Leveraging Learning through Technological Fluency

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Abstract

This thesis will describe a new initiative, Technology Works Enterprises (TWE), a radically different learning environment for low-income, at-risk adolescents. Traditional vocational education, particularly for youths who do not excel scholastically, does not meet the needs of the modern economy nor of the youth involved. I will use in depth case studies of the individuals and the developing learning culture to highlight thow the approach described here can succeed. I will probe which aspects of the technological and educational infrastructure of Technology Works helped to make the project successful. Finally, I will review how this approach compares with other related research.

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Leveraging Learning through Technological Fluency

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1. Introduction

During the summer of 1995 I was able to take the leading role in creating a technology-based learning environment in which high school students who were deeply disaffected about school, society and learning went through a turnaround experience. This thesis documents the events and presents some case studies to show how individual participants responded to the experience.

There are three primary goals to this work:
1) To document that it is possible for at-risk adolescents without prior school success to demonstrate significant achievement on difficult projects.
2) To probe and clarify which aspects of the technological and educational infrastructure helped to make the project successful.
3) To articulate the knowledge and ideas needed to create this type of learning environment.

In particular, the questions I will address include:
- How can deep learning occur where there is no pre-set curriculum, but rather where the paths and materials grow out of the interests of the learners themselves?
- Does the concurrent learning of several programming environments support deeper learning experiences in each?
- How do these learning experiences leverage learning in other domains?
- In what ways can "immersion experiences" contribute to the development of technological fluency?
- Can the development of technological fluency lead to the necessary capabilities and preparation for employment?
- What constitutes a finer-grained sense of the types of activities needed to truly benefit by learning by doing?
- What experiences and activities can lead to a richer repertoire of heuristics for teachers to apply dynamically rather than programmatically?
- How can we get a better understanding of how, when and when not to intervene in children's learning experiences?

This thesis will consist of a description and analysis of the interventions and interactions at the project and how over the course of the summer they impacted upon the actions of the students. I will use in depth case studies and a large number of examples of learning stories in order to pass on these experiences so that they can be incorporated, adapted and improved upon in other settings.

1.2. Motivation

"There is no need to add to the criticism of our public schools. The critique is extensive and can hardly be improved on. The question is what to do. ..the

'crisis of the school' consists in reality of a great many crises in the lives of children..."
- George Dennison, **the lives of children**

This statement, apropos today, was written almost thirty years ago. If anything, since then the crisis of the school and the crises in the lives of children have worsened. In the interim educational researchers and practitioners have developed many new technologies and methodologies. Yet the potential benefits, particularly among the poor and minorities, have gone largely unrealized.

Conventional wisdom and practice within the educational establishment is that a loosely structured, fast-paced, personalized, learner-driven, project-based, intellectually challenging, peer collaborative learning environment is appropriate only for youth deemed the best and the brightest, those who are selected for advanced work classes. This same point of view relegates those who have not done well to an almost opposite environment; highly structured, slow-paced, standardized, directed, task-oriented, intellectually-stultifying, non-collaborative environment.

This thesis takes the exact opposite direction for at-risk youth. We provide them with the same challenges and freedom normally only afforded to the elite. This project is an existence proof of the validity of this approach for that population.

The need to address the needs of this segment of the population is critical. Many societies are facing a crisis with their youth brought about by the confluence of various major structural and attitudinal changes. These include the changing nature of work, the dysfunction and subsequent distrust of large, bureaucratic institutions, and the alienation felt by many young people. The symptoms of this crisis include large-scale, structural unemployment and underemployment, high drop out rates, substance abuse, and increasingly pervasive and brutal violence. A large segment of a whole generation risks being permanently disenfranchised and marginalized due to being unskilled and unprepared for active and productive participation in modern society.

Not only does this work describe the utilization of a different approach to working with at-risk youth, it also describes a different approach to achieving the mission of vocational education. Vocational education, and much of traditional school-based education, is designed around the premise that the prototypical job is working on an assembly line. For youth who were pegged as most likely to wind up in an assembly line job, this meant learning environments where punctuality, obedience, and rote skill were privileged, and individuality, creativity and problem-solving were not so important, if not discouraged outright [Anyon, 1981]. However, the nature of work is different and the prototypical job now requires the ability to learn, to analyze and decide, to think flexibly, to draw from a broad range of experiences and skills, and deal adeptly with a wide range of problems, people, and situations. Successful companies utilize rapid and accurate observe-analyze-decide-act cycles, and technology plays a large role in each phase. Certainly, preparedness for work includes the development of expertise in the mode of work and thought, and of facility and fluency with technology. This does not imply merely a familiarity with computers in the shallow sense. Rather, this thesis demonstrates a powerful use of technology is not merely to augment performance of work processes, but to help open new areas of knowledge to more people. This work describes a way to achieve this.

Another fundamental change in work is that career paths are totally different, and vocational and traditional education have not kept pace with this change. People now expect to change employers, and perhaps even careers, relatively often. In the past career paths were rigidly determined at young age. There was a strong differentiation between experts/professionals, who had access to knowledge and were expected to treat the problems, and the common people who did not have access to knowledge and were, in a sense, to be treated [Ilich, 1970]. A very different outlook and methods of practice are needed when there is a need for life-long learning, and information technology provides everyone access to more knowledge than the experts of the past could command. Work preparedness must include adapting to this new type of world and helping everyone develop their ability to learn how to learn.

1.3. Scope

This work describes my involvement with the at-risk adolescents at the first phase of Technology Works Enterprises (TWE1). The first phase is known as the Technological Fluency Immersion Program (TFIP). Technology Works Enterprises (TWE) itself is a broad initiative scheduled to begin in January, 1997. In the summer of 1995 we ran TFIP as a pilot project to test the feasibility of some of the premises of TWE. This thesis will provide an overview of the TFIP project and its social and educational rationale. I will use case studies of learning stories to highlight and provide depth to the critical factors. The thesis will explore lessons from this involvement to shed further light on concepts in learning and the design and use of technological tools. Finally, I will address issues on dissemination of the methodology and new technologies for learning.

1.3.1 Technology Works Enterprises: School that's not School

As Project Coordinator for TFIP, I was part of the planning process for the endeavor, and then had day-to-day responsibility for the implementation of the project. TFIP ran as an initial pilot project for seven weeks in July and August, 1995, 7 hours per day, 5 days per week. Twelve low-income adolescents from rural Maine participated in the project. None of them had experienced academic success and all had bleak visions for their futures.

This thesis describes how a different approach to learning that uses technology as a primary tool can leverage learning among a population that, while they must use significant intelligence to survive in a difficult environment, do not view themselves as intelligent or mobilize this intelligence in other, particularly academic, settings. In particular, this thesis will attempt to unpack and provide exemplars for the guiding concepts of Constructionism, learning by doing, authentic activity, and the construction and leverage of powerful ideas.

We envisioned Technology Works Enterprises as a radically different approach to what could be called vocational training. Tech Works will be a broad effort running over a number of years providing new paths to preparing for work in a knowledge-based economy. We envision that the youth, once they undergo a Technological Fluency Immersion Program, will flow between TWE, work, and perhaps school, as determined on an individual basis. TWE will not operate like traditional vocational education projects, but will incorporate principles from Constructionist-based learning.

To test the feasibility of using the concept of Technological Fluency as a viable basis for long-term, practical benefit, we ran TFIP as a seven-week pilot project. Thus, what we did and how we did it were altered to fit the time constraints. We believed that by developing a technological fluency that this could be leveraged into an ability to work on various problems later. We knew that since the pace of technological change is so furious, that any particular language or tool that they might learn in this summer was bound to be different or obsolete soon thereafter. Thus, we did not want to micro-train them on any specific technology. Rather, we wanted to utilize open-ended technologies with which they could develop this technological fluency which they could always use in other settings.

This is very different than the approach normally taken in vocational education. Usually there is an overwhelming skill-focus on particular tools. We were criticized by other project leaders for not teaching word processing or keyboarding skills. This is even what the participants expected, although this prospect did not excite them. Also, since most people in vocational training have not excelled in school, the work is highly constrained and broken into little chunks. The reason for this is that since they did not learn well in school, they must not be too bright. And the only way to help them is to cut the knowledge into smaller and more manageable chunks. We did the exact opposite. We afforded them the freedom and respect normally granted only to the best and the brightest. We expected that they would perform well, and made sure they knew of our high expectations.

1.3.2 Training and Development Corporation (TDC)

The idea for Technology Works grew as a collaboration between Seymour Papert of MIT and Chuck Tetro, CEO of TDC. TDC is a non-profit corporation dedicated to learning, particularly for job training, preparedness, and re-skilling. TDC operates several Job Corps centers in the U.S., and also runs summer youth training projects and worker re-training programs in the state of Maine.

TDC initiated a set of innovative Work Enterprise projects, including Theatre Arts Works, Culinary Works and Media Works. In each of these projects the participants would actually run enterprises within the selected discipline under the guidance of professionals. In particular the Theatre Arts Works (TAW) project was inspirational for Technology Works. Each project pulled its participants from the same pool of youth; poor teenagers and young adults from rural Maine. For the most part, these youth had not experienced success in school and, given the economy of the area, faced bleak futures.

The mill town of Bucksport, where the headquarters of TDC as well as the TAW and TFIP projects are situated, is prototypical of the situation Maine and many other states and localities face. The Bucksport economy was dominated by a paper mill where the majority of people in the town worked. However, with growing automation and the changing world economy, the mill employs fewer than one third of the number of people it did even ten years ago. Naturally, this reduction had a devastating effect on the local economy. Factory jobs that formerly provided good wages disappeared. The jobs that remained were fundamentally different, requiring new technical, analysis, and decision making expertise. This same effect was repeated throughout most of the primary industries in the state: shipbuilding, paper, and logging. A totally different set of expertise, experiences, and culture of work existed, yet the educational and training institutions have not kept pace with the changes. As a result, many teenagers and young adults are in danger of being marginalized and left out of the new economy.

Coupled with the changing economic climate is a change in the nature of funding for social programs. Government funding is dwindling. Alternative sources are rare and hotly contested. Social programs need to provide better results with fewer funds. This requires innovation and to meet this TDC developed TAW, TWE, and other new initiatives.

1.3.4 Theatre Arts Works (TAW)

Theatre Arts Works is run by Bill Raiten and his wife Elena with the assistance of June Carter. Both Bill and Elena had a tremendous amount of theatre experience, in all aspects of production; Bill primarily as a director, actor, and acting teacher in New York and the northeast United States, and Elena primarily in the various aspects of production, primarily in Russia. The TAW program had a similar mission to TWE except that it used theatre rather than technology as its starting point. Indeed, TDC initiated a broad set of Opportunity Works Enterprises based upon a belief in learning by doing and that the optimal environment for a training program is a setting in authentic activity and guided participation. The

TAW participants were from the same social, economic, and educational background as ours. Unlike TWE, TAW had run for several years and had maintained a core group of participants. Also, the TAW participants were slightly older than those in the initial TFIP program, ranging in age from eighteen to twenty-two.

TAW was extremely successful in its mission. It is not that it developed highly successful actors or theatre professionals (although several participants were extremely talented). Rather, it provided a constructionist venue where young people could:

- perform meaningful activities of their own choosing
- take on real responsibilities
- accomplish goals of personal and group significance
- and thereby radically alter their typically poor views of themselves as intelligent and capable citizens of their communities

So even though there was not a direct path from TAW to theatre careers (although it is hoped that one of the participants will soon enter college to study photography), the constructionist participation led to positive changes in the lives of those who did the most at TAW. One participant got off drugs, earned his GED, and is working optimistically towards a future he had previously thought unreachable. Another, at 19, learned to read. Others learned math and language skills that through all of their previous schooling had eluded them. Others also had dramatic improvements in their overall lives. All this through the catalyst of their activities in taking full responsibility for all aspects of putting on plays and performances at TAW (with, of course, the loving support and interaction of Bill, Elena, and the staff).

Unfortunately, because the success of TAW does not fit the normal school and social program paradigm of direct cause and effect, TAW constantly fights for its existence and funding. Even though the direct cause and effect paradigm is largely a myth as learning and development is much more complex, bureaucratic funding and assessment relies upon testable, standardized methodology, whether the assessment gained by this methodology is accurate or not.

1.3.4 Technological Fluency Immersion Project (TFIP)

The Technological Fluency Immersion Project was run as one Summer Youth Employment Program (SYEP) project. The participants were twelve teenagers between the ages of fourteen and eighteen; four girls and eight boys. To qualify each had to be from a family below a certain income threshold. TDC ran numerous SYEP projects throughout the state. During enrollment they expressed a preference as to the project in which they wanted to participate. They went through an interview process with a TDC counselor and were placed in the various programs. In order to provide as objective a basis as possible for program assessment, each project, including TFIP, was composed of participants representative of the group as a whole. Our kids came from the Bucksport, Bangor and Brewer areas. None had performed well in school. Some were in various social programs. One was in foster care, having recently survived a period of homelessness. Others had other problems that involved them with the social service agencies of the state. As facilitators of the program, each of us decided that we did not want to read the background material on the participants, not wanting to bias ourselves as to their character. We wanted this project to be a fresh start for each of them.

In addition to the TDC administrative staff who helped provide logistical and administrative support to the project (not to mention graciously giving up their offices and headquarters in order to provide space for the TFIP project), there were four staff members for the TFIP project. I was program coordinator. Cavarra Corr, a graduate student at the University of Massachusetts at Amherst, was the other full-time staff member. Cavarra had extensive experience as a teacher, primarily in East Harlem, New York. She did not have experience with computer technology except as a user, although she did have considerable experience with video and software for multimedia. She joined the project at the end of the second week.

Because my participation was delayed due to the birth of my son, two other people graciously and bravely worked the first two weeks without the benefit of planning or familiarity with the program goals. Laura Allen is a teacher in a private school in New York City. She had worked with LOGO and LEGO/Logo for quite a number of years. She also runs the Stonington Retreat workshops for teaching with LOGO and LEGO/Logo, in which Seymour Papert also participated. Willie Mercier is a elementary school teacher in Bucksport. He had just participated in the just completed Stonington Retreat workshop, which was his only experience with LOGO up to that point. However, he is an excellent and respected teacher, and knew many of the TFIP participants. After the first two weeks, Willie and Laura resumed their planned summer activities, although due to their enthusiasm and dedication continued to participate in TFIP on a part-time basis. Laura also ran the workshops for local children in Stonington, whose impact on TFIP are described later in this thesis.

This thesis will describe the events and activities of the TFIP summer program. Chapter two will provide examples and cases from TFIP to illustrate the immersion approach and how this set of adolescents acted. Chapter three will provide a discussion of the principles of TFIP and the issues raised. Chapter four places this work in connection to other research efforts.

2. Case Studies

This section includes case studies from TFIP. By no means is this an exhaustive set. Rather, these cases are indicative of what transpired and serve to highlight the key elements of the life and processes. The cases are based upon my observations of and interactions with the participants, and are drawn from my daily diaries and the participants' comments and projects. After I present the cases, the following section will analyze and discuss the salient issues.

2.1 The First Days

I did not begin at TWE until the start of the second week. The first few days of the project were difficult because the computer equipment did not arrive until the middle of the following week. So Willie Mercier (a local elementary school teacher who had attended a teacher workshop run by Seymour Papert of MIT and Laura Allen), Laura (a private school teacher who worked with Logo and Lego/Logo and had an association with Seymour for a number of years) and Seymour had to make do with what they could muster.

They scrounged up two powerbooks and a Macintosh. They had a few programmable bricks and some Lego. Still this was not enough material for the twelve teenagers. The three of them had to innovate to find activities to engage the participants without the benefit of technology. This was more difficult because the adolescents with whom they were dealing had not had success in learning or work environments, and thus were not self-motivated in this setting. Nor were they a cohesive group at this point. They were unfamiliar with and untrusting of each other.

To get things started, they proposed running a Soapbox Derby.[1] The group did not greet this suggestion with overwhelming enthusiasm. Quite the contrary, many in the group viewed the Lego and Microworlds as too childish to take seriously. As keeping a veneer of coolness was very important to them, playing with children's toys potentially could crack this image. This made it even more difficult to engage them.

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[1]The Soapbox Derby gets its name from a children's race contest. They children build vehicles that race by coasting down a ramp. We adapt this for Lego vehicles rather than the wood of the original derby. It is a canonical Lego/Logo activity. We often start children out with Lego/Logo in this simple activity and then add layers to it. We challenge the children to theorize about what will make for the fastest car to go down a ramp; a heavy one? A light one? One with lots of wheels? Once they theorize, they start building accordingly. Then they test and race. If the results are not as expected, they modify the designs or the theories, or both. Once they have experimented with building vehicles with Lego, we start to add motors, programming, sensors, etc.

