the projects required that one touch on various fields. There is math of various subtypes, science, engineering, and often language and history. Moreover, there are elements of ethics, rhetoric, and social studies. They are bound together in a coherent whole, where often the various parts support one another. This provides context and relevance for the math and science. It provides value and meaning. The result is that the villagers who left school dissatisfied worked their way through many difficult, unfamiliar fields in order to bring their projects to fruition.

The mathematics of this project is not simple. They applied various branches of mathematics in order to solve the problem. None of the participants had what the grammar of school would consider the knowledge prerequisite to the math they did. Yet, rather than making the project impossible, the so-called prerequisite knowledge was applied in the context of constructing their projects.

There is a lot of mathematical knowledge required to determine how much water was needed to grow for how big an area of particular types of crops. They measured the real

space. As real terrain is not as neatly configured as pencil marks on paper, the measurement and calculations are also not neat. They had to know what was critical to maintain and what they could smooth. They had to create maps based upon their measurements. As they were constructing the maps on the computer, they decided to create various views. They therefore had to maintain proper ratios and relationships among elements. They used coordinate geometry to determine distances and layouts. They used variables and algebra to calculate. They wrote formalisms in their programs to manipulate their objects, maintain accuracy, and create meaning. They used various symbolic representations to make their work consistent and functional. They built mathematical models to run simulations to help determine the best choices. They had to calculate area based upon the real measurements. They had to determine the density of crops within their farmland. They then needed to determine how many plants they could support and the volume water those plants required. They had to figure out how deep a reservoir they needed. They knew that this would not be constant as water evaporates at particular rates depending upon climate. Water also seeps into the earth. Since the ground was not level, they had to determine where and how to level it and where to dig irrigation ditches. Leveling and digging requires renting machinery which costs a substantial amount of money. Determining the site depends upon factoring the costs of the various plans with the benefits of best yields. They needed to calculate the various costs to provide the data upon which to base their determination.

All of this is serious mathematics. Yet, these same people who did not feel competent at math, who left school as soon as possible, whose experiences of math in school were

problematic, worked their way through these problems in Logo. Certainly we were there to help them through this process. But, as noted earlier, for sustainability the main work was theirs, not ours. They really did the design and construction of the simulation project. Moreover, these were just the first projects. Assuming that our project will continue and expand, which it appears it will do, they will continue to work on projects of this nature. Clearly, they will deepen their experiences by having more projects with which to make more and deeper connections. Seeing an idea once and using it is one thing. Seeing it repeatedly, using it in a variety of circumstances, provides its power. Working in this manner, they were developing a fluency with mathematics, and mathematics on the computer rather than just with pencil and paper. They were becoming fluent with the ideas, able to express and communicate their thoughts, and use math and computation as a means to understand and address each other and their environment.

The role of the computer is critical in a number of aspects. The issues are inter-related so it is not possible to untangle them. However, it is clear that while our approach would have been better than their school experiences even without computers, our approach would have suffered without the computers as well.

Computational tools allowed simulation, collaborative joining of various parts of the overall project, graphic representation, individual expression of the ideas, rapid cycles of expression, operation, reflection, and debugging, dynamic manipulation of symbolic expressions, and working on large projects in pieces. One also cannot underestimate the fact that working on computers makes one feel connected to the modern world. Building

on the computer may not be cognitively more difficult than many other things people do every day. Yet, they value the work on the computer in a way they do not sense satisfaction from other activities. People believe that if one can build things with technology, then one must be smart. This claim is disputable, but in some ways its truth value is irrelevant. Simply because people feel that way, it is empowering, and that is good.

Another important aspect is that people *have fun* while they are doing this. There may be times they are frustrated. There are certainly difficult times. However, we try to create an ambience that is light, supportive, and fun. We hope to demonstrate that learning can be one of the most enjoyable experiences in life. And, since the process was both enjoyable and meaningful to their lives, they put in the work and developed an understanding of knowledge domains that School emphasizes. Yet, in the typical School presentation, these villagers did not stick with or enjoy the subjects. This contributed to their lack of belief in their own intelligence. This is what was being reversed within Project Lighthouse.

Our use of the computers also runs counter to most trends in educational practice. We emphasize construction and programming. While we use a variety of tools, our initial focus in the overall project as well as within individual projects is to program. Many educators now feel that programming is too hard, and prefer to emphasize *end-user programming* [Nardi, 1993, Williams and Begg, 1993]. In end-user programming, the tool is specific to a particular class of problems. The learner is the end-user, and changes

parameters in the environment, or, as in the case of Excel, supplies values and can add functions. In any event, the educational design is to minimize the chances of being lost or going wrong by limiting the expressiveness in the environment. This is not due to any bad intent. Rather, it is fueled by a belief in doing as much as possible to not let things go wrong combined with a worry that the quality of teachers is not high enough to successfully carry out work in open, less constrained environments.

Just as we have demonstrated how our approach can be successful when working with students who have not done well at school [Cavallo, 1996a], this approach can also bring out the best in and help develop the expertise of teachers who have not been held in high esteem. It does take a different set of skills and attitudes than does lecture-style classroom teaching. And in order to develop these skills, we must give teachers the time, opportunities, and support necessary. Still, the successes in BuriRam, Lampang, Mae Fah Luang, and Chiang Rai provide and existence proof of the possibilities.

Also important to note are the differences between our approach and the problem solving, the word problems, and the concept of project in typical School. Making calculations based upon measurements, setting up formalisms and equations, using algebra and geometry, making maps, drawing to scale and adjusting scale, and using Cartesian coordinates, and so on, were all foreign concepts, even if they had been covered in school. The vast majority of those working on the projects had left school after only four years. The children who joined us likewise had either quit or were totally alienated by and disenfranchised by their school experience. The math they had learned in school was

not a useful tool. However, everyone managed the underlying mathematics in the context of the problems they had chosen.

As the design project continued, we observed how the efforts of some of the villagers were exceptional. In a later interview, one of the villagers, Denchai, told me that he did not do well in school. He did not like it at all either as he felt the punishment was too often and too severe. He did not act up in school so the punishment was not for misbehavior. Rather, the teachers inflicted it for anything not to their liking. Denchai left school as soon as it was legal. Outside of school he played soccer and helped his family with the farming.

Given his behavior in our project, it was hard to imagine Denchai in trouble for anything. As participation in our project was strictly voluntary, Denchai did not need to show up or to work. Yet, he cheerfully came and worked diligently every day. When I asked him why he continued to come and work so hard, he said he felt it was very important to help his village and he saw these projects as crucial in improving life there. He also thought it was personally important to develop expertise in working with computers. Plus, he said it was fun.

What was so striking was that Denchai had quickly become a quite adept computer hacker.[9] Atypical of many of our experiences with more educated people, Denchai, similar to others who participated in Project Lighthouse in other parts of Thailand, dived

[9] That is, in the positive sense of hacking.

in and figured out how to build the projects he wanted. If something did not work, he was not daunted. Rather, he debugged the system and worked until it was satisfactory.

I was particularly awestruck when I observed Denchai adapt code particular to his project. I was developing a small Logo application to draw various types of graphs based upon entry data. The idea was to help support budget decision making for the local tambols. Denchai does not know English. Yet, he would observe the functioning of my program, and, if there was a particular effect that he liked, he wold inspect the code, and adapt it for his own projects.

He would find a command that he did know within the language. Even though I never explicitly taught lessons on syntax, by the structure of the code he could determine what was a function, or an argument, or a variable. He would look through my function definitions to understand how they worked, and what was creating the effect in which he was interested. He would then transpose the work to his own projects, not merely copying code, but applying the underlying concept to enrich his own work. This is excellent no matter what, but considering he could do this without being able to read the English, know the words the mnemonics represented, nor even choose to question me through a translator about what something meant, this ability is remarkable and truly something special!

This was atypical of my experience in Thailand with teachers. At other times I had observed people merely copy my code verbatim without thinking of the overall context or

the differences between what I was doing and what they were doing. This happens when people are unfamiliar with programming and cannot yet tell the difference between background context and the actual programming construct for them to adapt to their own project.

While individuals are working on their projects, it is common for someone to get stuck and ask the workshop facilitator what to do. For example, if someone wants to achieve a particular effect, they will try, not succeed, and then ask how to perform the task. I have a heuristic not to just tell the answer unless I feel the person will become too frustrated and quit. I believe that if I answer the specific question, the person will not engage in the thought process deeply and will merely proceed. I endeavor to step back, engage them in a discussion about the situation, debug it with them collaboratively, and hope that they can see their way towards deriving the answer. My goal is to have the person generalize both the process and the particular answer. If this succeeds, then the next time they will not need the assistance. Often, in order to do this, I set up a structurally parallel situation so that solving the problem in the parallel situation, or seeing the commonality overall, will help the person to determine the general principles.

However, in workshops in Thailand, I later discovered that at times people had copied the parallel situations I had set up only to provide a context for the examples. Perhaps mistakenly, I had not paid proper attention to the context examples, simply providing function without due attention to overall programming concepts, structure, and heuristics, let alone paying attention to aesthetics and elegance. I was mortified when I saw this as

people had copied my code letter for letter rather than concept for concept. As they were beginners, this was hardly their fault and clearly was mine. They had not yet had the opportunity to distinguish between form and substance.

Yet, Denchai, despite not sharing my language or that of the programming environment (at this time we were using the English version of Microworlds), with far less education and even less programming experience, never made this mistake and could figure out the constructs. Later in that same day, I noticed him going through the on-line help vocabulary command by command. He would find the command, look at the code example provided, and then try it in his own project. In this way, he was teaching himself the language.

This clearly is someone with considerable intelligence. How he did not do well in school is clearly not from a lack of ability. When I inquired about his interests and background, he too had worked with engines. After leaving school, he moved to Bangkok to help earn income for his family. After his first job, he then worked in a motorcycle parts shop. He told me that by listening to the diagnostic dialog between the manager and the people come into the shop, he was able to learn how to diagnose problems in the engines. He would practice on his own and other bikes.

Like Ae, Denchai developed the sense that he could figure things out. By learning how to build and repair engines, and by working on the farm with few resources, they developed a *bricoleur's* spirit. That is, they would make what they need with what little they had. If

something did not work, they fixed it. If they did not have the right tool or material, they improvised. They took this spirit and applied it to computational technology.

Through further discussions, we found that many people were aware and proud of the mechanical expertise and innovation among rural Thais. One of the local NFE teachers, in fact one of the few that actually came from a village, also worked a lot with engines and farm machinery. They took me to visit their farms.

From the dirt roads of the villages, everything looks as one might expect. The houses are simple. There are some simple barns, some in disrepair. There are the farm fields. However, I was fortunate enough to have local guides who led me into the barns where I quite astounded by viewing little mechanical wonderlands. The barns were filled with various types of simple, indigenous machinery and systems for working on them.

At the farms everyone who could used a small Kubota diesel engine to power a wide variety of local technological contraptions. Indeed, these Kubotas (where the Thai pronunciation puts the emphasis on the last "a," as in Ku-bo-taa'), are ubiquitous in Thailand. They used the little motors to power rice mills, well-water pumps, irrigation pumps, one-person tractors, field vehicles, and even lightweight trucks. The barns contained little pulley systems for lifting the motor from one device to another. The logic of each machine was open and obvious. Upon a relatively quick glance, one could determine the causality of the mechanical constructs.

Figure 1--rice mill in barn in Nong Baot

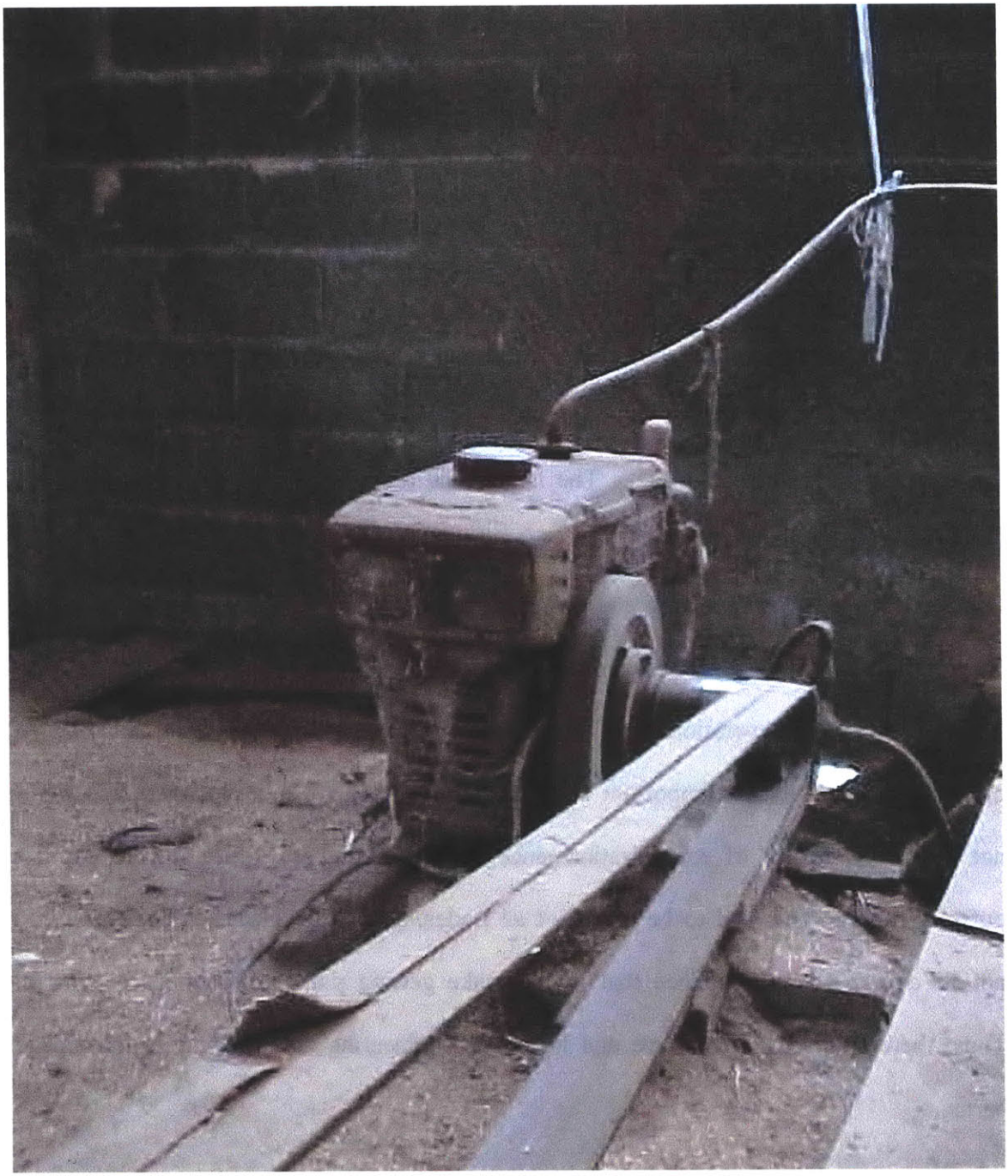

Figure 2--kubota motor driving rice mill

The innovation and creativity were remarkable. The utility was tremendous. They had taken objects for other, often quite specific, purposes and combined them in a general-purpose melange particular to their needs, resources, and budgets. The experience and expertise of those who worked with these engines and devices were quite impressive.

The small one-person tractors were particularly impressive. People could not afford large tractors. Rather than having to plow by hand, the Thais developed a one-person tractor that could house the little Kubota, which would power the plow.

Inside some barns were rice mills. The large mills too were powered by the Kubotas. Unlike much modern technology, the functioning of the machine was open and apparent. One could easily see the system and its causal logic. There are several apparent reasons for this. One is that this openness facilitates repair. A second is that this makes it easier to learn this machine's operation and, by extension, the mechanical principles to apply to other machines. This was important because everyone had to be a generalist and could not afford the luxury of specialization since there was not any other way to pay for outsider experts. One had to be a jack of all trades. Third, the machines likewise could not be overly specialized since that would make getting parts prohibitively expensive. Thus, there was some innovative and ingenious engineering hidden away in the village barns.

3.7 September-February, 1998-9

After I left BuriRam, the work continued with difficulty. This was primarily due to the fact that there was no one there to facilitate the effort. Tragically, the woman who was in charge of the NFE office died due to injuries suffered in a motorbike accident. Unlike

many people who work in large bureaucratic organizations, she was very innovative and took considerable initiative. She was truly dedicated to the people of her region, and worked diligently to improve education. After her death, the teachers with whom we were working in the project were transferred to other duties. We thus lost the continuity of effort. No one familiar with the educational methodology or the technology was available to work on this project. The PDA staff had other obligations. Thus, the effort here hit an unfortunate and disappointing roadblock.

Khun Bangkok came often to work in the area. A new NFE supervisor was selected who re-committed personnel to our project. The Suksappatana Foundation hired a few recent KMUTT graduates from the Information Systems (IS) department to work on the project. KMUTT staff came to run a few workshops to help familiarize the new staff with the ideas and technologies. Still, despite these efforts, there was a gap in the projects we began in August, 1998. This setback naturally affected the villagers, who, while they were still cooperative, were not yet self-sufficient to continue unaided. The dam project stalled. Denchai continued to work, but he followed the lead of the others at the site and did not continue the real-world projects. Rather, he helped tutor the younger children on working with Microworlds Logo.

Surprisingly, the KMUTT graduates with degrees in IS had not had the opportunity to really program while they were studying at the university. Although they studied computers, their courses were all lectures. Their homework was with paper and pencil. The only programming required was a short senior project. Both of the graduates working

with us did small projects with Excel. Thus, they never had the opportunity to program. Yet, they were certified for their *knowledge* of Information Systems.

This lack of real experience is clearly not their fault. There are numerous reasons for this situation. This is not just due to a privileging of the fact-based School grammar over practical engineering experience. There are insufficient resources to provide all students with adequate computer time to work on projects of significant size. More insidious, many of the teachers have had no real experience either. When the economy was good, the majority of the better students would take jobs in private industry, as the pay was significantly better. The next level of students remained to teach. But often they had no opportunity to program and engineer real projects either. This created a vicious circle.

However, while we needed people with programming experience to work with the villagers, there was no one available. Still, the project did not stagnate. Khun Bangkok and his crew used what the tools with which they were familiar and kept the constructionist and technological focus. They thus shifted to work with the local ladies' cooperatives in planning and implementing new business ventures.

This switch of tasks and the reasons behind it are extremely critical, however. When we first discovered and settled upon doing the dam, irrigation, and agricultural projects, there was tremendous excitement and hope. People naturally were extremely excited about the prospect of doubling their income. They held considerable trepidation as they knew this project had failed each of the past two years, that the project was complex, and that they

felt inadequate to tackle such a difficult project as they were "just simple villagers." Still, after the initial reluctance, they were willing and participated diligently on the project.

Nevertheless, people, including those working for Project Lighthouse, discontinued the dam project. Why would this be the case? Why would the villagers stop when the math showed that they could double their income in just one year? Why would the Project Lighthouse staff stop when there was such a promising beginning, when it could have such important and tangible benefits, and when it could truly establish the validity of the overall project?

The easy answer is that the fear and uncertainty was overwhelming to all. The villagers still felt incapable of accomplishing such a difficult project. The Project Lighthouse staff felt too unfamiliar and non-fluent with the technology, the methodology, and with working on such open-ended, large-scale projects. Significantly, this was the case even though they had just graduated with degrees in Information Systems. Still, in all fairness, they had never been required to attempt such projects, or even any open-ended, non-trivial, non-classroom tasks. Thus, what could have been a momentous accomplishment was deferred though fear.

This raised the issue of preparation. In our proposal we emphatically declared that the staff should have a minimum of six weeks of workshops combined with six weeks of working on their own technological projects before beginning work with learners. The idea was to have them have a chance to develop their own skills and technological

fluency. While this still may have been insufficient to successfully finish the dam project, its lack undoubtedly doomed this, and probably any other serious project.

In every project on which we have worked, we have strongly urged the administrators to allow the staff to devote a significant amount of time to preparation. In every case the administrators refused, albeit politely. The rationale was always funding.

This, however, is the epitome of penny-wise, pound-foolish management. While they saved money initially, they lost the benefit of a better skilled workforce. In the case of the dam, less than one year's results would have more than paid for the extra development time. In the case of Project Lighthouse, such a significant result would have justified its existence and appropriation by others. Even still, Project Lighthouse has demonstrated and justified its approach. The dam would have proven the validity beyond any doubt. With sufficient time and resource, where that resource could have been the time of just one experienced and technologically fluent person, the villagers could have designed and managed the construction of the dam. This would have led to a second crop. While we would never allow a textually illiterate teacher to gain such a position, we are not yet accustomed to thinking of the necessity of having technologically fluent, or even mathematically or scientifically fluent, staff.

Fortunately, even thought the staff and the villagers dropped the dam and irrigation projects, they did not quit either. They worked with three cooperatives in Nong Baot. As we did earlier, they began with brainstorming about possible activities. One group,

impressed by the price of mushrooms at the market, decided to cultivate mushrooms. Another investigated alternatives to selling the low-grade rice in bulk. The third looked to vary their crops to grow vegetables.

The group growing mushrooms pooled all of their money, went to a vendor, and purchased all they could of one variety of mushroom. They chose this species because it fetched the best price in the market. They had the men of the village build them a hut to house the plants.

Typical to this area, the men did the necessary carpentry. There again is math involved in the construction. They had to build to the specifications of the women. They wanted a particular size to house their plants. The roof had to be of a certain angular construction. The men pulled this off flawlessly. Yet, upon my questioning later, they did not consider this to mean that they were good at math. They felt themselves inept at math. What they did was not math. It was carpentry.

Their project began beautifully. The first mushrooms came in nicely. They sold them easily for a good price. Soon, their project declined. The mushrooms at the bottom of their racks soon developed a fungus. This spread upwards throughout the whole crop. None of the mushrooms could be salvaged. No new ones grew.

Khun Bangkok arranged for an agricultural expert from Siam Cement Company to consult with the ladies group. The Siam Cement people explained that since they began

the racks from the ground, the fungus was inevitable. They advised them to begin about a half meter above the ground. They also advised them not to grow only one type of mushroom. They would achieve a better cash flow if they grew different varieties, as the different ones would mature at different rates, providing a steady flow of income and not overwhelming them with everything ready for harvest at once. The women took the advice and began again.

Khun Bangkok and the KMUTT graduates, Nan and La, continued to work with the women with Excel. The women had begun other business ventures prior to their involvement in Project Lighthouse. Most ventures failed. But when Khun Bangkok inquired, they did not know how much they had spent on which ventures, and the relative success and failure of the various efforts. They worked with them in Excel, showing how to track expenses, plan budgets, create formulas, try hypotheticals such as varying price to see effect.

When I met with this group, the leader of the group told me that in the past numbers were just floating in the air chaotically. As she told me this, she waved her hands around in a whirling motion. She explained that now with Excel she can pigeonhole the numbers and they have meaning. As she said "pigeonhole," she jabbed her finger sharply. She told me she felt quite proud of her new, mathematical expertise. She said she was ashamed that she had quit school after four years and was uneducated. She felt this meant she was not intelligent. She was now changing this view of herself, and felt quite confident about the group successfully attempting new ventures.

The rice alternative group had a similar experience. The farmers typically sold all their rice. The different grades fetched different prices. The low-grade rice barely paid anything at all, around five Baht (eleven cents) per kilo. The price was so low people barely paid attention to its sale.

After some quick financial planning with Khun Bangkok, this group decided to make rice cookies and a small rice waffle out of the low-grade rice. Khun Bangkok worked with the women until late at night as they spent the day working. After about four hours of work with Excel, the head woman said her head was hurting from all the thinking, apologized, and asked permission to go to bed.

The next day, the woman appeared very tired. Khun Bangkok worried that he had pressured her too much. The woman said no, it had been one of the best nights of her life. She said that she could not sleep that night, thinking about how she had not accomplished to the level of her potential. She vowed to continue working and learning, for her benefit, for her family, and for her village. She too felt incompetent at math, but now was seeing how she could use it and how she could gain competence.

Interestingly, her daughter and family lived nearby. After these discussions, she decided to open a small shop in the village to provide groceries and household products. She created her own interesting bookkeeping method. Rather than entering the change into her ledger, she omitted it. She did so because she felt the calculations were difficult.

However, her records were not inaccurate because she left the change in the drawer to begin the next day with change for her customers. She thus had a feel for some mathematical properties, as making mistakes with money were literally costly.

3.8 The Current Situation, August, 1999

The Foundation, the villagers, and indeed all participants in Nang Rong periodically reflect on the flow of the project and decide what to modify. For the past few months, Denchai has been away performing his duty to study as a Buddhist monk. He will return shortly. Khun Lynchee, the leader of the mushroom project, is now performing the role of a Project Lighthouse facilitator, helping others learn about Constructionism and how to apply it to projects in the villages. More KMUTT students have joined the effort in this region. They are new to Project Lighthouse, however, and are just beginning to learn the technology and methodology. Some of the more experienced students, like Nan, have re-located to Lampang in order to help the large effort there. Khun Bangkok continues to make numerous trips to the region to monitor the situation and to help.

The existing projects are continuing and new projects are being undertaken. More people are becoming familiar with the approach and with computers. People believe that there is a good understanding of Constructionism, but that the level of fluency with the technology is still quite lower than desired. Helping to develop this fluency is the current focus. While the project in BuriRam has not achieved all that was hoped for or all that was possible, it has achieved enough, both in actual projects and in how people feel about

what they have learned, that people continue to choose to participate. My hope is that they will successfully address the water issue this year.

3.9 Emergent Design in Context

The latent expertise of the people in this part of rural Thailand emerged through the constructionist use of computational media. Working on projects chosen by the participants facilitated not only their interest and participation, but it also facilitated the mobilization of this experience and expertise. Focusing on the development of technological fluency enabled the participants to draw from this knowledge and experience to express themselves in the new projects. By using an Emergent Design approach within the overall project, at each site, and with each learner (design all the way down) enabled this to emerge. It could be reasonably asserted that the new approach of Emergent Design, practiced within a learner-centered, project-oriented, constructionist learning environment facilitated growth and development in ways that prior educational environments had not.

Chapter 4 – Project Lighthouse Sites

4.0 Introduction

The previous chapter highlights the emergence of important elements that provide the foundation for powerful learning environments. The discovery of the engine culture and the entrepreneurial spirit of the women's cooperatives as a rich basis for connections and learning emerged through the applied methodology. This demonstrates emergence at the level of a particular site. This chapter describes activities at other sites within Project Lighthouse in order to demonstrate how the sites varied and how the development emerged in different ways. This also demonstrates how the project as a whole emerged and developed where the resulting positive differences were a source of strength not often exhibited in top-down approaches.

4.1 Mae Fah Luang

Mae Fah Luang is a region of Chiang Rai province in the north of Thailand. It is tucked up against the border of Burma. Non-formal education is quite prevalent there. This is partially due to the weakness of formal education in the area due to the usual reasons of poorly trained teachers and very small populations of children. It also is due to the lack of regard the residents have for the value of the existing schooling. Another major complicating factor is that a large majority of the residents are from hill tribes, for whom, for the most part, Thai is a second or third language (after their hill language and sometimes Chinese). A final reason, I believe, is due to the strength of the NFE staff in this area.

When we initially planned Project Lighthouse, although we wanted to have one pilot focus on village learning centers, we did not plan to include Mae Fah Luang as one of these sites. Importantly, and to the great benefit of the project, an experience in our first workshop at the Chiang Rai NFE center changed this. I, along with Savalai Vaikakul and Brent Ridley, ran a short, five-day introductory Logo workshop in late August, 1997.

Although the original project plan specified six weeks of workshops and combined with six weeks of project construction, due to numerous reasons but primarily administrative problems on the foundation side, this did not happen. As noted elsewhere, the failure to give sufficient time for staff to gain familiarity with both the technologies and the approach to learning severely curtailed the possibilities within the project. While often the decision not to devote such an amount of time to staff development is made for budgetary concerns, this is a short-sighted decision, saving money at the outset but losing money, and more importantly, diminishing results in the long-term.

Another problem, which we confronted often in the first year of the project, was over-crowding of workshops. We tried to specify that no more than twenty participants should attend any workshop. Our idea was that if there were too many people, the intensity and effectiveness of the immersion experience would be diminished. We also would be less able to support the participants in their projects and less able to get to know them as people, learners, and participants. This would hurt our overall mission.

This idea of ours ran into several problems on the Thai side. First, there was a not an unexpected expectation on their side that our mission was to teach a particular piece of technology. Such a process is familiar to people. In such workshops, many more people than we requested can be accommodated. Despite the fact that we said many times that our purpose was not merely to teach a piece of software but to learn it as a concrete path towards thinking about learning in a different way, people constructed a very different meaning. For a Constructionist point of view, this is not surprising in the least.