As the group began the Soapbox Derby, some participated more than others. Some were openly hostile. Various of them built their cars. Others scrounged around to find materials to build the race ramp. With the cars and ramp in place, they commenced trial runs. Unfortunately, as was typical in the early days, the group did not only have to deal with the technical and theoretical issues. They also had to deal with the disruptive and destructive efforts of their peers. Sometimes a few would ridicule the others, particularly if things did not go as expected. It appeared that one of our group, Alan, deliberately attempted to step on and break the vehicle of a classmate as it rolled off the ramp.

Still, through the efforts of the three adults, the activity did generate enough interest to spark some debate. How could they determine if their design modifications helped or hindered their speed? How could they time the cars properly? How could they determine if each one was starting simultaneously? How could they construct a ramp that would not give any particular position an unfair advantage?

A few began to become involved. This was a different interaction than they were accustomed to in an environment that they still identified as school-like. They were not used to open-ended activities where they acted as theorists; where there was not exactly one right answer; where they could be creative; where they could be playful. As has been shown elsewhere [Anyon, 1981, Apple, 1979], activities in schools for students from lower economic classes often take the form of following directions. obeying, not showing creativity, and answering direct questions. Tasks that are open-ended, require analysis, demand creativity, or are free from are typically not part of the agenda.

For the Soap Box Derby they first began with two people holding their cars at the top of the ramp while another would call the start of the race. They decided this was not quite accurate enough as one could gain an advantage over the other. That all was not pre-determined by others and simply presented to them was advantageous because it forced them to confront many issues hidden in the overall project. Rather than being decided for them by a higher authority, they had to find their own just solutions.

At first they thought that they could control the start by building a starting gate. As usual, they recovered this idea from their own experiences watching or participating in races. But how could they create this? They tried to create a Lego mechanism that would raise the starting gate. They reasoned that if the cars were leaning against the gate, as the gate raised the cars would be released at the same time.

But in discussing and evaluating the plan, they found a flaw. They had already built their cars. The vehicles were as varied as their creators. As they were experimenting with different designs to produce faster cars, the cars were all of different heights. They discovered that this meant that even with the mechanical gate, the shorter cars could escape the barrier sooner.

Then they thought that perhaps they could lower a gate into the track. That is, rather than mechanically raising the gate, they would mechanically rotate it down. There it would mesh into a slot they would create in the ramp. But this required time for them to build such a special and intricate device. This plan remained on the drawing board but there was not yet time or materials to implement it.

They were also dealing with a second problem, that of deciding how to time the cars. They decided to use a light reflectance sensor to cast a beam across the finish line. When a car crossed the line it would break the beam. Their program on the P-Brick could detect this and know there was a winner.

But problems remained. How could they time the race? How could they know when the second car broke the beam? At first, they were racing many at a time. But one the beam was broken, and if the next car was less than a car-length behind, which was almost always the case, the beam was still broken by the first car and there was no way to tell when the second car crossed the line.

They came up with a possible solution to the timing, starting, and finishing problems. If they put a touch sensor at the top of the ramp for each car, then they could determine the exact moment each car started the race. By connecting the sensor to the P-Brick, they could program the brick to note when each car started and utilize the built-in timer to begin the measurement. They then decided that, just as each car had its own touch sensor, if there were a light sensor to track when each car crossed the finish line they could determine each car's exact time.

What remained to do was to hook up the sensors and program the brick. To do this, Seymour and Alan formed a team. Together they would work out the timing. Alan knew that Seymour was famous. He felt honored to work with him. What made it special was how Seymour approached it. They worked together as colleagues. Seymour treated Alan with respect. Thinking out loud and discussing the issues, together they would discover how to solve the problem. It was clear that this was a different and powerful experience for Alan. He was being treated respectfully for his intelligence. He was solving a problem together with someone he respected, who in turn was respecting him. Seymour trusted the problem as real, and did not have the answer at his fingertips. Rather, they had to work their way through it together. This too was powerfully transformative as Alan, like many people, believed that being smart meant knowing the answers. That Seymour had to work his way through the problem was illuminating. How they worked their way through was a learning experience that Alan kept repeating throughout the project.

Alan and Seymour worked out the program to time the cars and display their times on the P-Brick. This was the first real technological project brought to completion and helped to begin the transformation. As the P-Brick was not designed with this in mind, even displaying the times in a form that they wanted required thought and construction. They could get the seconds and the decimal, but they wanted it to display so that it was easily discernible. Together they experimented repeatedly until they solved it. This was a touching and motivating moment for Alan. It helped to alter the way he operated at TWE, and helped lead to a different view of himself.

It was at this time that the computers arrived. This gave us other possible activities for the group. We utilized everything at our disposal in order to help provide transformative experiences. For example, receiving the computers provided an opportunity to have the group learn how to set up the machines, install software, and set up and maintain the local area network. Whatever new services or capabilities we would add, we wanted the kids to be the ones to perform the work, under our technical guidance. If machines would break, we wanted them to diagnose them and handle the repairs. We believed this would contribute to their learning and understanding. We also believed that once they became proficient at these tasks, they could provide this as a service back into the community. It is common knowledge that many schools and public institutions suffer because there is neither funding nor expertise to maintain and repair their equipment. We knew that it would be a empowering experience if the kids went back into the same schools where they had so much difficulty as the technical experts who could work with advanced technology.

In the first week due to the lack of equipment, TWE only met for several hours per day. Much of this time was taken up with meetings. The staff wanted to involve the group as much as possible in the decision making. So, they held a meeting the first thing every morning to plan the day's activities. They also formed committees to deal with the major issues. These included committees to get materials and build the ramp; to get the materials, plan and arrange the space into which TWE would move; and to prepare, install, and network the computers.

This too was an unusual experience for these kids. They were unaccustomed to having influence over their learning environment. Usually, school was something that administered to them. Here they were empowered to create their surroundings. Their opinions mattered. Of course, at first they did not believe that they truly had any control or influence. It was not part of their mindset that this could be true. When told that each one of them would run the meetings during the summer, they all joked that when they were in charge they would merely dismiss everyone for the day. Fortunately, when they did take over running the meetings, no one actually did this.

At first they still were not totally engaged. For the most part, they abhorred the meetings. They felt there was too much talk. They were uninterested and uninvolved and only wanted the meetings to end. They still did not know what the program meant for them. When I asked what their expectations were for the project, they unanimously said that they believed they would be learning typing, word processing, and performing office work. They thought it would be boring, but potentially useful in finding work later.

At first I merely observed these meetings. The group for the most part did not pay attention. They fidgeted, daydreamed, or talked among themselves. It was clear they still did not take this project too be theirs. It was as though they were on autopilot, only paying attention if their names were called or they thought they might be in trouble. This is not an unusual sight in many schools. So, even though I wanted the operation of TWE to be as democratic as possible, I suspended the meetings feeling they were presently counter-productive. We subsequently would only have meetings when someone, child or adult, felt they were necessary.

The first few weeks were a challenge. The group did not know or trust each other. They felt no need to be supportive. They also had no clear idea what the goals of the program were. They hoped that they would acquire skills that would help them get jobs. They looked at us as school. And they did not like school. It was our first mission to find ports of entry for each of them and, dialectically, to help transform the culture from one of restraint of each one and each other to one of support and propulsion. That is, we needed to change the culture so that it became a learning culture. To do so we needed to impact each one in such a way that they wanted to do things and thereby learn. But each development, of culture and of individuals, needed to occur in conjunction with the other.

There were no instantaneous transformations. As they treated the project like school, and therefore not in their interest, they did not bring enthusiasm or curiosity to their endeavors, and thus were not self-motivated. They did not have clear goals or ideas about what we were attempting, so we had to search for entry points to engage them. If we were able to get someone started, almost always they would quit at the first obstacle. And, though they did not realize it, almost everyone encounters some obstacle when programming or building technology. Thus, there were always obstacles. While we could view these as opportunities for learning, to our kids they were yet more evidence of their stupidity. So, not wanting more negative reinforcement, they would quit at some bug or unexpected turn of events.

Helping to find ports of entry for each one meant getting to know the child and what might be interesting to that particular individual. So, a significant amount of time was spent just talking to them individually about themselves, their lives, their interests. Here again the focus was not on any particular bit of knowledge we wanted to convey. The focus was on the life of that child. And through those lives we knew that there would be something about which they would be passionate. And through that passion an interesting project on which to work would emerge.

Having a malleable tool with which to build was an essential element to enabling these multiple ports of entry. If the computer tools with which we worked afforded only certain styles of interaction or only certain projects, then we would not have been able to reach each child. This was where Microworlds LOGO was a critical element for us. Each child could build the type of project they liked; whether it was an animated story, or a video game, or a geography puzzle, or a car race, the project that interested the child could be built. If we used tools designed only for particular investigations then we would have needed a large palette of such tools to satisfy each child. Even still we would have lost as there would have been no common set of experiences or language on which to build. On the other hand, the primitive graphics provided in Microworlds LOGO was initially a turn off for these kids, whose tastes were quite sophisticated based upon their familiarity with video game graphics. Having them work with what to them was a "childish" technology was an unnecessary added difficulty.

Simultaneous to trying to learn what mattered to each child, we worked on building an environment where their views and interests mattered. This is not to say that we abdicated any role. As we as staff members were also legitimate members of this new community, we too had an interest that the place would be interesting and fruitful for us as well. Thus, we attempted to create social structures that could foster a free and supportive environment in which to work.

Democratic meetings were one instrument to help achieve this culture. Another was our insistence that hurtful remarks not be tolerated. We did not want sarcasm to impede the work and energy of others. We also instituted "demo times" at the end of the day when any volunteer could demo any project of which he or she was proud.

At first this met with some slight derision and we had to be careful not to allow anyone brave enough to demo to be hurt and therefore lose courage. But his proved to be a powerful way for good ideas to spread through the culture. As one child or another displayed a particularly nice effect, the other participants wanted to copy it and use it in their work. This was a great and rather organic way to spread knowledge through the group.

Another critical element to building a democratic culture in which the youth felt they had a vested interest and actual impact on the social structures was that they needed to see that when they might expect that the adults' interests and theirs conflicted, that they actually had seem real impact on the course of events. That is, it is easy to be democratic when everyone is in agreement. The real tests are when there is a true conflict in interests.

Naturally, situations emerged where conflict was evident. I knew that if they saw we stepped on their interests early on, we might lose them for the duration of the project. On the other hand, if the staff felt there was a problem, we needed to make this known and find a mutually acceptable resolution even if they did not agree with our concerns.

The first such controversy was raised by one of the kids. Willie had placed a suggestion box in the room where any child could, either anonymously or not, leave a suggestion about what to change. At the end of the second week, one child objected to the music being played by some colleagues. In particular, there was a song "Rape Me" by Nirvana. The anonymous author felt that this was inappropriate music.

The kids expected the staff to make a ruling. We did not do that. We called a special meeting at the end of the day and I read the note and then asked what should happen. After some discussion (which naturally rambled and covered other ground as they discovered they had rather varying tastes in music), they decided that each one playing music should wear earphones so that no one else could be offended. They also came up with the very intelligent and considerate suggestion that extra earphones would be placed in the room just in case any kid could not afford them and thus would be embarrassed. Other controversies included handling Timmy's Dope War animation (described later) and playing video games during work hours. We handled each issue through the same protocol. A meeting was held. The issue was discussed. We would try to reach consensus on a solution. If no absolute consensus could be reached, we would decide by majority vote.

I also began a session with the idea that we should all debug the TWE project itself. They were actually stunned by this. They had become familiar with the concept of debugging with their programming. Now they were being asked to debug the project. They truly did not know how to start. I think this must have been due to the novelty of it. Never before did they have the opportunity to discuss the merits of an institution in their lives, let alone to alter the course of its activities. Certainly they could not do this with school. Unfortunately, probably because of their lack of familiarity with this type of discussion, although possibly because they did not yet believe I would take them and their ideas seriously, they did not make many criticisms of the project. I decided to make three columns for their input, what they liked; what they did not like and wanted to change, and a wish list. Most of their comments wound up in the wish list category, although there were a number of items in the "like" category, mainly having to do with how they liked their autonomy in the project.

I do not believe there was any one event that changed the culture from the initial lethargy and distrust to the emergent one of activity and support. There were lots of small victories that led to a building of trust. There were also lots of individual triumphs that led to stronger beliefs in themselves. These were particular to the time and events, and particular to the individuals in our program. But the principles we applied are transcendent. The belief in and caring for the youth as intelligent beings, coupled with an insistence on proper treatment of each other, while performing projects of interest to each one, helped to move the individuals and the group in a direction new to them in a learning environment.

2.2 Justin

Day 3
Justin is by far the biggest kid. He is not being disruptive, but he is not participating at all. This has a deadening affect on his colleagues. His participation appears to carry weight even though, coming from Bangor, he is not one of the local kids.

Day 7
Justin does not appear to be doing anything much. He plays games whenever he thinks he can get away with it. He listens to music on the Mac CD player. He browses the encyclopedia. But he does not build any projects. Nor does he show any interest whatsoever in trying. He avoids the Lego activities. I ask him if there is something he wants to do or see. He says no. I ask him about what things he is interested in and he merely shrugs. We have a slacker.

Day 9
I check in with Justin a few times daily and always follow the same line of inquiry. He follows the same line of response. He does not cause trouble except for occasional ridicule of certain of his colleagues, especially during demo time. At my suggestion we peruse the example library in Microworlds to see if there is anything that might trigger some interest. There appears to be nothing, or at least he gives no indication of any interest or connection.

I am in a quandary. I want him to work on something but I want that something to be his, not mine. He is neither disruptive nor productive. It is easy to imagine that this is how he survives school. He does not cause trouble so teachers do not bother him. He drifts through school gaining nothing, but does not receive intervention because he is not troublesome. I do not know how to engage him. As he likes games I ask if he would like to build one. He does not answer. I am not going to try to force him to do anything, but because of the nature of the program I feel it is within my rights to expect him not to deter others nor to only play games. We are at a standstill.

Day 10
As I wander through the room, Justin calls me over. He shows me what he has done and tells me he wants to see how to do something. Without any fanfare or

any indication that today would be different than the previous days, Justin has made an animation with many meteors showering a creature. He asks how to get all the meteors to move simultaneously. He says he thinks it would be a cool effect. I sit with him for a bit and together we work through some programming on how to achieve this effect. When his meteor shower functions virtually concurrently, he says "Cool!" I feel extremely satisfied that we finally got any sort of emotional reaction from him.

Day 12
Justin has taken his meteor shower as far as he wants. Now he begins creating a Ninja Turtle Battle. Two creatures do battle with each other, each using its own personal arsenal of weapons. Blood and gore abounds. Justin is extremely proud that how when one turtle is decapitated, spurts of blood spew in random directions.

Day 16
Each day Justin adds to his animation. New weapons and new special effects appear. His artwork is quite refined, showing taste and experience from cartoons and video games. He is quite imaginative and this is reflected in the weaponry and story line. One ninja turtle can manifest ice storms and freeze the other until it shatters into pieces. He resuscitates himself by enabling a sunburst which heats him until he is whole (and water drips off of him onto the ground). The weapons are a mixture from medieval and outer spaces genres. Justin pays tremendous attention to the details of the background. He has built something exquisite and demonstrates that despite his early behavior, he does care deeply about things and can and will work hard on something that is intellectually challenging.

Day 19
We are having visitors. They are all involved directing projects with missions similar to ours: that of addressing the educational and employment needs of poor youth. Several of the visitors run traditional technology training programs. They only attempt to train kids to use word processing or spreadsheet programs. They no longer attempt to teach programming because it is too hard.

Justin now has his full Ninja Turtle battle animation running. The weapons are varied and have different effects. He demonstrates the more exotic ones, including the dynamically growing fireball, the freezing liquid, as well as the old standby meteor shower. The visitors ask Justin how he had created his special effects. He explains to them:

> At first I had these long procedures where each line was an action. But as my program grew, and I made more objects and weapons, it became harder and harder to know where I was and what to do when something went wrong. So Dave [the author] showed me how to use these small functions instead of all these lines of code. Now I have routines that

shrink any object, grow any object, create new objects, and stuff. I just have to say which object to shrink, how much to shrink it by, and when it should stop shrinking. Now it's so much easier and I don't get lost when things break.