This expectation combined with another particularly cultural phenomenon and left us with a workshop with more than sixty participants, triple the number requested.[1] The other factor in the expansion of slots was the difficulty in refusing participation to people. As word of our project spread, many people and schools asked to participate. The people in the foundation felt that it would hurt relations if we refused them. We argued that the workshop would be too diluted and ineffective for everyone and to ask the others to wait until we could ramp up. We were told that things did not work this way in Thailand and that would cause more problems than it would solve. We tried to hold the line but this was a design argument we lost. We did not argue strenuously as we depended upon the local foundation to help us to understand many things that were foreign to us. As we were just beginning our relationship, we did not want to begin with a scenario of our dictating to our Thai hosts. This was especially true in this case as this area that had many cultural implications of which we were not aware. It is another example of a design tension where

[1] In fact, despite our requests and pleas, this situation repeated itself several times. We began to joke that there was a 3x-multiplier effect just as in projecting dates for developing software.

there is no perfect answer but one is choosing among various options, each with positives and negatives.

This dispute underscored a recurring design tension between going deep versus going broad. We designed Project Lighthouse to go deeply in a few places so as to have the deepest and broadest long-term effect. We design the technological-fluency immersion workshops under the same principle. However, there is a drawback in equity. If we did not try to involve as many people as possible, then others would be relegated to the same, inadequate learning environment. These people would feel they were missing out and not as special as those chosen. This can be dangerous for both sides. However, beginning or expanding too rapidly inherently has the danger of so watering down any experience that no one can receive the expected benefit.

The original goal of working directly and deeply with the staff of the Chiang Rai NFE center was lost during this initial workshop. Many of the staff did sit in on the workshop, but, because their center hosted the event, they had to perform other duties to help the other, often influential and powerful, participants. Obviously this negatively impacted their opportunity to learn. However, hosting the event did establish Chiang Rai NFE as the first and primary Project Lighthouse site, placed these influential people on their side, helped secure on-going support and resources for them, and thus facilitated subsequent activities. So, despite that it did not follow our original plan and intentions, it probably did function in the best possible way establishing our project in this culture. The

inherently unforeseeable nature of the above immediate deviations from the plan points out the necessarily emergent nature of the project.

Perhaps the best, and totally unexpected results from following this emergent trail, were meeting staff from other NFE regions. They were invited as favors to other supporters. Dr. Suchin, who was chosen by Dr. Kasama Varavarn, at that time the Director General of Non-Formal Education, and Dr. Sombat, the head of planning for NFE and one of Dr. Kasama's top aides, to come to MIT to help plan and schedule the overall project with NFE. As he became more excited about the project, he wanted his home site, Lampang, to be included among the pilot sites. Through connections to Khun Ackachai, the head of the Chiang Rai center and Dr. Suchin, Ajarn Jirachai, the head of NFE for the Mae Fah Luang sub-district, was invited.

Ajarn Jirachai's excellence in so many dimensions brought him to our attention immediately. He quickly understood not merely the Logo programming, but also the ideas about learning and the concept behind the project itself. He participated wonderfully in all the discussions. It was clear he thought a lot about learning. What made it advantageous for us to work with him was that it was clear we agreed on many important issues. His projects were interesting, deep, and well thought out. He helped all of his colleagues. He was extremely pleasant and friendly and had a joyful and playful manner. Lastly, he stood up at the end when some people wanted donations of software and equipment to take a stance about what was and was not important in this project. It

took no time at all to decide to extend the project to Mae Fah Luang, where he was the administrator.

This decision added to the project in several ways. Primarily, it added because Ajarn Jirachai is such an excellent educator and he and his staff did wonderful work with children. Project Lighthouse added a way of thinking about learning and using technology that provided them with more tools with which to work. It also added in ways that other NFE sites could not.

We originally planned Project Lighthouse to work with children of all ages. We were directed towards working with NFE for several reasons. One primary reason was that Dr. Kasama was a big supporter. It also provided sites at which to work that were less structured and more open to experimentation than traditional formal primary schools. However, what we were not told and only discovered as we began to work, NFE cannot work with children until the age of fourteen, or after the end of compulsory schooling. However, because Mae Fah Luang was a small, rural site, with not so many children, the restrictions were much less. At Mae Fah Luang we were free to work with a wider range of children.

The residents of Mae Fah Luang are primarily from various hill tribes. Many speak an indigenous language and perhaps also Chinese. Thai is either a second or third language for them. Education of hill tribe children has been problematic for Thai educators for a number of reasons. Language difficulty is one huge reason. Others are the same as in

other rural areas in Thailand, i.e., little teacher training, high turnover of teachers, few resources, etc. Since this had been problematic in the traditional education, this was an excellent opportunity for Project Lighthouse to demonstrate new possibilities.

4.1.2 Activities at Mae Fah Luang

As in Nang Rong, we began with immersion environment to develop technological fluency. The children worked on long-term projects of their own choosing. As we did not have enough Lego materials due to their expense, the children's activities were limited to Microworlds Logo and building web applications. Even though Mae Fah Luang is very remote, and, we are told, only was electrified two years before our project began, through the generosity of the ThaiComm Foundation and Shinawatra Satellite, an experimental two-way satellite link was donated to Mae Fah Luang to provide connectivity. The use the people made of this link was quite powerful and it is this aspect of the work there upon which I will focus. Even though there were many other profound results, in many ways they mirror results in Nang Rong. Thus, I will focus on some unique aspects from this site. I will also follow the same protocol for the other sites described in this thesis.

4.1.3 Electronic Community Magazine

In July, 1998, Marina Umaschi Bers, Michael Best, and Josh Bers went to Mae Fah Luang to work in the Ban Thard village [Bers and Best, 1999].[2] We wanted to add more Constructionist technological tools to the project. This presented a good opportunity. The NFE center in Ban Thard actually draws learners from many surrounding villages. Some walk up to seven kilometers each way every time through quite hilly terrain they come to the center. We saw the magazine not only as a way to write and work with the web, but also to help build community across the disparate villages.

They used the Pluto software developed at the MIT Media Lab in the News in the Future (NiF) group [Driscoll, et.al., 1997]. Pluto enables a group to create, edit, and publish a multimedia, web-based newspaper. The software follows the format of a newspaper in the sense that one defines sections and places articles within them. More interestingly, anyone can author an article, but they submit them to an editorial board. Just as in real newspapers, the board discusses the articles and determines what they should publish and what to express. In this way the participants benefit not just from the writing, although that is a strong benefit particularly in this area where children rarely get the opportunity to write anything meaningful. They also benefit from the editorial discussion and decision-making.

[2] This work is described in more detail in their article, "xxx," to be presented at CSCL 99, to be held in December, 1999, in Palo Alto, California.

The children decided that one of the themes for their magazine would be wedding ceremonies. They would write about them, take pictures, show the costumes, add the music, print the recipes, and describe everything about the ceremonies.

When I visited Mae Fah Luang in March, 1999, the teachers related the following story to me about this project. When the computers were donated by the Suksapattana Foundation, through the donations of the Foundation's sponsors, there was not a facility to house them. Through the efforts of Khun Paron, the Siam Cement Group donated materials to construct a new facility to house the Lighthouse activities at the NFE Ban Thard, Mae Fah Luang site. Jirachai and the NFE staff decided to construct the building with lots of windows facing the village. They did not want the center to be separate from the community. They wanted the parents and other villagers to be able to witness the activities within the center with the goal of inviting their participation.

It deserves mentioning that although many people warned us of possible theft when working in poor areas, we have had absolutely none during the entire time of Project Lighthouse. We have had the same experience wherever we have worked. We believe major factors in this are creating an environment where people work on what is important to them, working on projects that have community impact, enabling a sense of ownership over the overall project, and the participants believing there is benefit from the project.

We only had ten computers for the project and more than seventy children participated. This too runs counter to the type of immersive environment we try to create, but since the

activity in Mae Fah Luang only emerged due to Ajarn Jirachai, it was the best we could muster at first. The children often worked in groups, but even still there were times that they could not work on the computer. In all of our projects a considerable amount of time is spent doing work not on computers. So, in Ban Thard you could see groups of children working together on the computers, or gathered together drawing plans on the basketball court in front of the NFE center, or gathering data throughout the village and hillsides.

The teachers told me that the parents visited often. However, when they saw the children talking, enjoying themselves, drawing outside, not sitting in classrooms, not listening to teachers' lectures, they began to complain to the teachers. "You are not teaching are children. They are not being serious. They are just having fun. Why are you wasting their time? This is not what school is like." The teachers tried to explain, but a few of the parents began to withdraw their children from the project.

Surprisingly, soon they brought them back. Now the teachers asked what was happening. The parents told them that previously the children had been ashamed of their nature culture. They did not want native clothing, or to learn the traditions, or to know their own history. Now, after talking to their parents and grandparents about all that is involved in weddings in order to put their community magazine together, this had changed. They asked their parents to make native clothing for them. They wanted to learn to cook traditional foods. They asked about the music, the crafts, the history, and so on. The parents said, "We do not know what you did, but whatever it was it worked so keep on doing it."

Before beginning Project Lighthouse, his majesty King Bhumipol of Thailand raised concerns about children not learning to socialize with each other because they were working individually only on a computer. We were quickly able to dispel this concern. He also expressed concern about bringing in new technologies and thereby hastening the demise of local culture and being subsumed in western culture and values. The experience in Mae Fah Luang demonstrates how this need not be the case. Through television, music, marketing, and other media, this erosion of local culture and inundation with mass marketing commercial culture was underway. Their use of the web as a place for construction of their own artifacts and narratives, and not just a place for consumption of others' artifacts and narratives, helped build a new appreciation for their own culture that previously had been dormant.

4.1.4 Electronic Commerce

Another new effort at Mae Fah Luang is to institute electronic commerce (e-commerce). In discussions with Ajarn Jirachai at the beginning of Project Lighthouse we worked on how to make the project sustainable. We knew that even though the initial expenses were donated by the Suksapattana Foundation, the sponsors, and the national education ministry, it was likely that this could not continue over a long period of time. This also could not cover the expansion of the program, assuming that it was to be successful. Finally, there would be added costs in terms of electricity, maintenance, and training.

One way of offsetting at least part of these new costs would be if we could use the technical infrastructure of computers and telecommunication to base a new electronic economy. Economic progress in the past was severely limited in Mae Fah Luang due to terrain, climate, and difficulties in transport. This is typical of many areas worldwide [Sachs, 1999]. Our hope was that as the people gained technological fluency, they could support their own e-commerce. They could use it to increase their agricultural efficiency, their buying and selling power through cooperatives, to be able to sell products to areas beyond their immediate geographical area, and eventually to provide knowledge-based services to other areas. They hoped to change the nature of the economy without having to open the area to more and more tourists, with all the incumbent problems.

This effort is just now beginning. People in Mae Fah Luang are creating their web stores and creating new products. Through the help of Michael Best at the Media Lab and Arnan (Roger) Sipikitat, of Chiang Mai and now a graduate student at the Media Lab, the Mae Fah Luang e-commerce site will debut at the Media Lab's e-markets SIG in October, 1999.

4.1.5 Integrated Learning Environment of the Ban Pa Sang Nang Ngen in the Mae Fah Luang District

As in the other sites, political issues having nothing to do with the project directly, or the ideas about learning environments, had a significant impact on the progress of the project. For a period of time, due to political reasons and jealousy over the recognition received through his involvement and success in Project Lighthouse, Ajarn Jirachai had

difficulty with his supervisor. Some of his teachers at Ban Thard were transferred, and then Ajarn Jirachai himself was temporarily re-assigned to a much more remote village, Pa Sang Nang Ngen. Only through the efforts of Khun Paron did this situation get resolved satisfactorily. And, true to the commitment and vigor of Ajarn Jirachai, he produced extremely interesting work in the new site as well. In this site the formal and non-formal primary education efforts were merged and working in the Constructionist way of Project Lighthouse.

I first visited Pa Sang Nang Ngen in March, 1999, accompanied by others from Project Lighthouse. This was the first visit to the site by any non-Thai. This site developed purely by Thai efforts. When I walked into the NFE center, there were many children busily at work on their Microworlds Logo projects. Many of them were celebrations of their hill tribe culture. Music they had recorded was playing from several machines. They had imported photos of their fellow villagers in their costumes, imported local music, and had produced little animated stories and histories of their tribe and its culture. The music was lovely and the pictures beautiful. The enthusiasm of the children was contagious.

Figure 1 -- Hill tribe woman and children at Pa Sang Nang Ngen Non-Formal Education village technology center

Figure -- Same group after children had uploaded digital photograph of the woman into their Microworlds Logo project

Some of the children grabbed me to proudly show off their new garden plots. They had planted tiers of new vegetables. Some of these vegetables were not typically grown by this tribe. The NFE and local agricultural agencies had introduced the ideas to them, knowing that these plants would grow well in these conditions. They believed it would help supplement their income and provide needed nutrition to their diets. They hoped that the new agricultural methods would also help change them from practicing slash and burn farming, common to that area, which causes so much ecological devastation.

Figure 3 -- Pa Sang Nang Ngen vegetable terrace

We retreated to a shady area to discuss what to do at this site. I asked many questions about what they were doing, what they thought, what they liked, what they believed needed to be improved, and so on. Naturally, they wanted to continue the Logo work they had begun. We also converged on the idea of using the agricultural projects as an integrating force for all the work. Just as in Nang Rong, we worked in a Freirean way, using what was important to people as the overall basis for study and practice. We discussed doing little experiments, both on and off the computer, about the new agricultural methods. They could look at top-soil erosion, scientifically measure the productivity of the various methods, work with both the soil and with Logo-based simulations, study nutrition and various diets, and so on.

4.1.6 The Mae Fah Luang Example

Mae Fah Luang provides a compelling example of what is possible in learning environments, even in areas where traditional efforts have failed, and even in the face of political adversity. As in Nang Rong, the expense of bringing personal computers to poor, rural areas was more than offset by the benefits, even in the short term. This does not even consider what should become possible over time. Rural teachers have performed extremely well. Children have learned an incredible amount. More importantly, learning has become a fun exercise, not drudgery.

Not only have the children learned considerable mathematics, science, programming, logic, and even social studies, but also they have learned something critically important about citizenship and participation. Rather than leaving the area, or remaining unengaged,

or just letting whatever happen, people have become active agents in studying and improving their environment. Children in Mae Fah Luang have taken control of a new fruit-tree orchard to provide food and income to their families. On my visit, which was at the end of the dry season, despite the protests of the elders who wanted them to show off their projects and progress to me, they left because there was a fire on the hills and they wanted to ensure that it was contained and, even though they had no personal property in that area, that their region would be harmed as little as possible. These changes in attitudes about learning, themselves, and their relationship to their culture and their community, is perhaps the best result from Project Lighthouse.