Justin has just described, in his own words representing his own thoughts, the benefits of abstraction and encapsulation. These are powerful ideas. But they are now deeply rooted within him while previous attempts in his educational life had not achieved this. When he was explaining the concepts to the visitors, he had not yet labeled these ideas. This would happen when he had to explain the ideas to his colleagues. They came to see the labeling of ideas, as well as the naming of procedures, also as powerful ideas for communication, building, and debugging. The ideas of procedural abstraction and encapsulation spread though their developing learning culture. It spread organically because of the felt needs. They then could apply these ideas in various projects.

Compare this to how powerful ideas are normally taught. A definition is given. Perhaps there are some pre-determined examples. Some problems, created beforehand by others, are presented which test the learners to see if they have grasped the concepts. To date these teenagers had not learned from this approach. They learned much better when the problems were their own. They had an investment in the activities and their successful completion. The tasks were deep and rich enough to require deep thinking and a rich network of connections. They could complete these tasks and communicate their approaches to their peers through the development of powerful ideas. As they completed more and more projects, they developed a fluency with the technology. And, importantly, they had fun and built stronger senses of themselves as intelligent people.

The visitors begin trying a sort of Turing Test with Justin attempting to discover if he was a ringer. That is, they wanted to determine whether he had learned to program such an impressive project only within the time frame of this year's TWE schedule, or whether he had already known how to program before entering. This was important to them because even though they also ran programs with the same aim as TWE, they had never achieved such dramatic effects with youth learning to program.

Visitors: "How long have you been programming?

J: "Two weeks."

V: "What experience had you had with computers before?"

J: "None really. I had played some games. I had a keyboarding class in high school but I stopped going."

V: "You mean this is the first time you have ever programmed anything?"

J: "Right."

V: "Do you do really well in school?"

J: "Not hardly."

V: "But someone must have given you the code. You didn't do all of this yourself, did you?"

Justin begins showing them what is provided within Microworlds Logo and then how we developed this into his own project. He described its evolution. He mentioned how I helped, but his understanding of programming and project building are evident. He articulately and with great facility describes what he does, how he does it, and why he makes the design and programming choices he does.

The visitors are incredibly impressed. One tells me that when they try to teach traditional programming languages and tools (e.g. Basic, Word Processing, Spreadsheets, etc.) in the traditional way, that their students do not build such sophisticated projects nor display such a fluency even after many months and many courses. It is clear to them that our approach was achieving incomparably better results. That Justin had accomplished what he had in merely two and a half weeks was as believable to them as was telling them that he had just landed from Mars. They all claimed that they would be in touch to see how they too could develop such projects.[2]

After Justin created such an impressive animation, the other kids were attracted to it. They wanted to know what he did and how he did it. And an amazing thing happened. It took a while before Justin had developed to the point where he saw the need for and benefit of procedural abstraction. It took a little bit of work, examples, and explanation for him to acquire the concept. But once he had it spread virtually immediately throughout the rest of the group. Soon everyone's programs had smaller, more general procedures and variables. Impressively, the newly found powerful idea of abstraction was adapted to the needs of each person. That is, they used small general helping procedures

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[2]Some groups did get back in contact with me. I do not know how many others re-contacted the administration of TDC. One agency in particular invited me to discuss the ideas with their staff and help them prepare a grant proposal. I thought they would try to develop something along the lines of TWE; at least along the philosophical lines of Constructionism. But what was totally frustrating was that their proposal was tame and absolutely along the same traditional lines that they had witnessed with their own eyes did not produce results as we did at TWE How they could not change despite their claims reminds me of junkies. Even though they claim to want to change their lifestyle, it is as if they are addicted to their traditional, treatment-oriented educational practice lifestyle.

within the context of what they were trying to achieve in their project, not merely copying what and how Justin used them. It was as though once one of them got it, they all had it. I never had to explain it to anyone else. They were developing their own computing culture.

Day 21
Those of our top workers who had expressed an interest were spending this week in Stonington, about an hour away, as teacher's aides in a Logo workshop for the kids of Deer Isle. As Justin and Michelle were by far our most advanced programmers, they were in great demand. It was announced at the beginning of the project that there would be openings for some of them to go to Stonington to perform this task so long as they demonstrated proficiency with Logo or Lego/Logo. But given the culture within the group at the beginning, only Michelle and her friends showed any inclination to go.

As some of them gained interest and began to succeed at programming, the group going grew to six which was ideal. While in Stonington our kids took on a completely new role for them: teachers and experts rather than poor performers in school. They were respected for their knowledge and were in demand. This had a powerful effect on them and they were quite proud (albeit silently) and highly pleased. When they returned to Tech Works at the end of the day, their colleagues were amazed and envious. This feeling was also assisted because they were also able to go swimming on this quite warm day. Once the others saw the enjoyment of the others, they too wanted to go. As some of them had not yet demonstrated the necessary proficiency in order to earn the right to go, the stragglers now had incentive to learn and perform. Within one day everyone had demonstrated the requested skills. Now we had to decide how to determine who should go since originally it was only going to be the first six. As per normal practice, we convened a meeting.

There was no fair way to legislate this. But as the original hostility and aloofness had subsided within their emerging learning culture, together they found ways to satisfy what needed to be done in an equitable way. They would try to even out the amount of times one could go. Some volunteered to remain in Bucksport on various days. They said that while they enjoyed going, they preferred being able to work on their projects. Together they did the math to produce a fair schedule and the problem was resolved amazingly quickly. That this group now could act cohesively and justly, and take charge in doing so rather than relying upon the authority of adults was an incredible and wonderful change from the first days. That Justin would prefer working on his programming projects to a short day and a swim was mind-boggling when compared to the Justin of the beginning of TWE. These differences, in just four weeks, were incredibly satisfying and helped not only to justify our faith in them and what we were doing, but also to help us persevere on the days when it felt like we were getting nowhere.

Day 22
Justin decided he had gone as far as he wanted to on the original ninja battle and to work on a medieval battle game. He had some playing cards and some other game in mind as a model for his new project. I was not familiar with this, but he had a clear vision of where he wanted to go and what features he needed to include. As in older dungeon and dragons games the users could choose one from a number of characters. When the characters travel through the dungeons, they encounter various puzzles and foes. Each character has particular powers and weaknesses, and functions in different ways depending upon the context.

This project would be more sophisticated than his earlier one as he needed to track the state of his creatures, for example what powers they had, or how often they had been injured. Thus Justin had track to track the state of a large number of objects. He also had created a much more interactive program where control would lie with his users rather than their being guided through a particular path.

His project was quite sophisticated. He was inspired by real video and card games and wanted his project to have the same feel and interaction. He made sure his artwork was true to the genre. He worked at length to provide the proper interaction for his users (and himself as a user). This required significant software expertise. But because the project was his, and interesting to him, and because he did not want it to be "lame," that is, it had to be a good example of the genre he liked, he did what he needed to do and learned what he needed to learn to build what he wanted to build.

Day 28
A curious thing happened towards the end of the summer. Justin's last project grew to a relatively large size. He had re-drawn and used up every available icon. He created a lot of procedures, turtles, and objects. I noticed that after he arrived he would turn on his computer and then wander around for a while. I asked him why he was not working and he told me that one day, mysteriously, when he booted his machine in the morning the system performance was abysmally slow. According to him, later that day it ran fine. The next morning the same thing happened. After several days of this, he told me that he now figured that his machine had to "warm up" like a car on a cold winter's morning. I told him that while that was a good hypothesis, I did not think that was the cause.

When we tried to investigate what was going wrong, we were truly hampered by a lack of tools for this query. There is no (obvious) way to check on the state of processes and objects. We did not have an easy to find method to see what was going wrong. This proved to be frustrating to him and he gave up ambitious development on this project, resigning himself to merely tweaking the functions he had. This was a pity. Fortunately we were at the end of the summer project.

Still, even this experience was gratifying in one way as Justin demonstrated sophisticated debugging heuristics. At the beginning of the summer, Justin, similar to almost all of the rest of the group, would quit at any obstacle. Once he gained confidence and a stronger desire to see his project through to completion, he did not quit but still they did not have a clue about how to debug when something went wrong. This was not due to merely being unfamiliar with what the programming environment afforded for debugging. This included not having a clear idea about how to debug in a logical and systematic manner.

Consistent with our overall approach at TWE, I did not teach or lecture about how to debug. Rather, when they were stuck I legitimately and authentically tried to help them. I used the heuristics that I had learned as a programmer. I would ask them questions or just try things, always being careful to leave them in charge and inform them about what I intended to do and why I intended to do it.

The pattern was always more or less the same. I would ask what they wanted to happen. What went wrong? What happened that was unexpected? What did not happen that they thought would happen? We would try to re-create the error. We would read the error message if there was one. It was amazing that they did not typically even notice what the message was at first. We would just try it. We would speculate about what caused the error. We would step through the code. I would ask them what they thought was the cause of the problem. Once they made a hypothesis, I would ask them why they thought that. If they could explain it, if they were wrong I would ask them to show me. If they were right I would ask what they should do to fix it. Then we would try their changes. Before running the modified code, I would always want them to predict what would happen. I believed this step to be essential, although if they could not answer, we would proceed regardless. We would try to remember similar problems from the past. We would look for analogous situations. (This was why the cold engine analogy was particularly appealing). They truly assimilated a systematic diagnostic process. They also saw that when trying complex problems it was not merely okay to be wrong at first, that it was almost always the case. They were used to a poor school view of what it meant to be smart. that is, being smart meant immediately knowing the answer. If one did not know offhand, then one was dumb. They saw that in engineering one is wrong most of the time but that it is okay and one is still smart. This too was an important lesson. Likewise, it was important to realize that errors originated from somewhere and merely trying to patch the right answer on top of an erroneous structure would not solve the problem for anyone in the long-term. These error debugging sessions were very powerful not only in that it afforded them the opportunity to build powerful debugging, diagnostic and repair experiences and heuristics, but also it afforded an opportunity to allow them to discover for themselves where they were going wrong and why and thereby build a stronger, more robust construction.

Day 29
The Open House is a major success. Each one in the group has significant work to demonstrate. In fact, they have done so much that in order to fit in to the space and allow our visitors to try some of the same work the TWE crew did, we have to limit what each one will show. Justin shows his latest program, the adventure game, and has a continuous stream of visitors. He tells me that he is now thinking of studying and working with computers, hopefully as a programmer building games. I had asked him previously during the summer what he planned to do and only received a shrug as a reply. He said that he had taken a course in high school but they only taught keyboarding. I asked what they taught in school for people who wanted to learn to program, and he, with a sigh, told me it was not like Tech Works and walked away.

2.3 Alan

Day 1
It is clear our twelve new participants think they are in school. And they are not happy about it. We decide to use LEGO/Logo for a Soap Box Derby project. Their task is to build cars that will go down a ramp the fastest. They have to theorize about what will make their vehicles go fast, and then build and test them. Alan is explicitly not participating, except to occasionally mock others who are participating. Worse, it appears, though it is not certain, that he is willfully trying to destroy others' vehicles as they exit the ramp.

Day 3
As described in the section on the first days of TWE, Seymour and Alan team together to work out how to use the brick for timing the race. This is the beginning of a very different mode of engagement for Alan. We are beginning to break his automatic pilot methods of working in a context he identifies as school-like.

Day 7
Alan is working with the programmable brick, touch sensors and light sensors to develop an accurate timer for the Soap Box Derby races. There is a great controversy about how to tell who wins a race; how to ensure that all cars start at the same time; and how to get a time for each of the cars racing in a heat. They animatedly discuss various proposals. As a group they can find holes in each of the proposals. The discussion is the first time they are cohering and cooperating as a group. It is also the first time they are truly engaged in intellectual pursuits at TWE.

Alan tries to write the program to control the sensors, coordinate them with the timer and display the values. He had previously begun this project with Seymour, but is having difficulty re-creating and extending his program so he quits. I offer to help but he is highly resistant. I sense that he is afraid of not being smart enough to do what he wants and thus quits to avoid the embarrassment and disappointment. I decide to wait for a while and approach him when fewer people are paying attention.

Day 8
We find a time when the others are away on break to work through the difficulties. I work with him by asking probing questions about why something is or is not working. I am careful not to put him in a bind where even if he cannot answer or can see a path, that this is an acceptable state. I express sentiments that it is normal to have to work through software projects in this way; that very rarely does anyone know immediately how to solve a particular problem, particularly one as multi-faceted as this one.

My method of working with him is to try and draw out what he is thinking and trying to do. I do not approach it at as me trying to communicate knowledge about something or convey the right answer. Nor is it a matter of Socratic questioning to lead him to the correct answer. We want the project to work, but the critical element is his construction of his thoughts about the entirety, not merely the point of the correct answer. In fact, incorrect answers at early stages of projects are often more fruitful over the long term for developing a more robust understanding.

As we are in the beginning of the summer project and have plenty of time, I prefer to explore more fully the space of what he is thinking about the projects at hand. We are not only working on solving a particular problem, but we also are establishing our relationship with each other and developing the culture of working at TWE. He is learning how I feel about him and how much I respect him, how I approach work and what I value. He sees how I view doing the work he is doing. Do I enjoy and value it? Do I hate it or resent it? Is he doing something that I would also do or would never do in a million years? Do I respect and even admire his work and thoughts? Is it busy work or meaningful work? We are learning about and working on a problem, but we are concurrently doing so much else besides that is also critical.

I believe that in this circumstance my primary objective is to try to make explicit what he is thinking and what he is trying to do, and use this as an object to think with.[3] We are working to build a technological fluency that, while developed

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[3]Part of our goal to build technological fluency is to help them build an awareness and a better understanding of their own learning processes so that they can reflect upon on improve them. This is often woefully lacking in traditional schools. Our approach at TWE uses this based upon the ideas of *deutero-learning* as expressed by Bateson [BAT, xx] and of *mathetics* as expressed by Paper [PAP, xx].

through many concrete projects, transcends any particular project. That we are working on a physical project makes this task easier than if the problem remained abstract. My goal is to assist him in the development of his ability to make his goals explicit, to observe and reflect upon the feedback from what has or has not happened, and then to debug and modify his design. It is through this that he will be able to subsequently work on other projects.

When he does not know an answer (which is often in the beginning as he will not hazard a guess to take a position, apparently in fear that he may be wrong), he has a tendency to quit or to create a diversion. This is typical of people who have not done well in school and a major portion of my time early on at TWE was spent attempting to address this tendency in the group. Verbal encouragement and my belief in their intellectual capabilities is necessary, but not sufficient to overcome this lack of confidence and spirit.

Alan was floundering on his own. He cannot bring himself to just dive right in and plow through the problems until he reaches a solution. In his school situations he has not had experience in open-ended, goal-directed problem-solving. **But certainly he does in his life and it is this experience that I try to draw on; his heuristics, his language and his confidence in areas where he does succeed and does have enjoyment.** I search for parallels and analogies in realms with which he is familiar and confident, and try to get him to bring stories and cases from these areas to cast onto the current situation. Our search is not merely through the domain of the problem but also through his experiences for him to find similar problems or examples and use these as metaphors for the current situation. I am not trying to place domain knowledge into his head, but rather I am trying to bridge from his knowledge and experience into the domain. We try to pull the problem out of an abstract concept, or away from a position where he is stuck, and find an alternative problem that has similar characteristics that he can then apply to the current problem. This approach seems more in line with a constructivist approach to learning.

I try to gauge how frustrated he may be; how close he is to the answer; whether he is merely missing one small piece of the puzzle or whether he has a poor framework for looking at the problem. My way of dealing with him depends on the mixture of these answers and other issues. My method of determining what he is thinking is to employ a clinical method of questioning [Ackermann, xx]. My questioning him to learn what he is thinking also helps him to clarify what he is thinking and often in itself leads to him discovering a solution or at least a path.

I begin by questioning him about what he is trying to do, He tells me he wants to time the two cars in the race. The cars are initially set against a touch sensor which is released when the race begins. The finish line is marked by two light reflectance sensors whose values will change when a vehicle crosses the line. In this case the problem is not that hard. He realizes that he needs to use the brick to control two touch sensors and two light sensors; utilize the built-in timer function; and display the result.

He attaches the sensors to the brick. He reads the display to see how the values change based upon the sensors' states. We sit at the computer as he begins to compose his program. Before he starts coding, I ask him to state in natural language what he wants to happen. He explains it perfectly and is quickly facile with translating from natural language into the Brick Logo logic controls for the program (with minor derailments to become accustomed to the syntax). He iterates through writing the routines for each sensor and then testing it on the actual race course.

Trying to get the times to display in the way he wants is an early indicator of some of his qualities that helped him so much later, but potentially could get him into trouble in other situations. He was not satisfied merely with getting things to work. They had to be exactly right, and he was going to endeavor to make them so no matter how long it took. In situations where there is only so much time allotted for things, this stubbornness and insistence on top quality could be interpreted as resistance or at least discouraged on the basis of a lack of time in a school period. Since the programmable brick measures time in tenths of seconds, Alan wanted the time to display accordingly. This degree of accuracy was also important for the measurement of the racers. But given the nature of the Programmable Brick prototype with which we were working, fancy displays and a robust programming environment have not yet been developed for it. Yet Alan was not satisfied with merely displaying the seconds and tenths merged as one number. He struggled with various different programming constructs; pored over the manual; tried this and that. But he refused to give up. Eventually he found that with two print statements and some literals he could produce a satisfactory display. It was hard to believe that this was the same child who a few days earlier was surreptitiously stepping on his colleague's cars and was quitting at the first obstacle.

The program works and he joyfully demonstrates it to the others. He takes pride in loudly proclaiming that he did it and I merely got in the way.

Day 9

Alan, among others begins work on his *slow car*,. Seymour proposed an idea that has caught on with some of the boys, who can design and build a car that continuously moves forward but does so as slowly as possible. No other instructions are given. A group excitedly commences work. They start by building motorized cars that operate normally. The various ones speed across the floor. They are rather enjoying this, which is again a breakthrough of sorts as initially they viewed the Lego and Microworlds Logo as childish and beneath them. They have found a way to engage in pursuits with these tools which are both challenging and stimulating, without being demeaning.

They know that one can set power levels to the brick. This is the first trick proposed, but they agree that each one should operate under the same conditions and setting power levels is disallowed by consensus of the group. They are constantly looking for angles, but they are making this creativity work for them.

They find that various drive chains produce faster cars than others. They now have their conceptual benchmark. How can they slow them down? The rubber band drives produce speedy cars. Gearing seems to slow them down. They ask me. I ask them what do they think. They tell me that I know and should tell them. I tell them that, yeah, I know but I only know because I tried building them, and besides, perhaps they can come up with something better. I say that I will build one too and we can all try to come up with the slowest. This seems fine to them and they accept the challenge. We have been developing a nice friendly rapport over the past few days, with joking and playing together, and we seem to be gathering some positive momentum.

Day 10

As we are still occupying the board room and guest area of TDC, it is imperative for us to leave the rooms as neat as possible. We end each day fifteen minutes early so all can clean their own areas. Alan volunteers to keep track of the Programmable Bricks, and to ensure that they are re-charged over night. We are having trouble with one of the bricks. I tell him I think it is "fried." Alan likes the expression, accuses me of frying the bricks and insists that only he should be allowed to care for them as "Dave the Brick Fryer" cannot be trusted. I am developing a tremendous fondness for Alan, his sense of humor, warmth and intelligence.

Day 11

The slow car race is proceeding. They have learned that gearing down will slow their cars. They experimented both with gearing up and gearing down. They watched the effects. They all adjusted accordingly.

We have measured off a space to serve as our raceway. They time their vehicles with a stopwatch, trying to slow down. Ron brings out his secret project, a car without wheels that moves by vibration. Ron had taken a bunch of Legos and gone off into another room to work in secret. He spent a large number of hours trying to adjust his design and weight distribution so that his car, although it does propel itself with a side to side motion, would not move backwards. The care, precision, and attentiveness he put into this project are impressive.

No one else had thought of this. In their minds, they had to build cars that looked like cars. Ron pointed out that nowhere in the rules did it stipulate that it had to look like or operate like a car. It only had to move forward without stopping. The others begrudgingly agreed and watched in amazement as Ron's vehicle teetered ever so slowly along the course. It traversed a ten foot long course in twenty-three minutes and twelve seconds. That it took so long allowed time for the excitement to build and everyone to come watch. The group was amazed and animated. I asked them how fast is Ron's car. They told me how long it took for his car to travel the set distance. I asked them how can that relate to how we are used to measuring speed? They said we measure it in miles per hour. So I asked them how many miles per hour Ron's car went. They had no clear idea how to calculate this. There is no doubt that they must have covered this type of question many times in school. But they could not recall it for this occasion. We broke down the problem. The car went ten feet. We knew how many minutes and seconds it took. What do we need to do? They saw that the units needed changing, and although they did not remember how many feet in a mile (they did know how many seconds in a minute and minutes in an hour, however). They were able to calculate that it would take Ron's car two hundred and four hours, nine minutes and thirty-six seconds.

But this remained somewhat abstract for them. They needed a better handle on what that meant. They knew that was slow, but how slow? I asked them what might be a better way to think about it than hours. They realized this was more than a day and decided to calculate the number of days. When they found that this meant the car would take more than eight days to traverse one mile, how slow Ron had made his car became much more concrete. Measuring in days per mile meant that Ron's car was **really slow**! What was especially gratifying was that rather than being mystified and disconnected from the calculations as they were initially, they developed a familiarity with the mathematics and put the math under their control on their concrete problem.

Everyone conceded the slow car race to Ron, but they decided to create two categories for entries; stock cars and funny cars. Again they pulled exemplars from their experiences, this time with auto racing. Stock cars had to be built like cars. Funny cars could be anything so long as it followed the constantly moving forward rule.

Aside from the end of Day 11
Today we also held a special meeting at the end of the day. Some of the kids have been bringing in music CD's from home and playing them on their Macs while working. One of our group objected to one of the songs, "Rape Me," by Nirvana. The objection was submitted anonymously, but stated that such offensive music should not be played publicly. In the meeting we discuss how to deal with this. Together they decide that anyone playing music must use earphones. This seemed the most just solution to them. Even though I convened and chaired the meeting, they determined what to do and how to decide. Again, this group that at first was divided, indifferent and at times hostile is forming a nice community. Given respect and some control over their lives, they are performing admirably.

I find out later the girl who objected to the song was about to testify in a trial against someone accused of raping her friend. We are never far from serious problems with them. They are coping with a lot. One is in a foster home and is about to be returned to her mother with whom she has had so much trouble and physical abuse. The last time she was supposed to return she ran away and was homeless. Another is about to be kicked out of her house and has nowhere to live. Violence is present in many of their lives. I am sometimes surprised that they can do so much while with us. It is not surprising that they find it difficult to work on things that they do not feel relevant.

Day 12
Various Lego/Logo projects have been built, both from individual exploration and group activities. They have begun to develop a familiarity with the materials and things that can be done with them. At our meeting this morning we brainstorm about what other types of activities we could do with Lego/Logo. As we have seen when trying to discover what they wanted to do with the summer project, they are unaccustomed to open brainstorming and reluctant to propose ideas. They are especially reluctant to try to debug TWE.

A number of Lego activities are proposed, including building a vehicle to navigate a maze. As he is gaining confidence about and enjoyment with working with the Programmable Brick, Alan decides that he would like to try this. The project is open-ended. He can design any type of object that can navigate a maze. But this design freedom has a price. There is nothing given to him as a starting point. He has to figure out everything.

At first he is stumped. How should he proceed? How can his turn? How can his vehicle see the maze? He asks me what he should do.

This is a critical juncture. Alan has begun to have some success, but he is still far from a daring hacker who will confidently dive into a new project. I want him to succeed in building this car, am nervous that if left solely to his own devices that he might quit, but know that if I give him the answers he will feel no satisfaction (since it would be my success and not his) nor will he be better off the next time he is in such a situation.

I ask him what else can he think of that displays the type of behavior he wants to create. Naturally, his first thought is of a car. He starts to work with that exemplar, but soon is in a quandary. Steering on cars is quite sophisticated. He used the steering wheel from the Lego kit, but how would he hook it up? He wants his wheels to pivot. How can he build such a steering mechanism? He returns to me with new questions.

I am cautious to see if he is becoming too frustrated and might quit. If I sense he is, then I would take a more active role in his design, perhaps showing him a sample mechanism that might help. But he is still energetic and engaged, so I feel it is better to just ask him questions to help him clarify what he believes the problems are. I ask him why he wants to use the car steering mechanism he is attempting. He says he needs it to turn the vehicle. I ask him to think about a car. Could a car navigate a maze on its own? He realizes that it could not unless there was something governing the steering. I know that we still are no closer to having a turning mechanism, but at least we are no longer bound by the constraint of exactly mimicking a car.

I ask him if a car's steering mechanism is the only way that something might turn. For whatever reason, perhaps because he infers where I am going, he says no. I ask him to think of how else something might turn. What other examples are available? What other moving things besides cars turn?

Being a skateboarder and cyclist, he thought of those two objects quickly and a skateboard turned out to be an excellent object to think with. How do skateboards turn? They typically have four wheels. The wheels are fixed along the vertical plane and do not rotate in the way that car wheels do, yet skateboards do manage to turn. While he did not think that tilting weight on a platform above the wheels was a practical solution either, he at least believed that a design similar to his collection of slow and fast cars might be modified to turn.

He played with one of his cars. Since his early cars had simple purposes, he utilized one front and one rear axle. He quickly realized this had to change (based upon his skateboard example). He switched to having a separate axle for each wheel. Then he added a second motor to drive the other rear wheel.

He began modifying his code to account for the second motor. He downloaded his program, placed the vehicle on the ground, started it up and NOTHING HAPPENED! His car that formerly moved just fine was now stuck. What went wrong?

He soon realized that he the motors were turning in opposite directions and thus canceled each other out. But he quickly also realized that this method contained a possibility for turning. Having worked with gearing on his slow car he realized that the weight of his brick might be preventing his car from having enough power to turn. When he removed the programmable brick from his car, it actually could turn. The motion was sporadic, but it did show evidence of the capability. Another remnant from his car reminding that he had to rid himself of was the idea that vehicles should have tires at all four points. The front tires on the non-drive wheels were creating too much traction and inhibiting turning. But at least he had an existence proof of turning.

He wrote his programs for turning right, left, and going forward and back. Using proper engineering design heuristics, he tested each routine in turn until each one worked. Then he combined all of them into a maze program, downloaded and tested it. To his surprise and consternation, programs that worked individually would not combine properly. When he tested the condition to get his car to turn right, it would. But when he next tried to get it to go left, the lights on the programmable brick began flashing and nothing would happen. At first he thought that perhaps old Dave had fried another brick. He knew that at times the prototype bricks could be sensitive. But because it worked on simple commands and on the subroutines separately he suspected that something else might be awry.

This was one problem we needed to work on together. He had used the Forever programming construct in each of his routines. Independently each Forever statement in each subroutine was fine. But together they produced a concurrency problem, with each statement trying to take control of the turtle. We found an alternative construct, and things were fine.

Next he started to investigate how to navigate a maze. When I asked him how he would move through a maze, he could only think of using his eyes. But he knew that having vision as he conceived of it was beyond the set of possibilities with hi Lego. How could he have a vehicle that could not see perform? I asked him again to think of other things that cannot see. He realized that some people are blind. He then acted out how a blind person might move through an unfamiliar room. He moved step by step using his arms as feelers. This easily translated into a Lego vehicle using touch sensors. Thus, the basic design of his maze car was complete.

Day 13
We are being visited by a Vocational Rehabilitation counselor from the state. She is the case worker for a number of our kids. We are showing her around the project. Various members of the group are explaining to her their projects and the programming behind them. She is amazed and quite impressed as this is the first instance of academic success for the ones she is following. She remarks how amazing it is that we have achieved so much in such a short period of time with people who had not previously demonstrated anything like this.

At this point Alan runs up to us and interrupts (manners and social protocols for them are as they were before TWE). He is extremely excited. I had given him Fred Martin's article on Lego design clichés, and he is using what he gained from this to modify the design of his maze vehicle. He tells us:

> I decided not to use the worm gears directly off the motor because Fred[4] says that it's not good for reversing direction and I need the motors to turn both ways. So now I'm going run the tooth gears from the motor and connect them to the worm gears to get the

[4] They are on first name basis now after my stories and his reading the article even though Alan has yet to meet Fred. But now that he knows Seymour and has heard of Fred, the MIT Logo group members are all part of his circle.

> mechanical advantage. I think now I'll be able to get the car to turn in either direction as well as go forward and back.

The counselor's jaw literally drops. She knows Alan and knows of his lack of academic success. What stuns and delights her is not only that he was explaining concepts that she herself did not understand, and thus was demonstrating an intelligence that had not previously emerged, but also that he was happy and excited about it. This was a child that she understood as un-motivated and non-performing. She told us that TWE was reaching and helping him in a way that nothing before ever had.

Day 14
I arrive at TWE about twenty minutes before the official start. Everyone else is already there and already at work. They are not playing games, smoking, talking, or anything else. They are all at work on their projects. We normally start the day with a meeting to discuss what we will do that day, as well as any other pertinent issues. They tell me that they do not want a meeting today and that they just want to work. We have arrived!

Day 18
Someone has brought in an old house dress. I don't know what prompted this, or what discussion were held out of my earshot. Before long Alan has donned the dress and is masquerading as our old school marm, reprimanding the others for making noise, not paying attention, and being "stupid." He alternates between being the school marm and good old Mom.

I have no idea what to make of this, but the kids are enjoying and participating in the performance. They are certainly responding to the direct teacherly commands of Madame Alan in a way that I could never do with them. The parody of school and the differences between it and TWE are a big part of the evolving humor. I realize that they have really begun to cohere as a group. Each morning and on breaks they are now playing hacky-sack with each other. They help each other with their programs and projects. These same adolescents who in the beginning of the summer were at best diffident, but also at times openly hostile to each other were now relaxed and friendly. The culture has evolved so that it is now acceptable to be supportive and curious.

Day 22
It is one of those days. No one's project is proceeding as they would like. Everyone is encountering obstacles. To some extent this is good as they are continually stretching their ambitions and attempting more difficult work. Alan is with Antoine and both are joking about how badly things are going. Alan tells me that the problem is that they are "dumb asses." "Look up dumb asses in the dictionary and you'll find our pictures there," he tells me.

In a way this could be disturbing, but his smile and joking manner belie his self-criticism. Alan never said this at the beginning of the summer. Earlier, considerable effort was spent trying to cover up any inadequacies. Now he can joke and tease about intelligence. He has begun to have some success, particularly in using and showing others how to use the programmable brick. Early on calling each other stupid was a favorite put-down. They are more comfortable with each other and their own abilities.

Day 28
Alan is still struggling to get his LEGO/Logo vehicle to turn reliably. Because the vehicle carries a programmable brick, its weight is relatively heavy. His car moves forward and back well enough, but it often stalls when tying to turn. He realizes he needs to trade speed for power in his design. He is experimenting with gear reduction to increase the power. He iterates through a cycle of taking his vehicle apart; re-building a gear train for greater reduction; putting the vehicle together again; and testing his design. He often has to change the other components of the vehicle to accommodate his new gear train.

While playing, he places a small Lego brick in front of the wheels as his car moves forward. To his surprise and joy, his car climbs over the brick! He creates a taller barrier. His car is powerful enough to climb this one as well. He had never realized or even considered that there might be a connection between the power needed to turn and the ability to climb barriers. He shows this effect to his friends. Suddenly, a whole new activity grows at TWE: creating climbing vehicles. To these boys, this resonates as a Monster Truck and Tractor Pull. They add it as a new event for our Programmable Brick Olympics.

The serendipity of Alan placing a brick in front of his car while he was daydreaming when frustrated with getting his car to turn cannot be exactly replicated with other groups. But we created an environment where these serendipitous powerful learning events are more likely to occur because of the thread of projects throughout the summer. The group expressed interest in a number of Lego/Logo projects during TWE. Alan had built a slow car that utilized gear reduction. He struggled for a long time working with gearing to enable his heavy vehicle to turn. From his surprise with the climbing incident, it appeared that he had not yet connected a strong schema about gearing and power in the context of mechanical design. When his car climbed as well as turned (but still was not extremely slow), the concepts appeared to coalesce. He had a powerful idea based upon several concrete experiences that only now transcended the immediate situation.

Day 31
We are finalizing planning for the Open House to be held on Day 34. They will show off their various projects to the visitors that day. It is becoming apparent that they are not comfortable with the Brick Olympics as it has been articulated. I try to gently poll them individually about what it is that is bothering them, and

begin to think that the competitive aspects are the cause of the dread. In our meeting I suggest that there be no timing or competition in the events, and that people just show their project in one or two events. This helps address another problem as we do not have enough Lego bricks for everyone to demonstrate every project they have worked on. The group decides that we will approach the Olympics as a group, and that everyone will try to show a project in one different event so our visitors can see the breadth of what was done. This decision seems to put the group at ease, with the exception of Ron who wanted to show all of his projects. The group agrees to grant Ron a special dispensation and allows him to demonstrate several of his creations, even in projects that others are doing with the stipulation that it is not competitive.