4.2 Chiang Rai

4.2.1 Introductory Activities

Chiang Rai was the first place we began working with Thai teachers, running a brief introductory workshop in August, 1997. Although the stated purpose was to begin working with teachers, we had triple the requested number of attendees. Thus, the intended audience of NFE teachers did not have a real opportunity to work and learn. Moreover, they did not have a chance to truly follow up after the workshop by developing their own projects or thinking about how to work within Project Lighthouse.

In November, 1997, Seymour Papert and a number of his students (Savalai, Marina Umaschi Bers, and myself) ran another technological fluency immersion workshop for Chiang Rai teachers, plus a few from Lampang, Mae Fah Luang, and Bangkok. We introduced working with Microworlds Logo and Lego/Logo. We also spent a

considerable amount of time in discussions about learning. Both sides are critically important. Merely discussing issues of educational philosophy without an accompanying activity too often devolves into nothing upon which people can act. This tendency is exacerbated when one is attempting a more radical reform. There is nothing concrete and few experiences upon which to base discussion. On the other hand, merely working with technology without an accompanying discussion may help embed the technology, but will also be unable to fundamentally change practice. Our goal is to help provide transformative experiences for the teachers upon which to base a concrete foundation for discussion about changes in learning environments.

Originally, people wanted just their technology instructors to enter our project. The reasoning was that since this project used a lot of technology, they were the proper attendees. While learning about and becoming proficient with technology is a goal, we want the project to extend into domains other than technology. An analogy is the purpose of textual literacy. We need to spend time learning to read and write, however reading and writing provides benefits in understanding math, science, and other fields.

The workshop was quite successful in that people did learn to program with Logo. But, more importantly, people did start to think more deeply about teaching and learning. Due to shyness and language difficulties, at first it was difficult to have large group discussions. So, we broke into smaller groups of five teachers with one or two of us. This way we could have deeper discussions and everyone could participate.

The teachers told us that even though they had all been to teachers' colleges, they never had discussed learning, only teaching. That is, they were trained in how to explain material, but not given the opportunity to think about how people learn. We spent a lot of discussion time reflecting upon and conversing about learning experiences both in and out of school. It was unanimously felt *that their most powerful learning experiences as well as learning the things they cared about the most happened outside of school and without formal instruction*. This was quite a revelation for them, as was the feeling of disjunction between learning and school teaching. At the end of the workshop, people chose whether they wanted to participate in Project Lighthouse and attempt to create new learning environments.

Although the teachers did not have an opportunity to work on any projects of their own, we ran another three weeks of workshops in January 1998. As January is the Independent Activities Period (IAP) at MIT, none of the students had class responsibilities during this time. Thus, a large group came and was able to work in each of the five original pilot sites. We had the benefit of several Thai undergraduate students joining us, which helped immensely. We decided it would be best if each group would focus on one site in order to build relationships and help develop deeper projects and activities. Most of the group began in Chiang Rai and then went elsewhere. Deb Roy, Michael Best, Carol Sperry, Athicha Muthitacharoen, and Piyada Phanaphat worked in Mae Fah Luang. Arjan Schutte and Warit Wikachool worked in Lampang. Cynthia Solomon and a group of fifth-grade students from Milton Academy, along with Sperry, Best, Roy, Vaikakul, Alice and David Cavallo all worked in Chiang Rai. Solomon, Sperry, and both Cavallo's worked at

Vachiravudh College. Vaikakul and both Cavallo's worked in Nang Rong. The Thai undergraduate students, Wikachool, Athicha, and Piyada, worked at each site.

It was interesting, though not surprising even though highly unusual for most educational institutions, that the unique character, talents, and interests of each of the visitors from MIT had different affects on the people and the sites. The visitors developed relationships with the teachers, administrators and learners from the various sites. Different sites picked up upon the ideas, words, and activities of the people who visited their site. They then took their own approach based upon their experience and relationship with the people who visited. Each site developed in different ways due to this, but rather than being viewed as something that deviated from a desired, pre-planned program, this is viewed as a strength. The relationships formed between the visitors and the hosts helped the hosts construct their own views on what was important, what to do, and how to do the activities. They then deepened their relationships with their students. Thus, the work was appropriated throughout the project through all levels.

4.2.2 Initial Situation

However, once the workshops ended they faced several problems. Due to the funding model within NFE, the center could not afford to give the teachers time to work on their own projects and develop their own fluency. They also needed the teachers to teach, as NFE centers are funded based upon the numbers of students enrolled. Not surprisingly, this encourages over-enrollment, and does not reward accomplishment. Since the technological "courses" attract more people than traditional ones, the funding realities

pressed teachers into service before they had an adequate opportunity to learn and develop under the new Project Lighthouse model. Given that the NFE teachers are poorly paid as is, with most working on temporary contracts without benefits or job security, and that certain classes of teachers are paid based upon the number of students in their classes, the pressures to begin immediately were too great to overcome.

When one examines the mission of a learning institution such as NFE, the fact that learning results and teacher development receive short shrift while funding models rule the operations seems ludicrous and obviously in need of reform. Yet, this rarely surfaces, not by anyone's bad intent but just through bureaucratic inertia and stagnation. How one can expect teachers to work with learners in areas the teachers have not had opportunity to learn is bizarre. Before Project Lighthouse, many in the educational and political establishment questioned the ability of these teachers to learn the technology, let alone to guide learners in working with it. Yet, when the teachers had adequate time to develop their own fluency, as demonstrated in each site, they excelled. They could be more effective than people coming from outside with backgrounds in technology and learning simply because they knew the people, the culture, the situations, and were better role models than the outsiders. That time and again neither respect nor time is given to these teachers is self-defeating and short-sighted.

The lack of development time led to a second detrimental factor. Even when the teachers believed in a more Constructionist approach to learning, they did not have adequate examples upon which to base their practice. They were familiar with instructionist

classrooms and knew how to operate in them. But how one could work in a learner-centered, long-term project-based environment was too foreign and too difficult to imagine and create fully on their own.

We inadvertently fed into this problem by the way we ran our workshops. This was design problem of which we were aware, but unable to decide how to do otherwise. Because we, except for Savalai, did not speak Thai, we spent more time at the front of the classroom during workshops than we would have if we shared a language with the participants. We told them numerous times that this was the case and described how we operate on a more individual basis. We told them how we would discuss more with each person to try to develop relationships with them; to get to know their interests and to base projects upon those; to observe their work and question them to try to determine what they were thinking as they programmed; and to use these factors as a basis for explanation and suggestion to help them make their work and thinking more robust.

Not surprisingly (we certainly should have known better given our approach and philosophy) the fact that we told them this many times was outweighed by what we did. People followed what we did, and not what we said. People came to talk about an "MIT way" of running workshops and insisted that everyone follow this. Again not surprisingly, most teachers could see through this contradiction, but felt helpless to disobey the instructions from above. This too slowed the progress of the project, although it still is hard to think of alternatives when one does not share the language.

4.2.3 New Life Hostel

One of the original goals for pilot activities in Project Lighthouse was looking for ways to provide better learning environments for at-risk youth. One of the efforts in Chiang Rai was the first to attack this situation.

Youth prostitution is a major problem in Thailand. This so tragically affects so many young women and men. The impact on their lives is devastating. The degradation is horrible, but health and drug problems compound the problems dramatically. Drug use debilitates so many of these youth. Sexually transmitted diseases are rampant. AIDS plagues upon this population. Even the specter of AIDS itself causes problems as this causes sexual predators to try to find younger and younger prostitutes to protect themselves from disease. When the prostitutes are too old or sick or damaged to continue, they are discarded with no basis for future earnings and no social structures for support.

The New Life Hostel in Chiang Rai is one attempt to deal with the prostitution problem. It is run by missionaries and they try to provide a safe environment and training to help prevent girls from entering prostitution or to help them recover. The young women live at the hostel, although some go to their home villages on weekends. The hostel provides rudimentary vocational training to them. The Chiang Rai NFE center provides their basic education. As almost all of the girls come from rural villages, they have had little formal schooling. Many are from hill tribes – for them Thai is a second language, which adds difficulty to providing learning opportunities for them.

In the August workshop, Savalai Vaikakul worked with a small group of them quite a bit. Savalai introduced Logo and programming. Since the girls' native language was transcribed into written form by other missionaries, they used the same alphabet as in English. This facilitated communication and programming for them as we did not yet have the Thai version of Microworlds Logo to use. They found that creating little animations was quite fun and this encouraged them to continue working within Project Lighthouse.

The Chiang Rai teachers, particularly one known to us as Mike, worked with the New Life group. They developed software projects, built multimedia presentations on topics of interest to them, and did turtle geometry, in addition to their regular studies.

In March, 1998, MIT Media Laboratory Professor Gloriana Davenport, assisted by two of her graduate students, Philip Tiongson and Arjan Schutte, led a one-week workshop for the New Life group. Professor Davenport is the head of the interactive cinema group at the Media Lab. The goal of the workshop was to introduce using images to tell stories. The idea was that this would be the first of a number of efforts in this vein, where each of these would build upon the previous one.

The initial workshop would use still images from digital cameras. The learners would do a photojournalism project on a mutually agreed upon theme telling a story using images and text. They would place their work onto the web upon completion. The learning goals were to further develop technological fluency, develop narratives, learn to use image and

text, think about light, texture, mood and other elements to strengthen visual storytelling, as well as to learn about the issues surrounding the topic of their stories. We planned for follow-up activities using video as well as still images to further deepen ideas about narrative. Other projects would with other media would also touch upon the issues of light, shadow, texture, and so on. The connections from a variety of projects in a variety of areas with a variety of media clearly provide a rich source for learning with depth.

The group decided their theme would be about the lives of people living in a nearby AIDS village [Davenport, 1998].[3] This is a village composed of people who have AIDS and were evicted from their villages, and moved to a new site outside the village limits. The young women worked in teams of three or four to put their articles together. They visited the village and interviewed a number of the residents. Several of the young women wrote about the impact of the visit. One of the groups took on the point of view of one of the villagers, who described his experiences and feelings. Professor Davenport felt it quite significant that they did not merely present their own views, but adopted the point of view of another to make their story more compelling.

This type of work follows the Constructionist approach of the project. Rather than teach photojournalism, or narrative using only text, or issues about health, by lecturing, by lessons, or by a pre-planned curriculum, Professor Davenport and her students let the young women guide them to the topic they felt most interesting. They went out and actually built something, in this case a web site telling a story with text and image. They

[3] This work is described in more detail in the article.

used technology, but did not spend weeks or months beforehand being taught the prerequisites.

4.2.4 Emergent Developments

As we did with every visit, we wanted our people to work directly with the learners, with the local teachers and staff from other Project Lighthouse sites. This was one attempt to rectify the workshop problem mentioned above. This provided concrete examples of how to work with students in a non-instructionist way. This also was an example of how we wanted to work everywhere. That is, with children doing real work in the company of people who know how to do the work and are passionate about the work and the children.

This work tapped into the joy that Dr. Suchin, based at the Lampang NFE felt about photography. As Dr. Suchin had become an integral participant in Project Lighthouse, he participated in the initial constructionist immersion workshops in Chiang Rai, the Pluto workshop in Mae Fah Luang, and now Professor Davenport's workshop in Chiang Rai. His enthusiasm for photography led him to help initiate such photojournalism and electronic community magazine efforts in Lampang. No staff participant at the Chiang Rai site felt similarly about photography and thus such efforts did not rake root there.

This, however, was not bad as the staff in Chiang Rai worked according to their interests and talents. For example, Nong, who came from Chiang Rai to assist us in the village projects in Nang Rong, worked in villages in the Chiang Rai region. As she had a background in healthcare, she focused a number of projects along this line. Neung and

Bom enjoy electronics and technology and had great success with children who liked working with machines. All of the teachers worked well with Logo, and when I visited the Chiang Rai NFE center in March, 1999, I watched the end of term exhibition by groups of students. Each one had chosen a theme and developed programs and a multimedia presentation on their theme. They had gone into depth on a variety of subjects, examining how something was practiced in the area, and proposing improvements. For example, one group looked at traditional medicine, another focused on vegetable farming, and a third on issues of poverty. The presentations were quite entertaining. Their engagement far beyond how these groups had previously done in school. What makes the results more positive is when they are taken in the context of the typical Thai public school experience. These children do not get the opportunity to choose topics of study, or to make presentations, or to critically examine their environment and propose alternatives. This type of work is a concrete example of achieving the goals in the original proposed education reform, with the target population.

What is particularly impressive in Chiang Rai is their commitment to improving the learning environment. This begins with Khun Ackachai and continues throughout his entire staff. They tried various activities and formulation. They review the results. They make adjustments in a continuing effort to improve their work. They also pull from as many resources as possible to reach more people and provide as good a learning environment as possible for as many as possible, particularly for those who have not had good learning experiences previously.

4.3 Lampang

4.3.1 Background

Lampang is an industrial city a few hours from Chiang Mai towards Bangkok. Due to the involvement, interest, and support by Dr. Suchin and his NFE staff, we decided early on to expand efforts to this site. Unlike the Chiang Rai site, which is in the center of the city, the Lampang site is a large and somewhat isolated campus. The Lampang site serves the entire northern region, while the Chiang Rai site at which we work serves the sub-district and another site serves the Chiang Rai region. Thus, the Chiang Rai site facilitates involvement with its surroundings, both by learners going out and by visitors coming in. The Lampang site, on the other hand, is more self-contained as a learning environment. This difference plays out in the projects of the two centers. This is neither good nor bad in and of itself. This just highlights the different design tensions intrinsic to the project leaders, project staff and learners in terms of what they want to do and what the environment affords.

4.3.2 Initial Activities

We began our initial activities in Lampang the same as everywhere else, by holding technological fluency immersion workshops. As Dr. Suchin and several teachers had attended a couple of these workshops in Chiang Rai, they were better prepared to begin work than in other sites. Dr. Suchin and the other administrators, particularly Ajarn Narawan, who held the same position as Ajarn Jirachai in Mae Fah Luang and Ajarn Ackachai in Chiang Rai, decided to allow the teachers to co-facilitate the efforts. This

helped them immensely as the burden to know the technology and help each student develop was not too great.

They outfitted a large room with the computers, and as this site and the Chiang Rai site had able technical support, they networked the machines, hooked up display projectors to the computers, and had a sound system.[4] This facilitated working in and presenting to large groups. These sites were internet-ready, but the local phone systems and national internet infrastructure were so weak that we were unable to use the internet and world wide web in the ways that we had designed. Through the tireless efforts of Khun Paron and the generosity of the ThaiComm Foundation and Shinawatra Satellite, we received two-way satellite hook-ups first for Mae Fah Luang, and, soon, for the other Lighthouse sites.