The events for the Olympics are settled. We will have:
- slow cars
- maze following
- path following
- ramp climbing
- obstacle course navigating
- tug of war
- weight dragging
- oval racing (Indy style)

It is just as well that they agreed to only demonstrate in one or two events because otherwise we would not have had enough Lego for all the projects. Others are also demonstrating their projects from the Bucksport tour where they have studied the uses of technology in the town and have built models for civic improvement (described elsewhere).

Day 34
Alan is now calling himself "Mr. Brick" as the recognized expert in utilizing the Programmable Brick. He refuses, even in the pressure of having a finished demo for the imminent Open House, to customize his program to adapt to the specific layout of a maze. He insists that the program must be general enough to navigate any maze. He goes through a repeated cycle of modification, testing and debugging in order to have the right program for his vehicle.

It is gratifying to see this young man, who at the beginning of the project was intentionally destructive, would not participate, when he would participate would quit at every obstacle, and who referred to himself as a "dumb ass" now felt it would be unacceptable and intellectually dishonest to tune his program. His project goal was to have a vehicle that could navigate any maze and that is only that with which he will be satisfied.

This is not a trivial problem. Alan learned that he had to avoid getting trapped in a cycle, that he might have to backtrack, that he needed alternative strategies for his vehicle to deal with obstacles, what to do if the car might be wedged, how to know if the car is wedged. His program grew in complexity and power as he kept experimenting in the maze.

We had constructed the maze with plywood and bricks. To change the configuration, the boards were placed in different patterns. If Alan was satisfied that his car could navigate the current maze, he altered it and tried again. This testing phase went on and on and the Open House deadline neared. Still, Alan remained determined to complete the project as intended. We are literally coming down to the minute of the start and Alan is still at it. He sees that turning his Lego vehicle is not precise, either because of impediments such as pebbles in the track, or simply because of his Lego design. He alters his program one last time to have the vehicle test in small samples how far to turn. When he finally succeeds, a great cheer is let out.

His demo is one of the hits of the Open House. His former middle school principal is one of our visitors and is impressed with Alan's work, as is everybody. But this appears to be particularly meaningful for Alan as a school official is certainly someone that he enjoys impressing and that he has not impressed previously. The success, emergent intelligence and perseverance of Alan is among the most rewarding parts of the summer for me.

[5] Part of our goal to build technological fluency is to help them build an awareness and a better understanding of their own learning processes so that they can reflect upon on improve them. This is often woefully lacking in traditional schools. Our approach at TWE uses this based upon the ideas of *deutero-learning* as expressed by Bateson [1972] and of *mathetics* as expressed by Paper [1980, 1992].

[5] They are on first name basis now after my stories and his reading the article even though Alan has yet to meet Fred. But now that he knows Seymour and has heard of Fred, the MIT Logo group members are all part of his circle.

2.4 Tom

Tom was our star athlete. He was a pitcher in baseball and quarterback in football. He too had to always appear cool, detached and unimpressed by anything. Early on, the main energy he displayed was an eagerness to ridicule his colleagues. This was symptomatic of the early culture within TWE, where some of the older boys dominated by their aloofness, ridicule, and lack of work and cooperation. Naturally, this had a deleterious effect on everyone. Getting this climate to change and become supportive was critical for our success. Key to this was reaching each of the boys, getting them to buy into the concept and to work. This change could not be accomplished meaningfully by force or punishment. That by the end of TWE we had built a strong, productive, supportive, friendly, active, and intellectually curious culture is perhaps the strongest testimony to what was accomplished.

My mantra at the beginning was "What are you interested in?" Since I did not know any of them before the program, I had to find out who they were, what they were interested in, how they responded to what, when to push, when to joke, and when to support and, odd as it sounds with tough, teenage boys, when to comfort. Working and talking together accomplished this familiarity and closeness. Naturally, a critical element for this change was that I had a consummate belief in their intelligence and potential for accomplishing difficult and (requiring intelligence) work, and a willingness to encourage and support them while they developed a similar confidence in themselves.

At first Tom's primary activity was browsing the on-line encyclopedia. With some encouragement and a little guidance, he was shown how to cut and paste pictures from the encyclopedia into Microworlds. He wondered how he could combine the encyclopedia data he retrieved, primarily about sports knowledge, into a project.

Over time he created a geography game where the players would navigate their turtle vehicles across the states (using the Maps provided as examples within Microworlds). Tom created several multiple choice questions regarding activities that occurred in or facts about that state pulled from the encyclopedia. When a player landed on a state (which the program would detect by the color representing the state), the player had to answer the questions correctly and then could proceed to the next state.

Tom decided that if his users had to answer everything correctly was too difficult and thus not as much fun because the games were too short. He discovered the benefits of user testing about which some software companies are still unaware. So he decided to allow up to three incorrect answers before your turtle is yanked from the game.

He kept adding aspects and nuances to his game so naturally the complexity grew. Yet, because it was in his interest to complete his project, he discovered programming heuristics to handle the complexity. And because this search was embedded in a task whose goals were his and therefore explicit and understood, he was able to connect these heuristics to their purposes, and not merely hear them as unattached programming facts.

He had to track the player's position, numbers of right and wrong answers, states already visited, etc. He had to manage the presentation of information, moving from the map to the state's particular screen (which he decided to put on separate pages since otherwise the screen became too cluttered), and back to the map in its last state. He had to track which data, questions and answers belonged with which state. He had to have programming control structures to branch according to the program dynamic state and user wishes. In all, without explicit instruction, he was able to build a sophisticated program that utilized variables, procedures, abstraction, user input/output, and multiple data types gleamed from various sources. He was later able to use this knowledge in all subsequent projects without experiencing a drop-off .

Tom was our sports fanatic and he was able to parlay his interest in sports into a meaningful project. No one else was quite so enamored with sports and it is likely this project would not have resonated with anyone else at TWE. But by combining the freedom to construct any project at all with a malleable technology that can support such an openness and variety, we found a port of entry particular to Tom's interests without cutting out the interests of the others. Through this he acquired significant programming skills attached to the construction of a project and therefore able to be applied, not picked up temporally in a vacuum.

Another important aspect to Tom's success was that we took time to allow things to develop and to go deeply into problems. Often in school situations the emphasis is on covering as much material as possible. Too much time cannot be spent on any one area or else required portions of the curriculum would not be met. This approach values breadth over depth.

We followed the philosophy of losing time rather than saving it. By encouraging them to go deeper and deeper into a project, adding layers, the realization of the power of powerful ideas evolved organically. These powerful ideas were powerful because they helped solve real problems in project development. As Tom learned from Justin procedural abstraction was powerful *because* it solved his particular problem and *because* it was a concise method of expression for events that are similar and *because* this conciseness aided debugging and control and, eventually, *because* it was *aesthetically pleasing*.

This aesthetic did not exist at first. They developed an aesthetic among themselves for cool effects, for code that could produce those effects, for better code that could produce more effects or effects more easily (e.g. once Justin got procedural abstraction it spread throughout TWE like a virus).

Contrast this with how powerful programming concepts are normally taught. The concept is named and presented as a given. A definition and explanation are given, followed by examples. These examples are, by necessity, concern pre-determined situations, which may or may not have meaning for the child. Then the child works on pre-determined problems in pre-determined domains which highlight the concept. These concepts are presented in a linear progression determined by the curriculum developer regarding which concepts need to precede which others.

But as we see comparing even the few cases from TWE, construction of knowledge is rarely such a clean, orderly, linear process. Some kids pick some things up before others. Some kids only understand some concepts in relation to each other and not in isolation, which certainly can be a richer understanding. Sometimes it takes a cluster of activities before the concepts can be acquired.

At TWE the adolescents often choose complex projects because they were interesting. In order to construct these projects they had to overcome the complexity and thereby deal with fundamental principles. They did not come upon these principles by watered down versions of real projects that by virtue of dilution also lose authenticity. Not was there necessarily a straightforward path to their finished product or ideas about the domains learned. There certainly was no way to predict beforehand what they would do or how they might come to understand the issues. This is potentially lost in linear approaches where the problems are pre-determined and the final representations are pre-set.

But such a free approach goes against the nature of large, standardized programs and assessment. Tom's geography quiz was extremely popular with our visitors and social program administrators. I was curious about this, as although it certainly was a very nice project, other projects were more difficult, intricate, complex, creative, or artistic. Yet, without exception, Tom's attracted the most attention. Why was this?

It occurred to me that Tom's project was the most *school-like*. It had questions and correct answers. It was about explicit facts. What was underneath and what thought and activity was involved was not as important. Almost every admirer commented that others could learn from Tom's project. Perhaps this was true, but without doubt the one who learned most was Tom when he constructed the project and pulled together the facts. This subtle point, key to Constructionism [Papert, 1990], is so often missed in conventional schooling where telling is privileged.

2.5 Antoine

When I first arrived at TWE, Antoine was pointed out to me as our major problem. He was described as a master of avoidance. I was told he was particularly adroit at playing the school game, possessed every trick imaginable, and could outsmart or outlast any teacher. Whatever was demanded of him, he would cleverly try to extricate himself from the activity, or, if that was not possible, perform it with the least amount of effort and result. He clearly felt that it was in his best interest to utilize his obvious intelligence to fight with the authorities in the best covert manner, even if this required more work, smarts, diligence, and effort than performing the requested task.

If Antoine only kept himself from working that would have been one thing. But he also liked to ridicule others, make sarcastic remarks, and influence others to feel it was uncool to do any work. Naturally, in the beginning this had a deleterious effect. Only the strongest could resist, and since none in our group had performed well in school, an alternative strength to counteract the sarcasm did not exist.

When I arrived, what to do with Antoine was the first issue with which I was confronted. One option was presented: give him very small, well-defined tasks, and monitor him closely. The rationale for this was that since he did not do what anything when left to his own devices, and when presented with a large, open-ended task, he merely found excuses why he should not or could not do them, that he could be better controlled and would have no recourse but to do the tasks if they were tiny and he were watched.

I preferred a different approach. I believed that what was essential was to help Antoine develop interest in and responsibility for his own learning. Without this, anything we might coerce him to do would be virtually meaningless. His work would never be truly his. All effort would still revolve around whether or not Antoine did what was asked by others, not whether or not Antoine learned. Undoubtedly, some of Antoine's teachers must have tried the first approach. Yet to date, while this might have kept some semblance peace in the classroom, this was never enough to enable Antoine to take control over, feel responsibility for, or believe that he could benefit from and enjoy his own learning process.

And how could it? What is the dynamic at work here? When posed in the initial way, the mission is to connive to get Antoine to do work that he is not interested in or engaged with. At best, he does what was asked and strengthens his resolve against what people are trying to get him to do. At worst, he becomes further alienated from and opposed to his own learning. In fact, it is not his own learning but rather but someone else's agenda. He does not learn in any personal sense of the word. He learns that he is happier avoiding what is prescribed. He learns better tactics for avoidance. He learns that the adults are there merely to get him to do what he does not want. And since his resolve and investment is stronger than that of his adversaries, he wins.

Why is it that we see so much of this type of behavior? Why are so many people so alienated from their learning? Why are so many very bright children turned into mindless, non-motivated idiots in so many school situations? One primary reason is that the tasks are artificial from the point of view of the learners. When they have no engagement with the material, the deeper learning cannot occur. And when the tactic is to take the same non-engaging material and chop it into smaller pieces so that the students can be better managed and controlled, as so often happens with students who do not initially do well in school, then there is even less hope for learning and a vicious cycle ensues.

What we did with Antoine was quite different. I argued that what we really wanted was for Antoine to take control over his own learning; that he be self-motivated; that he discover the joys of learning and working to achieve something. With the state of mind he was in, if the tasks were imposed from the outside, this would not likely occur. But if nothing was imposed from the outside, that is if we made no intervention, then also nothing would likely occur. What we needed was to know Antoine well enough to see what possible entry points there were and then try to leverage from them.

It appeared that Antoine was afflicted with a common teenage ailment, that of needing to appear cool and therefore unengaged. Due to this, he and others felt it was childish and beneath them to work with Lego or build animations in Microworlds Logo. I believed that to be effective I could not approach him in the public space. At the beginning of one morning, I asked him to join me outside. I asked him directly why he did not want to work on anything. He was taken aback by this direct approach. He told me that nothing interested him. This was interesting statement given that we had no pre-set agenda and they could work on whatever they pleased. To say that nothing interested him is to say that he is virtually not alive.

I kept pressing him about his life and interests. I told him that he was free to work on whatever he wanted, but that he had to work on something. Since a major goal of the project was to help him prepare for work, floating though without working would hardly accomplish that.

Finally he allowed that he was curious about the Internet and would like to find out what it was. He thought he could get some interesting information about theatre for his sister. He also told me about how he was interested in football and was a huge fan of the New England Patriots. He then went on for quite a while about how well he played football; how most people did not believe this because of his short and rather portly physique; how good he also was at basketball; how he had outsmarted so many at the carnival or in town, and so on. A common theme in his stories was how people thought poorly of or underestimated him, but how he showed them otherwise.

As it turned out, once he got started a torrent of words flowed from this formerly taciturn youth. He had interests and a life after all. When there was an environment and encouragement for the expression of his personal interests, and a validation of them, an opening existed for entry and engagement. The next step was to find ways for him to express and build something based upon these interests.

Antoine's interests led to three activities:
• He would be in charge of discovering what we needed to do to get Internet connections into TWE and then ordering and installing all the proper software

and hardware. From this he could then find information for his sister as well as create his own pages on football and the Patriots.
• He decided to create a Microworlds animation about auto racing.
• He would build a fast Lego/Logo car for racing

Getting Antoine interested was a start, but it did not mean that he immediately became a self-sufficient and self-directed learner. As was the case with all of our group, Antoine had a tendency to quit at the first obstacle encountered. It appeared that he had a terrible lack of confidence. He was reluctant, especially in public, to display that perhaps he could not do something. It was easier to show that he did not want to do it and thus his lack of accomplishment was not a matter of lack of intelligence but rather lack of interest. By watching this, and seeing the common thread in all of his stories, helping Antoine to gain confidence while not embarrassing him publicly was a key to helping him move forward.

Naturally, I gave him verbal encouragement but this in itself was not sufficient. Antoine needed to see his own success on projects he considered difficult. His belief in himself needed to be self-constructed and could not be merely transferred. Changing these views of selves was important for TWE to be successful in positively affecting their lives.

I left Antoine to his own devices as mush as possible. If I noticed he was taking too many breaks, or conversing too much, or bothering his colleagues, I made my way to his computer to see what he was doing. If he was stuck or having a problem, he tried to divert my attention from this.

Since Antoine smoked, he took breaks outside. When it appeared he was wedged, I would try to talk to him privately to see what was wrong. He never could admit that it was anything, preferring to seem in control. I had to find ways to surreptitiously sit with Antoine and help him overcome his obstacles without his colleagues knowing what was happening. Now, for the most part, since it was Antoine who was the primary culprit in ridiculing others, the others did not care that Antoine might be getting help. No one was ridiculing him. Nevertheless, he had a fear of seeming not in control, not smart, and, even though his worry was primarily self-generated, I had to respect his wishes to work with him successfully. We would find times and places when no one else was around.

One strategy I normally use when working with learners worked particularly well in this instance. I would ask questions in order to understand what Antoine was attempting and what he was thinking. In order to express answers to these questions, Antoine had to make things explicit that perhaps he had not realized. Often, the process of answering my questions helped him to realize what was amiss and what he had to do to debug his program. This way it appeared that he already knew everything and I was merely trying to find out what he was doing. Also, after several sessions like this, he began to infer the method I would use to try to find out what was happening and what was going wrong. In time, he could perform these steps himself and did only needed my assistance when solving his problems required constructs with which he was not familiar.

Antoine moved forward on his projects, but progress was slow. Midway through the summer, our group had an opportunity to work as teacher aides at a one week project in Stonington. The goal of this project was to work with children from the town of Stonington in using Logo and Lego/Logo. These children were poor as Stonington was primarily a fishing village (except for its summer tourist population). Our group could participate if they demonstrated a fluency with Microworlds so that they would be helpful at the Stonington project. When the opportunity was announced early in the TWE project, a list of tasks was created to show proficiency with the technology. One could only go to Stonington if one demonstrated they could perform all the tasks listed.

It was convenient that at first only six volunteered, because due to transportation limitations only six could go per day. However, when the six who went returned after the first day, they told everyone how much fun they had. Soon, everyone wanted to go, including Antoine. However, Antoine had not tried the proficiency task list, and did not really know how to do all the Logo tasks on the list. Thus, he did not qualify to work in Stonington for the second day.