In January, 1998, two MIT students, Arjan Schutte and Warit Wikachool, whom we all knew by his nickname of Peng, an undergraduate of Thai nationality, led a few weeks of technologically-based Constructionist project work. Although both were involved in the project because of their interest in learning and technology, and Arjan had done some work for educational technology companies, both had backgrounds in technology, not learning. Thus, they focused their efforts in Lampang on using images, developing web sites, and making multimedia histories using Microworlds Logo.

[4] We were indebted to staff at Lampang, and Neung and Bom in Chiang Rai, plus the Dr. Chaiawat and his staff, particularly Arnan (Roger) Sipikitat (who is now a graduate student at the MIT Media Lab) of the Computer department in Chiang Mai University for their able, dedicated, and cheerful work and support.

One of the first things they did was to re-arrange the layout of the room. At first, the layout was in rows of desks, typical to most classrooms. However, this type of layout focuses attention away from colleagues and towards the teacher, inhibits interaction, loses common free space, and structures the interaction towards a teacher lecturing. Since our approach is to place the emphasis not on the teacher but on the learners, their activity, and their interaction with each other, they moved the desks and equipment so that everyone was in a circle. This not only facilitates collaboration and interaction among peers, it implicitly but essentially re-directs the power relations of the site.

Due to the playful and friendly nature of both Arjan and Peng, the few weeks they spent in Lampang were enjoyable and helped establish another implicit but deeply felt component of Project Lighthouse. We wanted to establish that it is not a contradiction that learning environments can be fun while the work is difficult. Too often children view school as painful. They are old they need to put up with it, as it will help them later. Some accept this and some do not. However, this need not be the case. Often, the work undertaken in Project Lighthouse was more rigorous and more difficult than any of the learners had previously attempted in School situations. Yet, they not only willingly participated and worked without coercion, many excelled. This had a greater impact on their sense of themselves as intelligent and capable people more than any verbal encouragement (although of course we supplied that when necessary as well).

Peng was just one of a number of Thai MIT students who assisted in Project Lighthouse. They provided tremendous assistance to the project in many ways, and, we believe, the

project assisted them considerably as well. When we first began planning for the project, we held public informational meetings at MIT. Among those invited were the Thai students. A good number volunteered to participate. We held workshops at MIT to familiarize them with the approach to learning environments and to the technology. They did the initial work of translating Microworlds Logo into Thai and helped debug the localized version. They helped plan the project and provided good information that would have been slow to obtain otherwise. Four of them, Savalai, Athicha, Peng, and Piyada, went to Thailand to assist in the workshops and provide immensely helpful translation. Savalai went on to become a student of Papert's. The others all worked in the undergraduate research opportunity program (UROP) at the Media Lab. Their efforts were so beneficial to the project and to the students that getting the assistance of national students has become a staple of every project taking place in other countries.

4.3.3 Constructionist History Project

One significant project begun during the January work was by a fifteen-year-old young man studying to be a Buddhist monk. He took digital photographs of many artifacts found in the local temples. He then created a Logo-based multimedia history of Buddhism and Thailand by tracing the paths of the artifacts from temple to temple and city to city. He wrote the reasons behind the movements, putting it into the context of Thai history. It was a beautiful and deep project, and an example of a Constructionist approach to history and writing. Unfortunately, the project was lost when there was a system failure, and, although this was specified when the networking was installed, no

one was yet backing up the systems. This painful lesson helped insure subsequent diligence in backing up.

4.3.4 Lego/Logo Workshop

In March, 1998, as part of the introductory efforts, Fred Martin, a research scientist at the Media Lab, along with Wanda Gleason, an educator who formerly worked in Papert's group, and Claudia Urrea, a graduate student of Papert's, led a one-week Lego-Logo workshop. The previous week they led a similar workshop at KMUTT, a technical university in Bangkok. As usual, they worked directly with groups of students and teachers, who all built Lego projects. Other Lighthouse facilitators from other sites also participated. While the students and Project Lighthouse staff both worked on their Lego contraptions, the Project Lighthouse staff also participated in discussions about learning, about using Lego, and so on.

As we often do, the group presented a particular Lego design challenge. Everyone would build something of his or her own design to accomplish a particular task. The task varies from event to event. It can be something like finding and gathering all the ping pong balls into one place, or pushing a number of soda cans out of a marked circle, or navigating a maze. In this instance the challenge was to circumnavigate a tree in the courtyard. This task was made more difficult because of the cobblestone covering the ground. Thus, the vehicle needed to not only determine a proper path, but also needed to be strong, sturdy, and flexible enough to traverse the ridges and stones without getting stuck or stalled.

During the workshop Fred noticed the mechanical savvy of a group of the students. It turned out they were studying to be motorcycle mechanics. They showed tremendous creativity, resourcefulness, ingenuity, and analytical prowess. They were able to devise unique designs to accomplish tasks quite difficult with Lego. Some of them resembled motorcycles in that they only used two wheels. What was ingenious was that these two wheel vehicles could still turn and remain stable. Fred remarked that their technical expertise and building was the best he had ever seen anywhere over the more than ten years doing Lego workshops around the U.S. and the world. This includes working with engineering students at MIT, professors and researchers, science teachers, and professional engineers. This is high praise indeed, yet this group of children were not deemed academically proficient in their prior School careers.

One could try to explain this away by saying something like, "Well, what would you expect? They are studying to be motorcycle mechanics. Of course they have this ability." What such an attitude denies, however, is both that the intelligence required to accomplish what they did, and that this intelligence combined with their experience and interest can be mobilized as a basis for understanding other knowledge domains. This is the example from the Project Lighthouse work in Nang Rong, whereby, if one creates such a learning environment and sustains it over time, this potentially provides tremendous promise for many youth previously deemed incapable of doing serious academic work, or good with their hands but not with their heads.

These activities with Logo and Lego/Logo highlight a place where the technology affords something fundamentally different from previous technologies, particularly paper and pencil methodologies. The youth here, as did the youth in Nang Rong, Chiang Rai, Mae Fah Luang as well as other sites in which we have worked, were able to take their knowledge of and interest in engines and actively transfer it and apply it towards other areas.

While it was not a point in a one-week workshop, when we work in an environment over a long period of time, we use their construction experiences as a basis for discussion and reflection about what they are doing and why it works. This enables a concrete context for the discussion, and enables the situating of powerful ideas within the domain. For example, abstract concepts such as torque, force, surface tension, can be difficult for many to grasp in traditional classroom instruction. However, naming the concept in the context of a learners' own artifacts that they constructed themselves, that they in all likelihood struggled somewhat in order to get it to function in a desired manner, helps provide concrete and felt entry ways into the domain. As they meet more and more of these concepts through their own constructions and expressions, they develop a fluency around working with the concepts, materials, problems, and principles. This fluency is theirs, based upon their work, their interests, their ideas, and their struggles. It bumps up against the realities of getting something to really accomplish a chosen task in the way the learner designed and constructed. This happens in a culture of construction, around people who care about and know about, and, hopefully, are passionate about the domains of work.

When I introduce working with Lego to a group in a typical context of beginning a long-term learning environment and not merely for a one-week session, I do not begin with motors. Normally, I begin with running non-powered vehicles down an inclined ramp, with a goal of seeing which can go the farthest. Many children quickly transpose this into going the fastest, which raises interesting points. Before we begin, I challenge them to think about what type of design they will use to accomplish this. What will be better? Should they make a light or a heavy vehicle? (Children almost unanimously think having lots of weight is important as it will help them go faster down the incline). Should they have many wheels or a few? Should they use big wheels or small ones? Should they make a long vehicle or a short one? Should they make a wide vehicle or a narrow one? Interestingly, and importantly for developing a real-world view of scientific practice, there are many variations that enter this based upon environmental characteristics. For example, if one uses a thick board for a ramp, there will be a drop from the end of the board to the flat surface. This introduces a new complexity into the situation as the vehicle must be steady and sturdy enough not to be disrupted by the drop. If the ground is not exactly smooth, or has little pebbles, this adds another wrinkle.

The project helps get people to see how to put vehicles together to minimize friction (one of those concepts to be named). More importantly, it gets people to take a stance, to make a hypothesis. Then, as they begin building and testing, they not only measure their work, but we challenge them to think through robustly what is making a difference. They meet

the mechanical principles they will continue to see in an enjoyable way. They begin to think through how to work on their own experiments successfully.

After this, I often challenge them to build something that will climb back up the ramp. This will require motors and gearing. I challenge them to climb the most radical angle. Again, I pose the questions of what will make a more successful design. There is not just one answer. As they try out their various designs, we strive to be rigorous about what will work and why.

After this, we often pose various challenges as the group did in Lampang. One example I like to do, that connects with other activities, is to go out and examine the local environment and then build models of how they would like to envision their city or village of the future. This engages them with both a critical examination of their environment and an exercise at designing a future. This engages them with issues of how they would like their environment in the role of capable and positive actors within that environment. This is also where the project goes beyond science and math to study other areas of knowledge.

4.3.5 Northern Region Constructionist Learning Lab

In June 1999 the Lampang NFE center began a development program for teachers from the northern region of NFE, formal primary education, and a few from the teachers' college. This was the first internal attempt to broaden the scope of the project. The participants would take three one-week workshops on Logo, Lego/Logo, and

"photojournalism." While the names and structure sound very curriculum-like, the approach and activities were the same as in the other Project Lighthouse sites.

Ten of the teachers from the Lampang NFE, who for the most part have been active in Project Lighthouse since its inception almost two years ago, would each serve as a mentor and resource coordinator for five of the participants. When the participants return to their sites, they would begin to change the culture of their local learning environment. The Lampang mentor visits regularly, helps out, observes the situation, and offers advice and support to the teacher. The goal is not to replicate anything, but rather to facilitate the teacher's appropriation of the ideas.

4.3.6 Future Steps

The next steps, beginning now in November 1999, are to create local learning environment clusters. The idea is to build critical mass of participants, activities, and ideas, so that the people and sites can build upon each other. Rather than only working in NFE centers, the Lampang area will begin work in primary schools, Non-Formal centers, and community centers. The local teachers' college (called Rachabhat in Thai) will create a new line of Constructionist learning. The professors at the college will create new courses on constructionist learning and technology. The students and teachers will do their practicuum work in the local pilot sites.

4.4 Vachiravudh College

4.4.1 Background

Vachiravudh College (VC) is an elite private school for boys. The school used to only be open to members of the royal families, but was opened to the public some years ago. The school originally was fashioned after a British public school model. Some of the board of directors of the school felt the school was no longer functioning to the level they would like. They hired Dr. Chaianan Samudavanija to return the school to its high standing.

Dr. Chaianan has written extensively on education. His philosophy of learning is very similar to that of Seymour Papert, although Dr. Chaianan did not focus on technology. In November 1997 Khun Paron hosted a meeting between the Papert and the Lighthouse team, and Dr. Chaianan, the headmaster, and a few others from VC. Once the two teams met each other, discussed their views, it was evident to all that their was agreement on goals and methods as well as the beginning of a very solid friendship. The groups agreed to collaborate with each other, and to introduce the technology and the ideas of constructionism at Vachiravudh. Vachiravudh, in turn, would open its computer facilities without charge to host workshops for Project Lighthouse and for work with the public schools of the Bangkok Municipal Authority (BMA).

Some objected to the idea of including Vachiravudh in Project Lighthouse. They argued that Project Lighthouse was to assist those who had not been well-served by the existing educational establishment. Vachiravudh certainly did not fit that. Others argued that the goals of Project Lighthouse were to break mindsets and provide new models of

technologically rich learning environments. Certainly Vachiravudh could contribute to that. In addition, there is a nice statement when the activities and approach used in an elite private school is exactly the same as in a rural, non-formal center for hill tribe children.

4.4.2 Initial Activities

The team from MIT ran workshops at Vachiravudh in January 1998 for VC teachers and teachers and administrators from the BMA. Many teachers from Vachiravudh attended. The goal was for them to use the ideas, and begin to adopt the technology into their classrooms. This was to fit with the broader change effort already begun by Dr. Chaianan.

The results in the first year were spotty. Some teachers adopted more. Some did not change at all. This was the case overall, not just with Lighthouse activities. Dr. Chaianan was disappointed with the pace and quality of the change. This example reinforces the difficulty of educational reforms. In this case, the leadership of the school was firmly and actively engaged in the reform. The scale was relatively small, comprising just one school. There was a coherent philosophy for and support of change. Yet, the results were minimal. The entrenchment of the grammar of school is difficult to dislodge.

For the second year, he decided to do something differently. He took the two third-grade teachers (VC begins with grade three) and the computer teacher, and changed the overall

environment for them to be fully constructionist. They would construct both with and without technology.

Although it is still early, everyone is excited about the changes. The consensus among the administrators, teachers, and observers from the Suksapattana Foundation believe the year was quite successful. The projects of the students exhibit more depth than the traditional rote schoolwork. More importantly, the students and even the teachers are engaged in and excited about the work. The plan for the next year is to have the fourth grade teachers continue with this approach with the current third-grade students, while the third grade teachers initiate a new group of students. As the new approach becomes more entrenched, encompasses more people, and comprises more of a substantial culture with accompanying artifacts and lore, they can attempt bolder and broader changes in the overall school.

A critical component to enacting more sweeping changes is to gain parental and community support. As people are familiar with the existing educational system, and know what is required for success, if they believe they have the means to have a high probability of success within the system, they are less likely to support widespread changes in educational practice, even if they believe that the changes are for the best educationally.

Without a doubt the parents of Vachiravudh students believed their children were poised for success and were likely candidates to be admitted to the extremely scarce slots in the

most prestigious universities. This situation made it much more difficult for Dr. Chaianan and his staff to enact change. Fortunately, the board which hired him had significant clout and provided sufficient backing for him to take the chance to try to dramatically change the learning environment at VC. The board represented the upper echelon of Thai society and believed that a change towards a more constructionist learning environment was necessary.

Dr. Chaianan was frustrated not only with the pace of change at Vachiravudh, but also within Thai educational institutions in general. He hoped that he could convince the universities to broaden the criteria by which they accepted students. The existing testing system rewards those who cram, memorize facts, and thus neglect other essential elements of learning such as creativity, open-ended problem-solving, collaboration, and the like. Practicing his own emergent design, Dr. Chaianan adopted a rather brilliant strategy for working around the recalcitrance of the educational bureaucracy.

Stating that "Old bureaucrats never die, they just get by-passed," Dr. Chaianan is creating his own set of examinations particular to Vachiravudh. Since Vachiravudh College is prestigious enough, these examinations have respectability. He reasoned that if he could get prestigious universities around the world such as Cambridge and Oxford in the United Kingdom and MIT and Harvard in the United States to accept the results of Vachiravudh examination and educational practice, then the previously reluctant Thai bureaucracies would be forced to go along. In this way he would open up the process within Thailand.

4.4.3 Next Steps

Encouraged by the results of the first term of the constructionist third grade, plans to include adopt this method for both the third and fourth grade are continuing. Vachiravudh also continues to support efforts to help out public schools in the Bangkok Municipal Authority (BMA) as well as throughout the country and all Project Lighthouse sites in particular.

4.5 Summary

Each of the sites described in this section achieved learning goals beyond what they had been able to accomplish previous to Project Lighthouse. They are helping to serve as beacons of light towards new thinking about learning and learning environments in Thailand. Significantly, of the sites mentioned in this chapter the original project plan only specified work in Chiang Rai. The others were added via Emergent Design based upon compelling factors, primarily the interest of key personnel at the sites.

It is important to note that each site developed uniquely. While the underlying principles (constructionism, technological fluency, Emergent Design, project-based learning) within Project Lighthouse were applied according to the understanding of the people at each site, the activities, projects, organization varied depending upon the administrators, teachers, learners, community, and situation. The people were able to constructively develop their own sites. People at each site could pursue their passions. They developed relationships with different people from Project Lighthouse and appropriated and applied what they

learned with them. Emergent design transformed the unpredictable nature of how ideas would be adapted and put into practice from a bug to a feature.

Chapter 5 –Lessons Learned

5.0 Overview

The major lessons drawn from this thesis include:

- Technologically rich, learner-centered environments do fit with and can succeed in Thai culture
- Rather than being deficient, there is tremendous knowledge, experience and expertise indigenous to Thai culture that provides a firm base upon which to build and leverage new knowledge. We believe this to be universal and not merely limited to Thailand
- Working from projects of real interest, often based upon acting upon the real situations of the people, provides a basis for leveraging the existing knowledge and creating new knowledge
- Using computational technology in a constructionist, expressive way helps to mobilize the existing knowledge, helps make knowledge, previously abstract and inaccessible, concrete and appropriable
- The grammar of school often interferes with powerful learning environments and activities
- Use of this technology is viable even in impoverished and remote, rural areas
- Teachers with minimal education themselves and no previous access to technology can function at a very high level both with the technology and with new methodologies for learning
- Teachers must be provided with adequate time and resources to develop their own fluency and experience with both the new learning methodologies and technologies

- Resources and support must be provided to reflect upon, discuss, and improve practice on an on-going basis
- Using a dynamic, emergent approach to reform facilitates cultural appropriation and adaptation.
- Enabling everyone at each level to participate as designers of the learning environment not only facilitates learning of immediate domains, but also helps provide a consistent basis for practice of the principles of democratic environments

In the subsequent sections I will examine the above items.

5.1 Thai Culture versus Thai School Culture

Project Lighthouse succeeded in dispelling the initial objections raised about its feasibility. Learners sitting quietly, not asking questions, only following instructions, not taking initiative, not being technologically savvy, not being innovative, not collaborating, not being adept at problem solving, may be a part of Thai school culture but they are certainly not consistent in Thai culture as a whole. Quite the contrary! The innovation in indigenous technologies, the resident knowledge in the engine culture, the entrepreneurialism of the women's cooperatives, the voluntary participation, the initiative and wealth of projects, the ability of the teachers and learners all demonstrated the vibrancy, vitality, creativity, and competence in the Thai culture.

Rather than being deficient in ability to understand, learn, and perform, there is a wealth of resources and ability resident among Thais of all social strata. These talents did not

begin with project Lighthouse. They have existed for a long time. The learning environment within Project Lighthouse enabled these talents to emerge, be recognized, and built upon.

While all of our Thai colleagues, including the educators, were well aware and quite proud of the local technological knowledge and innovativeness, it did not occur to any of them to refer to this native expertise as a basis of strength upon which to build in the learning environment. In fact, there is virtually nothing written elsewhere about the growth of this knowledge after the introduction of the internal combustion engine. This work is among the first to begin to document the effect. The deeper point for educators is that all too often local knowledge and interests are ignored and not taken as strong foundations upon which to build and from which to connect, and the grammar of school and a fixed curriculum are adhered to even when the results are thoroughly disappointing to all concerned.

5.2 Building upon Local Knowledge and Interests

Time after time we witnessed people who had not done well at school construct quite impressive projects. Accomplishing these projects required significant knowledge that school and society deem important. Yet, if one takes seriously a curricular approach, with its attendant prerequisites to knowledge and its recognition of particular formal descriptions of this knowledge, then these accomplishments should not have been possible, or at least be an anomaly.

When we first met Ae we discovered, rightly, that he was quite an impressive person. He believed he could figure out whatever he wanted, and, if he desired, would learn to do anything that felt interesting and worthy of pursuit. However he had never considered school learning as relevant to anything he really wanted to do. His experience at the workshop made a bridge for him between the kind of learning with which he felt personally involved and the kind of knowledge that he had previously only encountered in a school context. Thus, it opened the way for him to pursue more formal study and develop an ambition for a more sophisticated career. He now is a partner in operating a private computer school.

Then, once we met the motorcycle mechanics students in Lampang, the technical teachers in the Chiang Rai Non-Formal Education center, then Denchai, and so on, we noticed the pattern of experience all of them shared. They all spent a considerable amount of time around engines, learning in an informal culture. They were able to mobilize and leverage their experience gained from one general purpose technology, the combustion engine, to address other domains of interest and importance through the mediation of another general purpose technology, the computer.

This broadly shared expertise within Thai culture not only was not recognized for its intellectual depth but also went virtually unnoticed. People concerned with the development of Thai society, worried that Thailand would not be able to develop their economy based upon knowledge-based industries due to the lack of technological innovative, problem-solving, and collaborative capabilities, mobilized to initiate Project

Lighthouse. What they did not recognize were the accomplishments, expertise, and capabilities demonstrated within Thai culture. Thai learning institutions also did not recognize this talent and thus not only could not leverage and build upon it, **these institutions often tried to squash it**. Each of the innovative, mechanically capable people with whom we worked was profoundly unhappy in school primarily because School did not let them do meaningful things. Freeing them to use their experience and bridge from it to projects of interest to them freed them to display their talents. Each of them has moved on from rather low-paying work with limited futures to technologically-based work.

5.3 Connected Projects

We witnessed people who had not done well at school construct quite impressive projects. Often these projects addressed real world concerns. Accomplishing these projects required significant knowledge, knowledge that school and society deem important. Yet, according to a curricular mindset, with its attendant prerequisites to knowledge and its recognition of particular formal descriptions of this knowledge, then these accomplishments should not have been possible, or at least only be anomalous.

A salient feature of this work, particularly in the rural areas, was the work on real-world projects as a basis for activity. Paulo Freire initiated this approach in his work with rural poor in the northeast of Brasil [Freire, 1972]. He engaged them in discussion about their situation and they searched for causes and remedial actions. Through this, people learned to read and write, to learn history, to do math and science, to study society. They did not

just study for the sake of studying, however. They questioned and worked as a means of taking control of their lives and environment. What they learned was not isolated and decontextualized, but rather it was integrated into their understanding of and acting upon the world. The knowledge and the process of gaining knowledge were tools under their control applied for their purposes.

The choice of projects and study by the learner is critical. We do not use projects merely as a means to get them to learn what we want. They are not pre-ordained, pre-planned, and prefabricated within a pre-determined, structured, rigid curriculum, used solely to teach a set of facts or concepts. Rather, their choice is an essential element to a positive, free, active engagement with their world. Instead of relying on the dictates of others, they take charge of their own learning and their own relationship with their environment and each other. The process of critically questioning the way things are, determining on what to work, choosing among alternatives, designing the projects, working cooperatively, analyzing the results, debugging both the process and the methods of action, and recursively beginning anew, is important in its own right as well as for any learning activity. While at first people may not perform this process well, there is no way to get better at it except through critical practice.

Through our use of computational technology, the work described here has a tool not available to Freire and his colleagues at that time.[1] We use the computer in the spirit of

[1] Freire and colleagues began using computers in their projects beginning in the late nineteen-eighties. When Freire was Secretary of Education for the city of Sao Paulo, they began Project Genesis, which created four pilot schools using a relatively high density of computers. In that project, the school community would get together and decide their theme for the year, around which they would base all work.

Freire's original work, that is, as a tool for critical questioning of and engaging with the world. However, computational technology affords new opportunities for investigation previously unavailable or difficult with other methods.

We were able to create *dynamic simulations* in *microworlds* to test various possibilities when researching where to place the dam, how to layout of the agricultural fields, how to re-design the irrigation system, which methods of rice growing worked better, what new business venture (e.g. mushroom, vegetables, rice products) to attempt, and so on. This is not only important and effective in rural regions. Previous work demonstrated how investigating urban issues also can produce tremendous learning and social effects [Cavallo, 1996a, 1996b]. The *social capital* [Bourdieu, 1977] gained by mastering and utilizing advanced modern technology also often produces a leveraging effect among those who do not have social status.

Another leveraging characteristic of computational technology is the ability to make previously abstract representations *concrete*. School has been empowered but also limited by the technology of the book. Creating dynamic simulations was extremely difficult prior to the computer. The calculations necessary were difficult and abstract. It took many years and much practice to prepare for this arduous work. The pathways and even the representations and ways of thinking about the problems are dramatically altered by computational media. Mapping the terrain for the dam project provided a concrete basis for understanding and calculating distances, maintaining proportions, dealing with area, and so on. Simulating within a microworld helped make concrete determining volume,

water flow, and accounting for evaporation and drainage. Just as we have seen young children understand previously difficult and abstract mathematical concepts like variable or recursion through programming in microworlds, so too does the complex mathematics underlying the dam and other projects become concrete, contextualized, and familiar. Mathematics becomes their own connected and concrete expressions under their control for their purposes, not an alien language or ritual without significance.

The use of programs and their components (e.g. functions, variables, data and procedural abstraction, objects and properties, conditionals, concurrency) provided tools of formal expression for the villagers to apply concretely to their projects. Through time (although for Denchai and others this time was minimal), these became familiar tools just as their wrenches, screwdrivers and the like were familiar. *They were formalizing, not recalling formalisms.* Jean Lave pointed out how many people did not typically use the formalisms taught in school on their everyday problems in the grocery store or kitchen [Lave, 1988]. Yet, they still applied some type of formalizing to determine best purchases or proper proportions. Here, they created and applied the formal expressions of their programs towards the real and concrete problems they faced. The world provided an objective test for the robustness of their formal expressions. This is practicing and learning mathematics at its best.

We see from the examples of the mathematics of the Brasilian street children or the examples in Lave that people can master the mathematics they need for everyday living [Nunes and Bryant, 1996, Nunes, Schliemann, and Carraher, 1993]. This work extends

that according to an important basis for learning mathematics in the first place. The Thai villagers are applying sophisticated mathematical thought to their issues and goals. They are expressing in formal terms their ideas about how things work and how things might be different and improved.

A pivotal issue in working on projects of people's own choosing in a Freirean way is *control.* People trust educational institutions to help instill principles of democracy and freedom. Yet these institutions are typically quite autocratic. Learners do not get to participate in meaningful decisions regarding their own learning and development. Villagers feel that schools in places like Nong Baot have no relevance to their lives. They do not get to engage meaningfully or effectively in what is important to them. Neither do they get to have an impact on their environment.

This work begins to change that situation. *Not only do the participants have a share in the control over their activities in the learning environment, but also this control is extended to their living environment.* They practice critical questioning of and engagement with their world. They change their agency from passive (or resistant) to active. Rather than waiting for others to examine, decide, and act, they take these roles for themselves collaboratively. This fundamentally changes their relationship to their environment, the institutions around them, and among each other. Rather than waiting for the government to build a dam and fail (!), they take this on for themselves. Rather than wait and stagnate, they investigate and create new business cooperatives like mushroom farming or vegetable growing. The feeling that one cannot do difficult things because one

is “just a simple villager” is replaced by feelings of competence. As one villager in Nong Baot expressed, “I stayed awake all last night because I realized how little I have done and how much more I can do. I feel like I have wasted so much time but now I am anxious to use what I am learning to improve life in my village." Another told us that "I used to feel that math was chaotic, with numbers floating all around. Now I can pigeon-hole them and give them meaning. I can use this to better decide what to do.” While these are self-reports to a receptive audience, the speakers' changes in actions also attests to their changes in beliefs. It is these changes of sentiment, more than learning any subject, that is the most important outcome of this type of engagement.

Just as Lave illustrated how much school learning is decontextualized and disconnected from the lives of most people and thus is later left unused, others have joined this trend, perhaps in less thoughtful ways, and advocate "authentic" activity as a basis for schoolwork. This movement arose as a reaction to schoolwork children feel disconnected from their interests and experiences and irrelevant to their lives. Moreover, because there is little connection and involvement, there is little recall or use in other, real-world situations where the learning is intended to be applied. Thus, the advocacy of authenticity. While some attempts by textbook publishers trivializes this concern by using the same problems and examples and merely substituting brand-name products such as certain sneaker manufacturers or types of candy for use in mathematics texts, others are more serious by studying biology through investigation of pollution in the local stream. Still, this focus on authenticity by virtue of appearance in the real world misses a major point.

As this section detailed, learners within Project Lighthouse certainly focused on many authentic problems and gained in many dimensions through this process. However, virtually all of them simultaneously also constructed projects in imaginary or even frivolous domains. For example, many constructed playful animations, computer games, multimedia stories, and other such arguably *inauthentic* projects. Still, they benefited not only from that experience directly, but they also benefited in their construction of the real-world projects from the technological fluency gained in the more fanciful, playful projects.

Important to this success was that all of the projects were chosen by the participants. The projects achieved authenticity not by the domain or connection to the real world, but because the choice was in the control of the learners who were not being coerced to do something they did not want to do. While the learners developed a more sophisticated, robust fluency through computational expression in multiple projects, the more fanciful projects were not used merely as an exercise before attempting the real world projects. The expressive nature of the tools allowed them to develop fluency with computational thought in their own vernacular and towards their own interests. Whether these interests were in making games or making dams, they remained *connected* to their interests, passions, and ideas, and, therefore, authentic.