Some others who did not go had demonstrated their proficiency, the roster changed on the second day. As usual, this required an ad hoc meeting of the whole group to determine how to fairly handle who could go. Since only six wanted to at first, this had not been an issue. Now all wanted to go, but all could not. The group had to deal with this in a way that was fair. That the group took this issue on as a group, and did try to work towards a fair solution was real progress for us. It was one of the first instances of cohesion we experienced. After much wrangling and discussion, an equitable solution was reached. Some volunteered to remain at TDC to work on their projects (as they learned that being a teacher's aide was hard and time-consuming, not leaving time to work on one's own projects). Everyone who passed the proficiency test would be able to go at least once. They would try to ensure that everyone went in equal amounts.

In order to go Antoine had to learn a considerable amount of Logo. In the three weeks to date, he had picked up some. It took him less than three hours to work through all the problems on the task list. When motivated, he could learn. He needed no small proscribed tasks or heavy monitoring. He set a difficult goal for himself and reached it quickly.

While at Stonington, Antoine had another powerful experience. Tough guy Antoine had to work with a bunch of little kids (ages 5 through 10). He was told that he had to be supportive and kind to continue to come to Stonington. One of the littlest attendees attached himself to Antoine for the day. Antoine kindly helped him through the building of the boy's projects. At the end of the day, the little guy went to Antoine to thank him. Antoine beamed and blushed. Once again Antoine was placed in a different type of interaction than he was accustomed and the results also were different.

Antoine's work in connecting TWE to the Internet also changed what had become his normal operating habits. He had to take charge. He had to find out what was needed to get TWE on-line. It was open-ended and without detailed instructions. We discussed what the issues might be, but I did not prescribe actions to him. He had to discover what he needed to learn.

He had to find out about phone connections, modems, Slip or PPP connections, Internet providers, and the like. Once he found out how we could get connected, he had to write a proposal to our funders detailing the reasons for the choices he made, the costs and benefits, and various alternatives to achieving the objective. He wrote his memos, included his spreadsheet, and gave it to the Administrative Secretary for TDC. As in any process like this, several iterations were necessary before the funder was satisfied with the information and reasoning.

Antoine had to keep his colleagues appraised of the progress at the group's meetings. As Antoine got more information and discussed with them why the Internet might be valuable, more of them became excited about the prospect. At every meeting, they asked Antoine "When will we be on the net?" Finally, exasperated, Antoine threw up his hands and exclaimed, "It's in finance!" At this point I realized he was ready for the work world.

Antoine built upon his experience from Stonington as a teacher's aide. It was a TWE responsibility to also introduce the technology we were working with to other Summer Youth Employment Projects (SYEP) and Job Corps youth. The goal of these introductory sessions was to provide other youth from similar backgrounds to those in TWE a chance to work with and become familiar with modern computer technology. Exactly what we would do we put to the group for a democratic decision.

They decided, after the usual wrangling, that we would gather the visitors for a meeting, describe what we were about, show a few demos of TWE projects, and then let the guests begin to work on their own projects in one of our core technologies, either Microworlds, Lego/Logo or StarLogo. Already, the group had become Constructionist in outlook.

Antoine developed into one of our more effective ambassadors. Some of our group resented the intrusions and having to lose time with their own work. We devised a schedule and changed the space so that the guests were in one room and TWE people were in another. They worked out a schedule so that six TWE people worked with the visitors and the other six could work on their own projects. Each would have an equal responsibility for attending to the visitors.

Antoine displayed not only a facility with the technical material, but a real compassionate understanding of how to work with the guests. He asked what they were trying to do. He patiently helped them to debug their projects. Numerous hard-edged teenagers showed tremendous pleasure at creating their animations, and thanked Antoine for his help. Others in the group also behaved similarly.

The difference between this supportive and productive environment and the atmosphere at the beginning of the summer when they were disinterested, sarcastic and combative was amazing. They had created for themselves personae where they were experts in technology that was difficult and required intelligence. They had skills in a field that they themselves and others respected. Their alienation from each other dwindled and they became a cohesive group.

One of the visiting groups proved difficult. They were disruptive, sarcastic, and could not care less about what we were doing or what was prepared for them. Our group hated this interaction. We had a meeting that afternoon after the troublesome group left, and almost everyone complained about their meanness, sarcasm, and idleness. One complained, "Don't they know what great stuff we have here? Don't they want to do anything?" I could not restrain myself from mentioning that it reminded me of another group of kids that we had here. They all laughed knowing I was referring to them, but also realizing how much they had changed.

The metamorphosis of Antoine, as with the others, was based in many small interactions. I could not point to any one thing that happened that I could say produced a particular result. Rather., it was the cumulative effect of many things: finding things that really did interest him; having belief in him and his abilities; respecting him and talking to him as a real person; keeping on him to make sure he did what he set out to do; watching him to know when and when not to approach him; building a rapport so that we could joke about his character and mine; getting to know him as a person to see what might resonate and what probably would not; knowing his background so that I could ground explanations in his language and experiences; caring enough about him as a person so that he knew I believed in him and wanted to see him succeed; allowing time for things to develop and change; knowing that it was not just producing right answers to particular questions but the ability to learn how to learn and discover processes for learning that were of long-term importance.

Someone who knew Antoine well told me at the end of the program how much it had helped him. He described Antoine as someone that was always put down and kicked around by the others in town. Antoine never had anything about which to feel proud. His identity was submerged and he was trying to express it by getting involved in activities that some of his peers might respect, but that certainly put him at odds with the community. With his involvement in TWE, he became much more assertive and bright. He spoke up where previously he was silent. He was proud of what he had done and was glad to share this process with others. Whereas before he answered me about his future with a shrug, a nervous laugh, and a returned question, "What future? McDonalds?" Now he talked about working with technology. Clearly he still has a long journey but he has begun.

2.6 Jimmy

Sadly, I feel we had the least success with Jimmy. Jimmy was constantly active and involved in everyone's business. He appeared not to be able to sit still or concentrate for long. He was certainly much more interested in conversation than anything else. We ended every day with the ritual of Jimmy looking for his keys (and/or money).

Jimmy, one of our youngest at 14, was particularly enamored with Michelle, our oldest participant at 18. He made sure he was stationed next to her. He was more involved in her projects than his own. If she took a break, so did Jimmy. While at first Michelle was tolerant of this attention, eventually she found it to be too much and insisted that Jimmy keep himself elsewhere. But because Jimmy was a sweet and kind person, he did not act up and thus fell into the limbo in which many children reside in their school lives: not good or bad enough to merit special attention.

Because he would not sit still for long, it seemed that Jimmy had 7-8 projects going, in all of our available media, all in various states of incompletion and disarray. When questioned about any project, a torrent of excuses flowed, all causes from outside his control. Often, sabotage was alleged. Why anyone would sabotage his projects and no one else's remained one of the great mysteries of life to Jimmy and the rest of us.

When we were preparing for visitors, all of the participants were attempting to complete projects to demonstrate. On his own, Jimmy built an animation project called "The War of the Drugs." It depicted a battle between tobacco and marijuana for the souls of people. It was quite ingenious and the quality of the artwork, especially considering the limited graphics, was incredibly realistic and refined. From this small project it was easy to see Jimmy had tremendous artistic potential.

The topic of his project reminded me of the work of Sylvia Ashton Warner described in her book, **Teacher** [Ashton-Warner, 1963]. In this book she described her work helping Maori children learn to read. Rejecting using the prescribed English basal readers because they had no meaning or relevance to the lives of the Maori children, she had them choose words of personal importance to them. She would write these words down on cards and give them to the children. As the children learned and collected more words, they would then build stories from them. This approach is now termed *organic reading*.

Ashton Warner relates how inevitably, the words and stories would be about two topics: sex and violence. These were primary themes in their lives; exciting, engaging and dangerous. Normally, these topics are not allowed in schools, and the topics in the books are tame and bland. Yet, by permitting these taboos the Maori children became engaged in the expressiveness of reading and writing. Freire also has demonstrated the utility and liberating nature of basing work upon the personal interests of those involved [Freire, 67].

Jimmy's Battle of the Drugs unfortunately caused a controversy. One of the employment counselors attached to the program thought that if the visitors viewed this, the project could be construed as advocating drugs, or being lax and permissive. He reprimanded Jimmy and brought his grievance to my attention.

The others became rapt observers. TWE was still in a developing phase, gaining their trust but still possessing remnants of being viewed as school and alien. How we reacted to this controversy was critical. It seemed to me that the others expected a severe punishment for Jimmy and a reinforcement of our being against them.

Likewise, it was a critical juncture for Jimmy. This was the first project he developed that came to fruition. It showed real achievement and promise. If this incident were to be turned against him, I feared we might lose him.

The counselor wanted severe action. As we were a project with public funding, how the visitors might react was crucial. If the program itself were reprimanded, we all would be worse off.

I asked Jimmy how he felt it should be dealt with. He agreed that it would be bad if his animation brought trouble to the group. He said he would not demo the project. The counselor lectured him about drugs, social behavior, and a number of other subjects.

I don't know what Jimmy heard. I don't know what effect this lecture had on him. But it did seem clear to me that real aspects of Jimmy's life that were expressed in his animation were made clear to him were unacceptable and bad. He was made to deny these aspects of his life in an environment that was supposed to be open and welcoming to him.

Naturally, how we dealt with this was also of tremendous importance to the others. They watched attentively as we handled the matter. It seemed to me that they expected a stern punishment. When I took him into the other room to speak privately, and when he was allowed to re-create his animation (which "mysteriously" disappeared, I believe it went a long way to establishing a greater trust between me and the group. Since in a normal school this would have been grounds for suspension or at least trouble, with probably the parents being called in, they expected this. When we dealt with it normally and Jimmy was not in trouble, the others opened up more.

I was pleasantly surprised that Jimmy was able to quickly re-create his program. He never appeared to work or concentrate. But somehow he had learned enough Logo to re-make his project (even improve on it) rapidly. It was clear he had absorbed quite a bit, mainly by watching others. This illustrates his intelligence and underscored my frustration in not providing a better environment for him to accomplish all that he was capable of.

This incident also highlighted perhaps our major problem at TWE; coordination and agreement among the staff. Because of the precarious nature of the funding, coupled with the fact that the staff came from various places around the country, the staff was never able to meet beforehand to ensure that they were operating with the same philosophy. even though there was a small staff (the part-time job skills counselor and an assistant in the project), there were problems coordinating because of different goals and outlook. Any project must have each member operating according to the same principles, and that was not always the case. To achieve this takes time and effort, and we did not ensure that we took this, and we paid the price for it.

Even though our 12:1 pupil-teacher ratio was relatively luxurious, Jimmy's needs were beyond what we could provide in the seven week program. We needed more time as he needed more individual attention. Because we could not provide it in the quantities required, Jimmy did not progress as he could. His difficulties were not due to lack of intelligence, as the following examples will illustrate, but due to other internal factors. With time and attention, these possibly could have been dealt with. The fact that to date his needs had not been met, nor did we have the time and staff to do so, illustrates how the developmental needs of children are all too subservient to the economic and standardization norms of schooling.

Learning in social situations such as schools is predominantly about relationships. Children, particularly damaged children, require time and trust to enter into meaningful relationships. Yet this amount of time, and authentic situations where trust can be built, are rarely affordances in school settings. With Jimmy we made some progress, but due to our time and cost constraints we did not accomplish what we believe we might have. Clearly, this must also have been the case throughout his school career. Because he was not a troublemaker, he kept moving on, falling through the cracks. But falling through to where? Given the realities of the modern economy, Jimmy faces a bleak future.

2.7 Bucksport Technology Investigation Project

Once most of the group had developed a familiarity with the technology by creating and completing projects, I proposed a new endeavor. We were to go out through the town, investigate how computers, software, motors, sensors and mechanized control were used within Bucksport. Upon returning to TWE each one would come up with ideas for how to improve life within the community, and then to build and program models of their improvements. They would then demo these projects at the Open House scheduled for the end of TWE.

I introduced my proposal at one of our morning planning meetings. I do not know what I would have done if they had rebelled against the idea, but, fortunately, they did not. At first they did not know exactly what I had in mind, but as I explained more about what the mission might be, and given their familiarity with creating Lego/Logo projects, they gradually accepted the proposal. Perhaps they were just giving me the benefit of the doubt, and perhaps they liked the idea of escaping the confines of the TWE site. But they did assent.

We timed the excursions into the town to coincide with when we hosted groups of teenagers from other Summer Youth Employment Projects (SYEP). Training and Development Corporation (TDC), our sponsoring organization, also sponsored other summer youth projects. The administration wanted to provide exposure to the technology we had at our site to youth from the other SYEP sites. Therefore they arranged for sites to visit us for half-day sessions over five days. One set of visitors would spend the morning with us and another set would work with Theatre Arts Works (TAW). Then for the afternoons we would swap visitors.

Because it was virtually impossible logistically for all of our group to remain at TWE and work while we had visitors, we needed to provide other venues for activity. Thus, I proposed the Bucksport tour. I had such a project in mind before the beginning of TWE. Since it was a goal that the youth would develop in such a way that they could gain employment, working on projects that addressed real needs was an important step.

These projects were not pre-determined for them. An important aspect to successful engagement with real-world situations is the ability to find the most important issues on which to work.[5] This typically is not afforded to most students from lower classes in their school experience as the choice of what to work on is made for them [Anyon, 1981, Apple, 1979]. Thus, this ability to critically examine situations for best engagement is never cultivated.

Naturally, it is optimal if this engagement originates in the group itself. But this group, as is typical, did not have the habit of active, critical engagement with

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[5]Howard Austin, an eminent business and technology consultant refers to this as the "Where's " problem.

their communities. I took it as part of my role to help create an environment where this consciousness could develop. The inspiration for this is embodied in the work of Paulo Freire [Freire, 1972, 1989, 1995]. Just as in school they had not been afforded many opportunities for creative work and critical engagement, this stance also existed in their relationship with their community. In fact, many of these adolescents had developed a destructive pattern both with the community and towards themselves, manifested in petty criminal activity or substance abuse.

The basic goal was not merely to try to know their world in the abstract, but to study and learn about their world by acting upon it. Even though most of them had lived in this areas their whole lives, when queried about how things worked and what was there, they honestly did not know. As is often the case for poorer teenagers, they did not feel or act like their environment was theirs. Why things were the way they were was not to be questioned, studied or acted upon.

Our premise was that by building technological fluency, the youth would be able to approach projects with a more powerful set of tools and heuristics. That is, they could use this literacy to understand and express concepts applied to situations in their environment. Having spent the previous three weeks working on projects in the classroom to gain fluency, now was the time to apply it to an expanded universe.

At our meeting we decided that half the group would investigate the town in the morning, and the remaining six would serve as facilitators and instructors for our visitors. In the afternoon they would switch roles. The six then divided themselves into three groups of two in order to thoroughly cover the town. Each group would compile lists of technology uses, and look for situations that they would potentially improve. Upon return, they would build their models illustrating their innovations. They would examine the town's infrastructure, as well as how the business and civic establishments utilize technology. Everything was open to investigation and innovation.

Bucksport is an interesting and fairly typical Maine town. It is not very large, having only a few thousand inhabitants. It is well up the coast of Maine, about thirty miles south of Bangor. One large paper mill dominates the town and economy. In the past most everyone's life was connected in some way to the mill. As the economy and methods of production changed, the mill drastically cut back on personnel, now employing merely one third the number of people as ten years ago. This had a devastating effect on the local economy. Through a ripple effect, the retail economy also suffered tremendously. Given the history of the town, there are few other opportunities for work besides the mill, and the mill is not a viable option anymore for all the inhabitants. Thus, there is a pressing need for creating new opportunities, and this is one of the underlying reasons for projects like Technology Works.

Immediately, we as outsiders were struck by the reception these adolescents received when they entered the stores. The store owners became extremely alert and watchful, clearly distrustful of and hostile to our kids' presences. The youth's alienation that we observed and were trying to counteract clearly had real causes in their everyday environment. It is uncommon for most people from middle-class, cultural majority backgrounds to encounter and endure such treatment, but it is reality for so many poor or minority youth. Of course it cannot help but have a deleterious effect upon their lives and outlooks, including upon their learning. It is another example of relevant issues that affect learning and learning environments that have little or nothing to do with the domain of the material to be learned.

Not surprisingly, for the most part our participants were somewhat uncomfortable when interviewing the store owners about the use of technology in their businesses. But I do not believe that this discomfort was totally attributable to the chilly reception. I thought that our group was also ill at ease with their mission and how to perform it.

There are several obvious causes for this. First, the project was my suggestion and my passion. It did not originate with any of them, and I did not allow time for a reasoning about or an excitement for the project to grow. There was no opportunity for the project idea to thicken and develop. Thus, they were unsure about what they were supposed to accomplish while they were out in the town trying to do the project. We definitely would have been better served if I had taken more time to allow the project suggestion to percolate and develop within the group.