5.4 Constructionist Computational Technologies

The mathematics of the dam and other water projects in Nang Rong were significant and varied. As the mathematics were situated in real world problems, they were not so obvious as in textbooks where the questions test the material recently presented. In our work in Nang Rong, how to represent a problem, what to do, what types of mathematics to use, how to express it, thinking mathematically, combining algebra, geometry, computation, and even some calculus, and coming up with viable answers, were all integral parts of our work. In a School sense, this is much more difficult than School math. Yet, our participants, teachers and students alike, did this work successfully. In a School sense, this should not have been really possible as they did not go through and pass the prerequisite mathematical knowledge.

Lucy Suchman, in her book **Plans and Situated Actions** [Suchman, 1987], described differences between how navigators explained what they did and how they actually performed. Their explanations were perfectly rational and reasoned, and they implied that it was this reasoning that guided their actions. However, she demonstrated that this capability was really post hoc and just an explanation for justification.

School curriculum often functions in the same way. Once we have learned something, we can look back at how we construct the logic of the domain. We look at what bits of knowledge are the basis for others. The potential pitfall for curriculum developers is that we then assume that we must learn the domain in the order of the building blocks. Is this truly the case, though?

In Nong Baot we saw the people use the mathematics for their projects. The more projects they did, the more fluent they became with the mathematics. We did not spend years preparing them for the high school and university level math they performed. Still, they accomplished everything they needed. Likewise, we did not spend years preparing them for the programming and computational thought they performed. Again, they accomplished everything they needed. They truly were developing their fluency with mathematics and computation, working on difficult, real world, conceptually rich projects of their own choosing.

There are similarities in this work and other work recognizing mathematical knowledge and use in informal settings. Foremost among this is the work with Brasilian street children (Nunes and Bryant, 1996, Nunes, Schliemann, and Carraher, 1993) and the work of Jean Lave (Lave 1988, Lave and Wegner, 1991). In the work with Brasilian street children work the researchers demonstrated the capabilities of the children in dealing with mathematical problems when the problems were posed in situations with which they were familiar from their lives in the streets. However, when the same conceptual problem was presented in a school context, the children could not perform the same calculations they performed when dealing with street situations. Their deficiencies were not in intelligence or even mathematical ability, but rather in handling a decontextualized, not personally meaningful, school context.

Likewise, Lave demonstrated how people really solve mathematical problems in real situations. The people she studied did not use conventional school formalisms, yet they

were proficient in solving real world math problems in the kitchen, in the grocery store, and so on. Lave successfully challenged the school mindset of math learning and proficiency for the real world.

A significant attempt to restore principles from learning by doing and providing context and authenticity to the work of learners falls under the rubric of the *cognitive apprenticeship* and *situated cognition* [Brown, Collins, Duguid, 199x, xxx yyy]. While there is no definitive treatise on cognitive apprenticeships, and thus it is not possible to specify exactly what they are, for the most part they invoke the image of apprenticeship learning as in a craft. They advocate learning in the practice of authentic work, not merely school busywork. They add the modifier cognitive to apprenticeship to emphasize that one can not merely learn crafts such as carpentry or masonry via apprenticeship, but also more typically academic domains such as math and science. Learners work on actual projects under the tutelage of masters in the domain, the role for the teacher. They begin with simple tasks and work their way to more complicated ones as the apprentices gain mastery.

Jean Lave and Etienne Wegner attempted to "rescue the idea of apprenticeship" from over-generality by delineating what they term *legitimate peripheral participation* (LPP) [Lave and Wegner, 1991]. They write:

> In our view, learning is not merely situated in practice -- as if it were some independently reifiable process that just happened to be located somewhere; learning is an integral part of the generative social practice of

> the lived-in world... Legitimate peripheral participation is proposed as a descriptor of engagement in social practice that entails learning as an integral constituent. [p. 35]

Lave and Wegner restore primacy to activity in contexts without resorting to over-simplification. After describing a number of apprenticeship situations, they add:

> ...researchers insist that there is very little observable teaching; the more basic phenomenon is learning. The practice of the community creates the potential "curriculum" in the broadest sense -- that which may be learned by newcomers with legitimate peripheral access. Learning activity appears to have a characteristic pattern. There are strong goals for learning because learners, as peripheral participants, can develop a view of what the whole enterprise is about, and what there is to be learned. Learning itself is an improvised practice: A learning curriculum unfolds in opportunities for engagement in practice. It is not specified as a set of dictates for proper practice. [pp. 92-3]

While compelling, their version does not account for the type of learning witnessed in Thailand. Perhaps not surprisingly, the contexts they investigated were apprenticeships and everyday life. Although they add considerable depth to understanding how apprentices learn, it is straightforward to view apprentices learning within as legitimate peripheral participants in communities of practice. They also note the role of children as learning as legitimate peripheral participants in adult world.

What, however, would be the community of practice in the Thai situation? The participants are quite at the center, more in control. What is learned also goes beyond learning math by being in a community of practice of mathematicians. Participation while immersed in a constructionist mathematics culture is a key component of our learning environment. However, the integrated nature of the environment extends beyond mathematics. With emphasis on control and critical questioning of and engagement with their world, developing fluency with mathematics and computation become tools for this engagement.

In *An Exploration in the Space of Mathematics Education* Seymour Papert challenges his readers to consider not merely reforms of mathematics education, but complete alternatives [Papert, 1996]. He proceeds to propose a number of dimensions on which to judge among the alternatives. One critical dimension is on the empowerment and disempowerment of ideas. Much of our work in Project Lighthouse was around this dimension. It could be argued that the school experience of the Thai villagers with whom we worked fell on the wrong side of the empowerment axis. Their mathematics instruction led them to feel not merely that the school lessons were irrelevant, but this was also internalized as not being intelligent, as just being "simple villagers." Yet, when having the opportunity to work on projects significant to them, the mathematical ideas were empowered, and, subsequently, they felt empowered.

William Thurston in his essay *On Proof and Progress in Mathematics* discusses what it is that we do when we practice math and makes some proposal about why we do it.

> ...as mathematics advances, we incorporate it into our thinking. As our thinking becomes more sophisticated, we generate new mathematical concepts and new mathematical structures: the subject matter of mathematics changes to reflect how we think. [Thurston, p. 340]

He goes further in discussing why programming is a legitimate and important operation within this endeavor. The work of the Thai villagers provides an unlikely but compelling site as an example of Thurston's ideas. He writes "The standard of correctness and completeness necessary to get a computer program to work at all is a couple of orders of magnitude higher than the mathematical community's standard of valid proofs." [p. 347] He adds "There is a real joy in doing mathematics, in learning ways of thinking that explain and organize and simplify." [p. 349]. And also, "Finally and perhaps most importantly, a mathematical breakthrough usually represents a new way of thinking, and effective ways of thinking can usually be applied in more than one situation." [p. 350] While he is talking about professional mathematicians, the statement is just as compelling when thinking about Thai villagers and mathematics, or children anywhere and mathematics. In our work we are attempting to enable people to feel the joy and the power of such mathematical thinking and fluency.

The role of constructionism within this endeavor cannot be underestimated. It can be argued that a constructionist approach is what enabled the connection to the local

knowledge of the engine culture of the young men, as well as the entrepreneurial culture of the women's cooperatives. By constructing real projects of real concern to them, they discovered the need for fluency with powerful mathematical and computational ideas. By working in cultures where there was knowledge of and passion for these ideas, the learners were able to construct their own understanding of these ideas. Rather than being "simple villagers" incapable of doing complex math, they were learning their own capabilities by their critical engagement with their world.

5.5 The Grammar of School and Powerful Learning

A primary goal in Project Lighthouse was to break mindsets about how learning takes place and what learning environments should look like. The success in connecting to the indigenous knowledge of the people, particularly those who had not previously done well in school, provides an existence proof of the possibilities. The fact that these powerful examples occurred out of the traditional school context questions the status of existing school methodologies.

If we look at school reform as a design problem, rather than as an existing entity to be incrementally modified around the edges, then we can see certain factors in a new light. Rather than taking certain elements as given, we can view them as design choices. Too often school reformers take as inviolate constraints elements that actually could, and should, be variable. An example of an interesting, well-designed project provides a salient example of this.

Janet Kolodner and some colleagues at Georgia Tech University also stresses the importance of design. They designed a very nice, thoughtful activities that placed the students in the position of designers on open-ended problems [Kolodner et. al., 1998]. One module is "Vehicles in Motion" which presents several design challenges to students. One challenge is to design mechanically-powered vehicles to carry heavy loads over a hilly terrain and another is to design balloon-powered systems.

Unfortunately, the constraints of the school interfered with the activity. They write "where we integrated designing with investigation and where we made sure that students were constructing and testing the devices they were designing, we found that *construction took too much time, that it required 'authentic' materials, and that teachers needed to understand the underlying science well to be successful facilitators*" [italics added]. The authors themselves state that the changes through time to there approach left "It is also far more structured and focused than we could have imagined."

What was their reaction to the limits? They decided to eliminate the harder, more time consuming elements of the project. Rather than have the students design their solutions fully, they only let them choose parameters and make small choices within a provided environment. Thus, they eliminated the primary elements that made the project interesting and fruitful. They did not do so because they felt it created a better learning environment. Rather, they did so in order to fit into the constraints of school as it is. When the constraints of school processes debase learning activities, then why do we not question and change the very processes that limit the learning potential?

5.6 Technology and Poverty

It is a legitimate question to ask whether it is wise to spend the considerable amounts of money on technology for children and learners in areas of poverty. Early experience shows that deploying technology can be an important component in human and economic development. However, this can only be understood in the long term and the project is still too recent for a judgment.

However, certain factors are critical. Participants in Project Lighthouse did not suffer from extreme poverty. To our knowledge, everyone had at least minimal shelter, food and clothing. Thus, donations of technology did not replace potential donations of necessities for subsistence.

The cost issue is rapidly changing, even in the short two years of Project Lighthouse. The price of computers is dropping dramatically. There is no technical reason why this should not continue. It is feasible that viable computers for children could be available in the very near future for under two hundred United States dollars. This drastically changes the cost equation.

Maintenance does need to be the large expense that it often is in educational institutions. Rather than being a pure expense, it can be a learning opportunity. Students who want to receive vocational training can practice and learn on the equipment. Rather than paying to install, maintain, debug, and diagnose system, network, and application software, the

students can also learn by doing this. This makes much more sense than training in inauthentic situations and simultaneously reduces costs significantly.

An early experience in Project Lighthouse can serve as the final point on this matter. On Papert's first visit to Thailand he was taken to a school in Bangkok. Upon visiting the computer lab, he saw a number of brand new Pentium machines. However, almost half of them in the lab were not functioning. When asked why, he was told that they had been broken for some time but the school always had tremendous difficulty getting repair people to come to service the machines.

When he subsequently visited a computer lab in the rural north, he noted that all the machines, none of them new, were functioning. He asked the woman in charge if they ever broke. She replied that of course they did. He inquired what did they do when they broke. She responded that she would get all her friends together and they would jointly try to figure out what was wrong and how to fix them, and, until the present, they had always been successful. This was our first encounter with the bricoleur spirit in rural Thailand.

5.7 Teachers' Capabilities

Another salient observation with an important bearing on the assessment of the world's learning potential is the pattern of learning we observed in teachers. An assumption that runs through discussion of education reform in developing countries is that most teachers, especially rural teachers are "under-qualified" and incapable of learning and teaching

advanced new ideas. However, our observations in Thailand that go directly against this assumption are consistent with what we have seen in other places, especially Costa Rica. In many ways the so-called under-qualified teachers turn out to be more capable of learning new methods! And, in particular, the constructionist approach taps into and draws out their expertise, sensibilities, and experience.

Just as many of the young learners could build from their experience with engines, so too could the rural teachers. Just as many of the young learners were competent bricoleurs, so too were many of the teachers. Just as working from real projects connected to the interests and expertise of the learners, so too did it connect with the teachers. In this situation, rather than working from a position of weakness in relation to the power and structure of academic institutions, these teachers were now working from more of a position of strength. They were able to draw upon their own experiences, their own interests, and work on projects of benefit to themselves and their communities. The teacher in Nang Rong who worked the most on the dam and irrigation projects actually asked me if he could continue to work with the villagers on these projects after I left. He insisted upon how important it was. When I told him that their continuing was the whole idea, he began working even harder.

Some policy-makers and economists have commented that the constructionist use of technology for learning environments in developing countries works well among the elite there, but is not viable for the majority of people and situations. This work provides an existence proof that this assumption is wrong.

5.8 Development Time and Fluency

Before beginning Project Lighthouse we proposed that the teachers participate in six weeks of workshops and have at least six weeks to develop their own projects. We believed this to be the minimum amount of time to enable them to begin working with students. Even this amount of time is merely a beginning.

As the fits and spurts of Project Lighthouse demonstrated, the accomplishment and development of the rural teachers required an intervention. They needed the opportunity, time, and access to people and resources in order to develop their own fluency with the new methodologies for learning and new technologies. Providing only a rudimentary introduction certainly opens minds, provides a basis for introductory work, and allows people to learn the syntax of the languages and the methodology. However, the deeper results arise from having deeper understanding and rich experiences. While we witnessed this with some of the participants, for the most part too many of the teachers were not allowed adequate time to learn, to develop their own projects, to discuss ideas with their colleagues and others.

Yet, we find repeatedly that administrators do not want to allow such development believing it is too costly. However, this view of costs is short-sighted. While it certainly is a cost to free teachers for such an amount of time, there is a much greater long-term cost because teachers are often afraid to go into domains they do not know well and work with materials with which they are not comfortable. This later impedes the progress of

the learners and of the learning environments. The social, educational, and, arguably, the economic costs of this is the long-term far outweigh the initial develop-mental costs.

Unfortunately, we saw several instances in Project Lighthouse where promising projects were aborted because the teachers lacked the confidence in their abilities both technically and also pedagogically. Rather than dive in and try whether they knew or not, they were uncomfortable placing themselves in a situation where the learners could see they did not know the answers. While often this makes for powerful learning situations as the learners can see how a more expert learner, the teacher or adult, goes about learning and working on problems when the answer is not known in advance, the teachers, accustomed to a more rigid, predictable, rote-learning environment pulled back. While understandable, this was quite unfortunate. This lack also reflects upon the need for support and mentoring for the teachers, which, while planned, did not occur at the level needed. This is addressed more fully in the subsequent section.