Secondly, their uncertainty about how to proceed and how to gather relevant information, actually, about how to do knowledge acquisition and critical interviewing, was also a result of their having had few, if any, prior opportunities to do so. Just as early on in TWE they struggled with open-ended projects in not only not knowing how to proceed, they also did not know how they did not know how to proceed and thus could not repair the process.

Constructing their projects in the initial weeks of TWE, they gradually began to develop expertise in the various skills required; conceptualizing, designing, planning, programming, debugging, building, etc. As the weeks went on, they became more adept and needed less support, advice and encouragement in order to successfully create new projects.

But this ability had not yet transcended the walls of TWE nor the boundaries of the types of projects they had attempted to date. That is, when confronted by a social situation, with open-ended and perhaps unclear goals, our participants who were overcoming their shyness, reticence, and lack of confidence within the confines of TWE, now faced the same set of difficulties. Apparently, for both social and psychological reasons, they were unable to bring forth their energy, enthusiasm, intelligence, and articulateness. However, this experience was a first step towards changing this and by the time of our project-ending Open House they acted differently.[6]

The groups did manage to canvass a good portion of the town and its shops. They compiled the following list of technology ideas. Some are relatively obvious: others are whimsical. The ordering is theirs. Others ideas did not make their official list, but still were developed as projects.

- Sensors on stop lights to adjust because of traffic
- Light sensors on street lights to come on appropriately
- Heat sensors for watering gardens
- Alarm sensors
- Sensors that take pictures of people who like to stare
- Sensors that sense other sensors
- Car alarms
- Sensors for fat people who try to buy twinkies
- Automatic air conditioning
- Cars that know what's underneath them
- Cars that sense stop signs
- A sensor that tells you where you are
- Crosswalk sensors [They explained this as meaning that when a person enters a crosswalk, a sensor detects this and a stop sign comes up out of the street to stop traffic.]
- Car wash sensors [It senses when your car is dirty]
- Lie sensors [They sense when someone is lying.]
- Sensors for the blind
- Following sensors [They explained this as a sensor that can tell you when you are being followed.]
- Surveillance cameras
- Bar code readers
- Negligence sensors [This one remained unexplained.]
- Smoking sensors
- Walk - Don't Walk sensors [Also unexplained.]
- Locks and vaults

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[6] Another example of this was when Shawn volunteered to emcee our first visit from the Theatre Arts group. On our first visit to TAW, one of their members acted as host, introducing their work and the skits to us. She also handled all the hosting chores, bringing people up on stage, keeping the dialog moving, and entertaining her audience. When we decided to host TAW, our group decided we should have a host to perform the same duties. Shawn quickly volunteered. However, when the TAW group arrived, Shawn froze and reverted back to the distant, aggressive, mocking behavior of his first days at TWE. But by the time of the Open House, this too had changed and all were hospitable and comfortable. That it changed gives me hope that with more time the improvement she saw over time at TWE would extend beyond TWE contexts. But this is not truly proven.

One member who suffered from a mental disorder also produced the following story. I have copied his text exactly. Bob is the custodian, handyman, and maintenance worker for TDC. He had helped the group previously in several projects, to get materials and construct the ramp for the soapbox derby, to build the maze, and to help wire and prepare the room for the computers and networks.

THE CONVERSATION WITH BOB
BOB TALKED TO ME ABOUT THE ALARM SYSTEM. THEN HE TOLD ME WHERE ALL THE ALARMS ARE THEN WE TALKED ABOUT HOW PEOPLE CAN GET IN WITH OUT THE ALARMS GOING OFF. THESE ARE THE PLACES WHERE THE ALARMS ARE. THESE IS A ALARM IN THE LIVING ROOM. THERE IS A ALARM IN THEDOORS AND WINDOWS. THERE IS A ALARM IN THE CONFERENCE ROOM. WHEN THE BUILDING CALL'S BOB AND THEN BOB CALL'S THE PEOPLE IN THE BUILDING AND IF NO ONE IS HERE THEN BOB CALL'S GARY. THEN BOB TOLD ME THAT THERE ARE SPRINKLERS IN THE BUILDING AND WHEN THEY GO OFF THE FERNIS GOES OFF AND THE PIPES FREEZE. THEN BOB TOLD ME THAT THERE WAS A ALARM THAT GOES OFF WHEN SOMEONE THROUGH'S A ROCK IN THE WINDOW THEN THE PERSON WHO WIRED THE BILDING CALL'S BOB AND THEN BOB COMES OVER TO THE BUILDING AND TURN'S OFF THE ALARM'S AND THEN BOB GOES BACK HOME AND WATCHES T.V.
THE
END

In general there was a certain fascination with alarms. I do not believe that any of them asked store owners about the alarms in their stores, which naturally would have increased the proprietors' suspicion and wariness. This situation became an exemplar to us for some of the difficulties the kids experienced while interviewing.

We decided to proceed along two paths. Even though we did have a relative luxurious amount of time to work with the kids, only having seven weeks for the project was beginning to work against us. As mentioned previously, the vision for the TWE project was that it would run year-round and the youth would participate to greater and lesser extents during the course of the year. At this point, we only had two weeks left in the program. We had responsibility to work with a number of other SYEP sites that would visit. We also had to finish projects already initiated in time for the Open House. Thus, even though there was not a lot of time for everyone to dive into and work on Bucksport projects, at least some of them determined that they would build projects based upon their tour and brainstorming sessions.

The Theatre Arts Works (TAW) were regular visitors of ours, and worked with our group late in the same afternoon of the tour. When I told Bill Raiten, the director of TAW, of our project and kids' experiences in town, he suggested that his group could help ours by working through improvisational sketches based upon the day's events. That is, his kids would pretend to be store owners, and our kids would interview them. We agreed that this had potential to be productive and enjoyable, and scheduled it for the next day.

We arrived at the TAW space and Bill explained the purpose of the get-together. This was after several phone calls from Bill to me during the day trying to clarify just what our group's objective had been during their quest. This lack of understanding again was evident during the improvisations. The theatre kids played their roles with their usual flair and dramatic plus comedic ability. Our kids were also very relaxed and performed quite well. Many of the improvisational sketches were funny. Many also went down the path of "Why are you asking me about burglar alarms? Are you going to break into my store?"

Our kids were very different interviewing their friends and colleagues of TAW. They were relaxed, direct, and probing with their questions. If only this could carry over!

Perhaps the most telling aspect of the whole exercise was the contrast between TAW and the TWE kids in comprehending the mission as they were expressing it, i.e. how are technology, computer control, and motors and sensors used within the town. The TAW group had difficulty engaging in the improvisations as they had no idea how to answer the questions posed by our groups about uses. The TWE kids, once they were more accustomed to the project and more at ease with their settings (i.e. at TAW and not in the stores), were very comfortable and articulate in describing what they were seeking. At the beginning of the summer the TWE kids were just as unfamiliar and unaware of this type of technology. Now they were somewhat fluent and facile with the ideas and could work with and express concepts about them.

Some of the more interesting projects that they developed were the:
- automatic garage door opener
- water sensing fishing project
- Dunkin Donuts cop detector

These will be described in a subsequent section.

WorldWideWeb Consulting

One other side-effect of the tour was that the group obtained consulting opportunities to build Web pages for some local projects. When they were out interviewing store owners, they met the owner of a local restaurant who also serves as the chairman of the committee to restore Fort Knox. Fort Knox (Maine) is an old Civil War fort situated across the river from Bucksport. A local private initiative was attempting to raise money for the restoration. In this effort they were pursuing all the normal channels; regional television, radio, and newspapers, civic groups, etc. However, our kids suggested that they could build Web pages for the effort to modernize and strengthen the effort and expand the potential base of support.

This was a radical change in their relationship with the town. Given the chilly reception they received by most store owners, here was an opportunity for them to provide an innovative and advanced service to the community. Indeed, it would be the first of its kind for this area, and provided by adolescents who were previously disregarded. The kids also then offered to provide the same service for Theatre Arts Works and TDC itself (not to mention Web pages for TWE). Unfortunately, as this came at the end of the summer, they could not proceed very far in the development effort, but the fact that they would and could do this illustrates the power of the TWE project and the successful efforts of and changes in the participants.

Ron and the Automatic Garage Door Opener

At the onset of the project Ron had the most experience with technology. He was the only one in the group that had his own computer at home. He claimed to have lots of programming experience, but this turned out not to be the case. He was quite adept with hardware and electronics, and was very comfortable in setting up computers and installing software. He enjoyed his early status as the technical genius of the group, and appreciated it when others would ask him for assistance.

However, he was unable to help anyone interactively. That is, if he could take the problem away to work on by himself, he was fine and could work well. He repaired a machine, installed software, and set configurations by taking the equipment off into a separate part in the facility and working by himself. But if the help requested required Ron explaining something to someone or coaching someone else, he either tried to avoid it or would say as few words as incomprehensibly as possible and then flee. (When we discovered that some of our crew did not know how to use floppy disks properly and were losing data, we asked Ron to explain and demonstrate proper use at one of our meetings. He agreed, but merely held up a disk and, head on his chest and eyes downcast, mumbled, "Here's a disk. Put it in the machine." And then he left the room.)

At the beginning of the project, Ron not only could not work with or near anyone (he set up his computer in a different room), but also he could not even stand close to anyone. If someone was talking to him, he would keep creeping back and away. We were gratified to see that after some weeks, Ron slowly crept out of his shell, even working on projects with others.

Several of our kids were said to suffer from Attention Deficit Disorder (ADD), and Ron's case was one of the most severe. He had trouble sitting still, and his retention, even from acts he had just performed just moments before, was poor.

Whenever something would go in a way he did not expect, which of course happens all the time when programming, he often became agitated. He would make wild claims about how nothing should have gone wrong because nothing had changed; basically, about how everything should be fine because he had done nothing wrong. Often, they were trivial problems, or had easy to find solutions but once something went wrong it so upset Ron that he could not function. My first task was almost always to get him to settle down and relax. I would try to get him to slow down, often merely saying, "Look. Look at the error message. What went wrong?" After some calming words and several iterations of the previous sentence, he would typically work his way through his dilemma.

Ron was incredibly productive, working in each of the environments we had. Complaining about the heat in the room, he first built a Lego/Logo fan that automatically came on when the temperature exceeded a certain degree. He built cars for the Soap Box Derby, having several models that he timed, modified, and re-timed until he was satisfied they performed optimally. As mentioned elsewhere, he secretly built his non-standard slow car, and then worked out the mathematics to determine its speed in meaningful terms. At first he avoided Microworlds Logo, believing that it was too childish and its graphics too primitive. He kept trying to convince us that Basic was a much better language to use than Logo. I explained to him why we were using Logo instead of Basic, but told him he was free to program projects in Basic. He did not do this and eventually did build nice projects in Logo.

He also disliked our use of Macintosh computers. He was familiar with IBM-type machines and wanted to stick with that. Again we explained why we chose what we did, but he spent a lot of time early on complaining often and loudly. I felt that he was worried he lost his guru status because we were working in unfamiliar territory for him. Naturally, he enjoyed the status afforded when people came to him to fix things or provide expertise. As it was difficult for him to deal with uncertainty, he resisted change. We still made sure we respected him for what he knew and did. As he worked more on the Macintosh and with the various versions of Logo we used, his expertise grew and his intelligence showed. He grudgingly admitted that there were good things about Logo and about the Macintosh after all. Still, when we received two Dell 486 machines towards the end of the project, he immediately switched. He still worked with Logo and Lego/Logo, however, now on the Dells. He also kept working on a Mac so that he could do his work with StarLogo. Surprisingly, I later saw that he did not know how to program well in Basic at all.

After the Bucksport tour, Ron explained that he believed that having to press a button to operate a garage door opener was silly. He said that your garage should know how to recognize your car and open for it, and that if any other car tried to enter, that the garage should know to set off an alarm. This was the project he would build based upon the tour.

Ron's project idea combines creativity and common sense. It is a good, innovative idea as one does not see exactly this type of contraption in the world. Yet, when one thinks about it, it feels obvious that having the human act as the interface agent mechanizes the human activity and subordinates the human to the machine. Ron's proposal turns this relationship around.

But, as is the basis for TWE's use of Constructionism and projects, what sounds simple can actually contain tremendous complexity and intricacy. Ron was excited about building his project, but immediately discovered he had no idea where to begin. How can a garage recognize a car and determine one from another? How could a mechanized door operate? He did not have experience in such problems to draw from and he did not know where he could look to find any examples. I wanted him to succeed, so I was prepared to help in whatever way he needed. But I held back waiting to see what he could come up with and allowing him to try. So, he began by doing what he could, dove in and built a structure for the garage.

While this had no direct effect on solving his major problems, it did serve to constrain the problem space. As he built the structure, how a door might fit in and operate became clearer to him.

He decided that a hinged door would be difficult to power and control. So, reasoning that it was more similar to an actual garage door, he opted for a sliding door mechanism. But this too posed problems. How could he get one to slide? Again he had no exemplars from which to work. He started to work on various mechanisms to try to get a door to slide.

This effort took Ron quite a while as his work stretched over a number of days. He would work on this project for a while, then, when tired or stuck, he would switch to a different project using different materials (e.g. Microworlds Logo or StarLogo). All of the group worked in this manner. Going forward on a project, and when stuck or finished with a goal or mentally weary, they would take a break or switch projects. While this manner of working is common in most professions, including engineering, it is uncommon in educational establishments for anyone younger than an adult, particularly in vocational training or Job Corps types of settings. All of our group appreciated this mode of work, remarking that they felt it made them more productive while simultaneously according them respect as responsible people.

Ron used his experience at TWE in using gears to experiment with various drive trains to power the door. He encountered several difficulties simultaneously. He needed enough power to move a tall and relatively heavy door. He also wanted to have a sliding motion which was difficult because it had to slide along the base straight and guided, but could not have too much friction from any component needed to provide those properties. He could not solve all of them simultaneously. He needed a lot of support in order to keep moving, but the support was of a very different nature than early on in the program.

Early in the summer Ron would quit and make lots of accusations about what prevented him from succeeding. His venom could be directed at anything, both animate and inanimate. Now, he still made accusations but he could be gently brought back into his work without too much time or effort. His tendency to immediately lose control when something unexpected happened, and to forget even something he had successfully done or said just moments before was frustrating. Yet, it was his condition and had to be handled.

Ron would try one construct after another in an attempt to produce the sliding. One after the other they would fail due to some cause. Perhaps it was under-powered. Perhaps there was too much friction. Perhaps the door would veer off course. With each setback Ron, with my help, persevered, debugged, and modified his design. This in itself was a tremendous achievement given his previous mode of working and quitting.

During one of his struggles we went through the building and searching for examples of how various doors work. Fortunately, there was a variety of types including hinged doors, horizontally sliding doors, and even an overhead door (down the street as the entryway to someone's garage!). Although we could not take these doors apart, we could play with them enough to get a good idea of how they operated.

Always with an eye to slowing Ron down and trying to make his activities purposeful, useful, and directed as opposed to chaotic, random and flailing, whenever Ron would try a particular construct I would question him to see what he thought he was accomplishing with his new component. I wanted to ensure that he had a goal and expectations explicit in his mind. This way he would have something explicit to reflect upon when he observed the actions after he tested his new idea. It was acceptable to me if he admitted that he had no idea why he was trying something or what he expected to happen. Sometimes when wedged it can be productive to just try anything new. But I still would want him to become a more careful and expectant observer so that even if he had no idea why he was trying something it was important for him to be able to see and what resulted that was different (or not different).[7]

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[7] Although we went through the following script more times than I care to remember.
Mike: "It's broken!"
Me: "What happened?"
Mike: "I don't know. It just broke."
Me: "What did it do?"
Mike: "I don't know it just broke."
Me: "Did you get an error message?"
Mike: "Yes. No. I don't know."
Me: "Let's try it again and see what happens. Now, what do you think will happen."

Once he had the structure of his garage and a door, by hand we played with how it might move. The next step was to abstract out how a motorized control could replace his hands. I asked him to think of other things that exhibited this type of behavior. What things in the world could he recall that slid mechanically? He thought of conveyor belts, something he called shakers (which he described as some sort of automatic sifting apparatus where a container would be moved back and forth to toss the contents), and a tow truck.

Interestingly, none of these truly operate in the way as he wanted his garage door. Still, that did not matter, and in fact the differences gave us entry points to discuss and thicken the underlying mechanical concepts. They gave us objects to think with. We built little components that could perform the tasks that his sample real-world objects did. We contrasted the components and his desired functions. We looked at what was available in the Lego materials. Finally we started to get something what approached what he desired.