5.9 The Need for Mentoring, Research, and Discourse

Another critical element to the project that was never put into practice was the creation of a "Fellows" program. Our goals for the program were to:

- mentor and support the sites
- provide expertise in the target pilot areas
- research and document the project
- help disseminate the findings
- help educational and other institutions appropriate the positive results

- promote a better public discourse on learning

However, we were never successful convincing the Thais of the necessity for such a body. The Suksapattana Foundation ran according to the way of most Thai foundations. Certainly, Khun Paron and Khun Bangkok Chowkwanyun, and previously Anita Horton, worked tirelessly on the project. They opened many doors, coordinated and managed all activities, spread the word about the project, and learned a considerable amount about learning and technology. Yet, in some ways the project did not progress as hoped simply because despite the intelligence, talents, and incredible efforts by the people mentioned above, the goals for the project through the Fellows program were beyond the capability of any two or three people to accomplish.

5.10 Emergent Design

Popular views about design, about reform, about planning, about control typically lag behind progress. New organizations are pioneering new means of control and change. Emergent design is the recognition that certain systems are too complex, dynamic, inter-connected, and chaotic to attempt to manage them by top-down, pre-planned, rigid means of control. Large educational systems are one-such system. The human brain is another. That this project is simultaneously involved with both systems is all the more reason to take an emergent approach.

The assumption of this work, leading to its advocacy of emergent design, is that no matter what one plans and does initially that there will be surprises, that people will not

and should not blindly follow but will construct their own understanding of their work and roles, and adapt according to their beliefs and positions. This is not a deficiency. Rather, it was the ability to be open that enabled us to see plainly the energy and expertise of the youth in the engine culture and the women's cooperatives. Indeed, if one is to follow the interests and expertise of the learners one must be prepared to adapt and continuously revise plans and activities. While this was a tenet of Dewey, modern computational and telecommunications technology unavailable to Dewey and those who followed him enables the creation of such environments on a broad scale.

By utilizing emergent design, Project Lighthouse was able to expand to Mae Fah Luang and Lampang immediately. This produced excellent results in each site. This enabled each site to focus on the activities most meaningful to that particular site. Each site used the same constructionist principles, the same technologies, and the same focus on technological fluency. However, each site developed according to its own special needs, interests, concerns, and culture. In this way, rather than every site everywhere following the same set curriculum over the same time period regardless of context, interest, or social situation, each site is free to maximize its efforts. Moreover, transferring control to the sites and to the learners is important in its own right for the development of responsibility.

5.11 Design All the Way Down

One can think of a radical reform as a learning project through and through. Activity and mindset are different at every level, whether administrator, teacher, or learner, than they

were in the previous formulation. As such, it makes sense to employ the best means for learning for every level and every person. In our formulation this implies a constructionist design and activity consistency throughout the project. Thus, there is constructionism *in* and *of* the learning environment. As design is shown to have tremendous potential for learning, we extend the design of the learning environment all the way down through the project.

In traditional reform efforts, the reformers achieve the best understanding of the goals and methods of the reform because they are the ones constructing them. It is then up to them to transmit these goals and methods throughout the large, widespread organization. While the reformers may be pleased with themselves, in practice this rarely, if ever, works. The mindset of the reformers is to blame the quality of teachers, or administrators, or even the students for not implementing their plan properly. However, as many have observed in other domains, this is always going to be the case [Shiba et. al. 1994]. People will implement based upon their own understandings, their own points of view, and their own goals. In such systems where the understanding of everyone, not merely the upper management, is the key element, then obviously the development of each person is critically important. For them to develop, they need to construct and take responsibility on their own.

Clearly, this will not happen without *mistakes* being made. However, the word mistake is somewhat misleading. We often learn best from our mistakes. If one is not allowed to make mistakes, then there is little chance for exploration, for reformulation of ideas, for

learning. The other side of the equation is that imposing one's will on those below may get the immediate activity desired, but will also create other undesirable side-effects.

An example of the positive effect of design all the way down is the development of the teachers and coordinators of Project Lighthouse. If the MIT group had made a fully detailed five-year plan as some requested, this would have denied the opportunity for development of all the teachers who put so much effort into the project as practitioners, researchers, and leaders. The coordinators such as Khun Paron, Dr. Suchin, Khun Bangkok, Ajan Jirachai, Ajan Ackachai, Anita Horton, and so on, would not have had the opportunity to develop as they did. Their comments and understanding of learning and learning environments from the beginning of the project to the current time have grown tremendously in depth and complexity. Not only did they develop, but also the project was tremendously enriched by their growth and initiative.

A natural conflict often emerges when people at all levels are empowered. Those at the previously higher levels may resist the changes and the loss of authority. However, for any project that strives to be democratic and help people to develop autonomy and responsibility, then this is a necessary conflict to emerge. Learning to coordinate and collaborate in new ways of sharing control was a goal of the project, and, indeed, emerged within the coordination of the project itself.

Chapter 6 –Conclusions

6.0 Overview

The primary conclusion to be drawn from the work discussed here is that global learning potential has been grossly underestimated. A second layer of conclusions concern the effectiveness of certain methodologies of promoting learning. Finally, a third layer addresses meta-questions of how to think about the design of innovations in education.

I contend that the primary conclusion is supported beyond any reasonable doubt as something that applies across the globe. *The barns that hid indigenous technology also hid latent expertise. This expertise provides a solid foundation upon which to build and leverage other learning. The constructionist use of computational technology on real-world projects provided the means to expose this hidden expertise and leverage it into powerful learning.* Our investigations bear directly only on a small number of sites in just one country and even there looked at a fortuitous sample of "latent expertise." But I contend that it is utterly compelling as an "existence proof." It shows that it is possible in principle to bypass commonly held assumptions about the conditions of learning. Moreover, I will note that some of the observations in Thailand are consistent with those that can be drawn from different but related projects in other countries, notably Costa Rica, and also the United States.

The second layer of conclusions is equally compelling when read in the spirit of providing existence proof: *the observations presented in the body of this thesis confirm that a certain pattern of constructionist learning will at least under some circumstances*

release latent learning potential that is hidden by standard models of education. I cannot make a strong claim that the methods as we put them into operation in Thailand can be directly generalized to provide a solution to the educational problems of the world or even of Thailand. But I maintain that they provide a compelling point of departure for discussion of new approaches to promoting learning.

On the third level, I contend that *the experience as a whole demonstrates beyond any doubt the possibility and necessity of a different and more flexible approach to the design of educational interventions.* Moreover, I maintain that by doing so it introduces a new *conceptual dimension* into educational discourse, which has not in the past included any kind of consideration of the nature of design as a theoretical theme. Recognizing the study of design – the consideration of alternative modes of design -- as a theoretical dimension for education provides a framework for bringing together in a systematic way a number of concepts (such as "breaking mindsets") that were present in an ad hoc form in the initial design of the Lighthouse project and some experiences in other constructionist education projects (e.g. the collaboration between the Media Lab and the Omar Dengo Foundation in Costa Rica). However, while I feel quite secure about the firmness of these conceptual contributions, the *particular details* of design methodology followed in this work is offered in the spirit of a very preliminary exploration. Indeed, some of the conclusions on this level bear on weaknesses in the work in Thailand and lead to suggestions for improvement.

6.1 Hidden Learning Potential

The most salient of all our observations in Thailand is typified by realizing that the mechanical innovations hidden away in the barns of what appeared to be simple villages also hid the latent expertise of the villagers. The list of indigenous technologies developed is incredibly impressive. People learn in informal situations not only to repair these contraptions but also to hack and kludge, to work around, to innovate, to adapt to local situations and needs. The skills needed to do this successfully are significant and are a major subset of the skills desired by educators. Yet, when surveying the educational state of Thai society, rather than being counted as a strength, the rural areas are viewed as backwards, in horrible shape, and perhaps not even savable.

Before we began work in Project Lighthouse, people criticized our plan stating that rural teachers would not be able to learn the technology, let alone teach with it. Perhaps the most important accomplishments in Project Lighthouse were the recognition of the intelligence and expertise of the people and teachers in the rural areas, and the concrete demonstration of how technologically rich, constructionist learning environments could build upon and leverage this experience and expertise

6.2 Alternative Paths to Learning

In these examples, as in Thailand with the engine culture, people learned what they needed in informal settings. The key to where my work goes beyond theirs lies in the generative power of the constructionist use of digital technology. The commentators are impressed that the Brazilian street children learn some elements of mathematics because

it is rooted in their lives and interests. Agreed. And this is how the Thai villagers learn about motorcycles and internal combustion engines. The difference lies in the next steps. Arithmetic is useful for the Brasilians. But it does not open out onto larger areas of knowledge. The internal combustion subculture in Thailand went a little further. In particular it supported the development of a bricoleur attitude and a degree of self-confidence in learning and inventing. But the larger difference came when we introduced digital technology. This technology is learned in a manner that is close to the situated learning recognized by Suchman.

The new feature is that it carried with it many embryonic forms of powerful ideas of science, mathematics and management and serves as a bridge into appropriating these ideas and the areas of knowledge built on them. *The constructionist approach, immersive environments, building technological fluency, and applying this on projects of interest and importance to the participants combine to break through barriers to learning and break mindsets about what is possible and how learning environments must function.*

6.3 Design all the way down

The third level of conclusions bears on the idea that consideration of design has a bigger role than has been given it in thinking about education. How can we assess the degree to which the work in Thailand supports that idea?

(1) First I submit that the idea itself came from this work. Of course it might have come independently. But the fact is that it did not and so the work should get some credit for engineering the idea.

(2) More specifically, I submit that any idea that a pre-designed curriculum could have done what we did is open to the following objections:

- Arguably it would have been impossible for any curriculum design committee to have anticipated these actions
- Even if the usual practice of "covering" all the knowledge to be learned were possible it would require enormous expense and risk drowning the specific knowledge we found so useful in a mass of knowledge that could potentially be useful.
- Even if the actions could have been anticipated in a cost-effective way, doing so would have deprived the local practitioners of the benefits of learning to design their own teaching and learning experiences.
- The best results occurred when there was a close connection among people, or among people with a passion for a particular domain area or way of working, or a connection to the interests and needs of a community, or to take advantage of a particular time. This is inherently unpredictable and the results themselves only emerge when provided the freedom to capitalize upon opportunity. Could the discovery of and connection to the engine culture have emerged otherwise? It certainly had not previous to this work.

(3) Project Lighthouse did overcome a number of obstacles to the idea of Emergent Design, among which were the absence of good local examples of the kind of features that could come about emergently. I conclude this section by discussing a central example: the role in education of mindsets.

What do we mean by mindset? Mitchel Resnick refers to a centralized mindset when he demonstrates how his StarLogo environment can facilitate shifting this mindset to better investigate emergent, decentralized phenomena [Resnick, 1997]. A major portion of the work of Papert deals with changing mindsets both with regard to learners and educators thinking about learning environments [Papert, 1980].

We can think of mindsets as what exists within a paradigm. Rather than being able to objectively reason our way through every situation, we are predisposed to look at data, at causality, and at remedies and activities through the filter of our mindsets. For example, an educational administrator may look at a room full of children busily scurrying around, talking animatedly with each other, having no overall center of attention, working on a variety of things, and have a mindset that this situation is disorderly, confusing, chaotic, out of control, and non-productive. The administrator may want the teacher to clamp down, impose discipline and order, and make everyone sit in their seats. A different type of educator may view the same situation and have a mindset that this is active, engaged, creative, and joyful. This educator may encourage the teacher to keep up the good work.

The difference in reaction and remedy reflects a difference in mindset about learning environments.

How do mindsets change? Kuhn reminds us that one reason why paradigms are important is simply because they are stable and do not easily change. Mindsets do not necessarily change by dint of logic or persuasion. Even when things are not working satisfactorily, the first and often the only inclination is to look within the same paradigm, within the same mindset. However, when enough evidence accumulates that is sufficiently compelling to challenge the existing mindsets, the possibilities for change are open.

The goal of this work was not to provide a blueprint for a new educational system. It was not to produce a reform in its traditional sense. My view is that history has proven this is rather hopeless. Rather, the goal was to change mindsets about the operation and necessities of learning environments. The most important element in order to achieve this was to provide concrete examples that go against the established mindset. If these examples provide an existence proof, particularly working in situations proven most difficult according to existing mindsets, then the evidence is all them more compelling. This work, although accomplished with minimal resources, succeeds in providing such an existence proof. The next steps are to refine and to expand; to experiment more boldly; to believe all human potential; and to work to enable all to achieve their potential.

Robert Pirsig's book Zen and the Art of Motorcycle Maintenance is a novel about different styles of thought [Pirsig, 1974]. Pirsig questions the limits of rational thought and restores privilege to emotion, to aesthetic, to the bricoleur approach. It is not the point here to accept or to reject Pirsig's work or philosophy. However, it bears noting that a philosophical stance no longer accepted by most maintains a vice-like grip on educational thought and practice, and even on most educational reform efforts.[1]

Despite a growing acceptance of new approaches to management and organization, and to change and management of change, the mindsets in educational institutions and of educational reformers remains, for the most part, mired in the paradigms of the past. Reform efforts remain top-down, rigid, and fully planned. To suggest otherwise is deemed unscientific, irresponsible, or incomplete. Curriculum is set as the one best plan. A reform must proposed the new best way and it is up to educators to implement the exact plan or they are at fault or incompetent. The reform plans dictate the best way to implement the changes.

The view here is that there are alternatives. This work does not suggest the new best way. Rather, it strives to illustrate possibilities, to provide examples, to propose alternatives. Rather than accepting planned hierarchical systems as the most privileged model, a more biological model of system, with instantiation, adaptation, and propagation. Current views of complex systems highlight the problems of planned hierarchical systems in dealing with highly complex, dynamic systems. Biological

[1] George Lakoff and Mark Johnson term this the *obectivist* stance and provide a compelling examples of how this type of philosophy permeates our thought.

models are proving more fruitful and resilient. It is time we change our mindsets regarding what learning environments need be, and how we must plan and work to change and improve them.

A sample of failed top-down approaches is addressing the inequities in modern societies. One of the major goals behind Project Lighthouse was to begin to address the widening chasm between rich and poor, both within and among societies. Such deprivation and widening gaps is unconscionable at a time of unprecedented wealth and possibilities. This problem is complex and has many inter-related and hard to detect causes. Even when explicit and oppressive controls are removed, it appears that certain people and groups remain mired in cycles of poverty. How to escape and transform the situation is fraught with difficulties.

The work in Project Lighthouse, while only a very rudimentary beginning, provides hope for the possibilities of change. All areas have a wealth of expertise. We now have better potential to enable people to take control of their own learning, their own environment. We now have an improved potential to learn and to develop in accordance with the wishes and the cultures of local areas. What is required are changing mindsets and the will to try.

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