His design was quite idiosyncratic and reflected his ideas and ways of looking at the world. He used two motors with crown gears to drive a single shaft from both ends. In the middle of the shaft was a worm gear which drove another shaft underneath with an eight-tooth gear. At the other end of that shaft was another eight tooth gear, which drove a gear rack attached to the top of the sliding door. He used a pulley wheel to hold the door on track at the top, and small, solid Lego pieces to guide the bottom. He placed flat Lego pieces for a smooth floor to reduce friction. Naturally, this product came from many small efforts, tests, and repairs. But the final result was clearly Ron's creation.

Next we went to work on the programming and controlling the opening and closing. Ron had already learned that merely using time to control how much to power a motor was not exact enough to produce consistently reliable effects. In the case of his garage, the door had to begin and end its traversal in relatively the same position. This was because it could run off the track in either direction, or leave the opening to the garage uncovered. Neither of these cases were acceptable to Ron. So he went to work on adding more exact control to the operation.

Prior experience from TWE helped provide a starting point for controlling the movement of the doors. Ron recalled how Alan hooked up the light sensors to determine when the cars passed the finish line in the Soapbox Derby. So he reasoned that he could use light sensors to determine when the door was fully open and closed. He set sensors at points where one edge of the door should stop when fully closed, and at the other edge where the door should stop when fully open. When the sensors detected the presence of the door, his program would turn off the motor. He decided to have the sequence of events be for the

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And then we can continue. Almost always he solved the problem easily.

sensors to detect the presence of the car, open the door the proper distance, pause for the car to enter the garage and then close. By breaking the events into such blocks, he wrote the Logo code relatively quickly. Next he had to figure out how the garage could know how to determine one car from another.

This is clearly not a trivial problem. Nor is the solution on which Ron eventually settled flawless. Yet it does demonstrate the feasibility and was a good start. Given the properties of the Lego materials with which he worked, Ron decided that his garage would detect identity based upon color. He would allow a black car (his) to enter, but disallow any other colored car. Clearly, this would be insufficient for the real world situation Ron originally considered, but was sufficient to provide an interesting illustration of the idea.

Ron knew that the different colors would provide slightly different readings for the light reflectance sensor. He placed a light sensor on a Lego gate he constructed to monitor cars approaching his garage. He built several Lego cars of different colors and noted the readings from the sensor. Then he wrote his code to branch accordingly.

Handling this part of the project also proved to be quite intricate. The difference in feedback from the readings among the various colors is not very great. Ron did the best he could in a straightforward manner to have his program perform different operations (i.e. open the door for the black car; set off alarms for the other cars) based upon the different sensor values.

But after he worked through the day on the programming and other modifications to his project, a strange thing occurred. When he went to test his garage, what worked in the morning no longer worked. He tried several times to no avail. When he looked at the sensor readings, they were totally different from the morning. What went wrong?

As the day went on, the amount of sunlight into the room varied drastically. Since the sensors are quite sensitive to ambient light, the feedback was very different based upon external conditions. Ron did not know what to do about this. How could he maintain the consistency needed for his program when external conditions beyond his control were so varied?

Ron was sad and in a quandary. He had no idea how to proceed. He was nervous that he might not finish his project in time for the Open House. A colleague from MIT, Rick Borovoy, was visiting the project that day and he sat with Ron to try to help him find a way to solve this dilemma. Rick helped him to see that because he could never rely on the sensor readings to be the same each time, he needed to re-set his thresholds based upon the exact time they were needed. That is, whenever an event occurred that would trigger the need for the sensors, each sensor took a reading to set as its baseline. Then the differences would be set relative to the dynamic baseline.

Rick did not give the solution to Ron. But it is doubtful, especially given Ron's agitated state that he would have found it any time soon. Because the Open House was imminent, Rick led Ron through the brainstorming re-framing the issues in such a way that Ron could find an answer that fit within his framework.

Ron took tremendous pride in his project. He made sure his mother and little brother saw it operate when they came at the end of the day to get him. He demonstrated it to his colleagues at TWE who were quite impressed. It now sits on the Lego/Logo demo table at the Media Lab.

The water sensing fishing project
Much of the local Maine economy is connected to fishing. Bucksport itself is on the Penobscot and TWE is located one block from the water. After the tour when discussing projects, and assisted by their growing familiarity with Lego components, the kids suggested studying features of the bay and trying to learn what might make for better fishing.

They knew that they could use temperature sensors to monitor the conditions at various depths. They wrapped and bound a heat sensor connected to a programmable brick in plastic. They submerged the brick in the bay so that it would sample the temperature every fifteen minutes.

They realized that this in itself was insufficient for a full view of what might make for better fishing conditions. They knew that they would need to have some fishing results to correlate with their temperature data.[8] They also knew that other factors were important. We began to discuss what else might be important and how we could measure and track these elements. But with the impending end of the project, the main ones who were interested in this project decided they wanted to finish their other work, and this project ended here.

Debbie and the Dunkin Donuts cop detector
Debbie was a bright young woman who displayed many talents at TWE. She, perhaps more than any other, enjoyed chairing our meetings and was quite adept at reining in some of her more rambunctious colleagues. She could terminate silliness and reach consensus without alienating the offenders. This was quite a skill, especially given that she had no real authority nor an age advantage as I did when leading the meetings. She took control over all management tasks to organize everything connected to the Open House and did a fantastic job as the day went perfectly and everyone did their part.

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[8] Although they did not use the word "correlate," it was exactly this that they expressed. This was typical with the group at TWE. They knew well many important concepts, but did not express them in the language of science. A good portion of my work was to provide bridges from their world into other ways of seeing and describing the world.

She also displayed a tremendous grace and generosity in supporting our one participant who had relatively severe behavioral problems. While this member was very sweet and kind, the load of doing the work with the technology was somewhat beyond what he could muster. He became proficient at setting up hardware and installing software, and helped to keep track of TWE's equipment in a database. Debbie helped this fellow to build various small animated stories and geometry projects in Microworlds Logo. She showed tremendous calm and patience in working with him.

But Debbie herself did not easily go beyond dabbling with these technologies. She too only was building relatively small scaled projects, although she did so in Logo, StarLogo, and Lego/Logo. Admittedly, she had a considerable amount of outside distractions with which to deal that summer. She had to spend several hours each morning at the high school making up work she did not complete during the school year. She also had a number of other issues intruding into her work from the outside world. Her mother was about to give birth to a new sibling from a differently blended family. This meant that Debbie was helping to mother her other siblings but also was helping to care for her mother. Debbie also had a few court appearances to make in a situation that was very emotionally draining. As is often the case in the lives of adolescents, there was a lot going on and a lot of pressure that certainly affects their work.

Debbie rather enjoyed the Bucksport tour and contributed quite a bit. But still she was hesitant to actually model any of her ideas. She did not really resonate with the more creature-like or automotive projects that many of the boys built, and though she did not object, neither did she dive in.

One of the TDC staff, Cavarra Corr, sat on the patio one beautiful Maine summer day with Debbie and a friend, spread all the Lego out on the ground and said they were staying until they built something. Cavarra herself was not familiar with either Lego or Lego/Logo construction. Nevertheless, taking the time and interest to directly engage and support Debbie in a project was sufficient to get something rolling.

Debbie had suggested the Dunkin Donuts cop detector after the Bucksport tour. She said that doughnut shops should have sensors to detect whenever policemen were wasting time squatting there and that these sensors should trigger an ejection of the policeman from the facilities. So, this is what she set about constructing.

She preferred to build the ambient structure first. She worked long and hard at setting up a reasonable facsimile of a real Dunkin Donuts layout. The overall size and configuration were similar, as were the counters and stools. Once this was built and her creation felt "real enough,"[9] she set about determining how to perform the activities she desired.

Of course there was no way to create a true Lego policeman that was different from another Lego creature. So she decided that the blue Lego man represented the police, and the others were civilians. Next she needed to determine when the blue man was seated on a stool. Even though she had built four stools, she decided to begin with automating just one. She had several options. She said that she could put touch sensors on the seats so that she could know when one was in use. But this would not tell her whether it was her designated target. So she added a light sensor to detect the blue costume.

Next she had to decide what to do upon detection. At first she connected lights and alarms across the top of her doughnut shop. When the sensors detected the seated presence of the blue figure, the alarms would sound and the lights would flash until the figure was no longer at the seat.

Next she added a lever mechanism under the seat that would catapult the figure out of the shop. The lever mechanism was quite sophisticated given that she had previously not attempted anything very mechanical. She wanted a rapid force that would only work under program control. As was typical of this group, she had an image of how the action should appear, and an idea of what she wanted to occur. But she did not have an inkling of how to proceed.

Again we used plain objects to model the event. I asked her to describe what she wanted and she told me in words. I next asked her to show me how it would work. She used her fingers to demonstrate a flinging motion. We used this as our model to examine the movements. I asked her to next use Lego pieces, unattached, to perform the actions. She quickly did that and I asked her to slow down the steps so that they would become visible to me. As she did that, we talked our way through the steps, looking for how she could get the Lego to do it without her manual intervention. She saw that she needed a fixed point where the lever would rotate, and a pole for the axis of rotation. At the other end would be the chair. By stepping through it this way she was able to create the desired effect.

[9] That was her descriptive phrase.

2.8 Vignettes

This section includes some small vignettes, samples of activities that occurred during the course of the summer. Each helps to highlight part of the life at TWE.

2.8.1 Some StarLogo Activities

Midway through the summer, I introduced StarLogo to the group. About half of the kids began working with StarLogo, and the other half kept busy with their many existing projects. Mickey and Brenda in particular were smitten with how StarLogo worked and what they could do with it.

They began by playing with the sample programs, and then modifying them to test out how to interact in the environment. I was impressed at how quickly they took to the view that they could learn best by writing their own programs. In other words, I did not suggest that they do so in this instance. This was now their preferred mode of operation.

Mickey started working on how viruses might spread. He approached this project differently than he had previous ones. Previously, rather than concentrating primarily on one tool as most of his colleagues did, Mickey had multiple projects in each environment operating simultaneously. He had several Lego projects, numerous Microworlds programs, worked on planning for the space, the activities, the Open House, and was collaborating on bigger group projects as well. With these other projects Mickey just dove in and started working with little planning, navigating according to his likes and dislikes and things emerged.

He began this way with his virus contagion project in StarLogo but it immediately was not satisfying. When he ran his program, he did not know what he was expecting or what he was seeing. He wrote his code with wonderful facility, but was unclear on what to make of it when it ran. I asked him what his theory was of how disease spread and what he was trying. He really was unsure. So we started discussing what some of the factors might be. He talked of immunity, mutating diseases, proximity and contact, the state of being sick, though perhaps not in exactly those terms. Once he had established some hypotheses in his mind about what he wanted to test, then he was better able to see what was happening and derive some benefit from his explorations. What was intriguing was that while Mickey normally was an extreme tinkerer in his work, he had to adapt his preferred style to work in a different environment. But because he was familiar and facile with the underlying Logo programming paradigm, he could make this switch without too much trouble.

The type of tinkering that Mickey normally did had worked well for him up to this point. He would play with Logo and try anything that came to mind, observe the results, determine if he liked the effects, and would modify or incorporate the code based upon his preferences. But in his early work in StarLogo this did not suit him well because he could not determine what had actually caused what he was observing. He needed to step back more and theorize earlier in order to try to make sense out of what he was seeing. Otherwise, it was all noise and he did not know what to do or change. Once he had this, he could then tinker as much as he pleased.

The next use of StarLogo had a serendipitous trigger, as did many of the other more interesting occurrences at TWE. Our lab was completely composed of Macintosh computers, despite the strong objections of Ron. Because of some software concerns, and also because we wanted our participants to be familiar with the technology that exists in the workplace and since that technology is predominately IBM-type PCs, we ordered and received two PCs. Ron immediately began setting them up and the first thing he did was to customize the screen saver design. He experimented with several of the possibilities before settling on his final choices for the two machines.

Our remaining kids liked this ability to customize the screen saver, but were frustrated because this option was not available to them on their machines. Since Mickey and Brenda (plus one of the kids from the Theatre Arts Works program) had played with the sample programs included in StarLogo, including the geometry programs, they decided to program their own screen saver in StarLogo.

They began by modifying the existing routines, playing with shapes, patterns and colors until they achieved results that they liked. They did not merely want to use an existing program, preferring to make their own design. Once they had created a basic pattern on the screen that they liked (by having the turtles emanate from the center and march in a coordinated fashion to their proper places), they decided that they wanted their design to "pinwheel." That is, they created a multi-colored flower and then wanted it to spin around the center of the screen.

They had worked with Microworlds Logo enough so that they knew how to program a turtle to draw a circle. They reasoned that it would be the same in StarLogo. Each of their StarLogo turtles should perform the command **Fd 1 Rt 1** forever and the reasoned their design would continuously loop like a pinwheel.

They were quite surprised when their design, rather than gracefully spinning, appeared to burst into pieces scattering in random directions across their screen. How could this be? If one turtle creates a circle when given that command, why don't several thousand turtles create several thousand circles. This dilemma provoked much interesting mathematical discourse among the three involved, with me in the role of interlocutor.

That they were doing geometry or mathematics was of no specific concern to them. They had something interesting that they wanted to accomplish, and mathematics was the way to get there. First they realized that while perhaps each turtle was creating a circle, because there were so many of them and because they were "either going through the edges and re-appearing on the opposite side or were each bouncing off the edges," their circling was not perceptible. They also realized that the floral shapes they initially created and wanted to pinwheel were globally emergent patterns, but were actually just a bunch of points. From the individual turtles' points of view, they had no idea they were part of any greater organization. So Brenda and Mickey began thinking of circles and geometric shapes in broader ways, realizing that not only could one think of them as whole objects, but they could also think of them from the individual point's perspective.

They went through quite a number of attempts trying to figure out how to get their pinwheel effect. They realized that the turtles had to be re-oriented once they arrived at their locations to begin the pinwheel. Following the point perspective, they tried to have each point know its relation to its neighbors so that they could coordinate their movements. As they tried one idea after another, they started to work in a real and thoughtful way with angles, planes, and trigonometry (though they did not know that). They eventually discovered a method to create their desired pinwheel effect. While what they did bore no relation to their school geometry, neither by motivation nor by method, they gained new understanding of mathematics and programming as a means to mathematical understanding.

2.8.2 Questioning TWE Activities

One day when our kids were working as teachers to other Summer Youth Employment Project (SYEP) groups, one of the counselors from another project told us she thought we were doing a disservice to our kids by allowing them to "play" with Lego and Logo. She thought we should be teaching keyboarding or word processing or some other work-related skill. She said they needed to be prepared for work and where would they be able to get work with such things.

Certainly it is true that there are not many jobs for working with Lego (except at Lego itself or perhaps at MIT). When I explained to her that with the rapid pace of technology, training today in a particular skill leaves one obsolete soon. Not long ago there were many courses and jobs for keypunching. Now that has been rendered obsolete by personal computing and word processing programs. These people, unless they were re-trained, are now once again unemployed. I told her our goal was to help them learn engineering and build technological fluency so that they could remain employable as technology evolved. This explanation satisfied our critic.

But I could not help wondering that one part of her displeasure was cause by the fact that our kids were enjoying what they were doing so much. She was annoyed that they were "playing" rather than training for the drudgery of work. But the joy of creation and engineering new artifacts was a very important component of Tech Works and, I believe, a major factor in our success. Even tough it was fun, our work was harder, more challenging, and more rigorous than perhaps any other project. That this and fun should not be mutually exclusive is an important lesson.

2.8.3 Kids and their Aesthetics Regarding Commercial On-line Services

After we hooked up to the Internet, the kids asked if we could connect to one of the services that had chat rooms. I was opposed to this as, though they were certainly free to do so on their own time, I did not believe that would be a productive use of the time at TWE. Participation in TWE was a partnership directed towards particular goals. As the chat rooms did not meet any of those goals, I viewed this as I would spending the afternoon on the telephone talking to friends: not part of our work. However, the kids used my own words against me, as they argued that if they did this after work hours then it was their own time and not part of TWE. Presented this way I could not argue with them without destroying our trust. So, I reminded them that while at TWE they had certain obligations to uphold and that someone from the staff should be there when they connect.

With the computers and software we had ordered for TWE naturally there were promotional diskettes for an on-line service. The promotion gave two hours of free connect time after certain hours, so the kids had their entry. What was most amazing was that while they were connecting, and following a difficult, arcane script in order to register, the procedure set up by the on-line services company offended the kids' senses of software engineering aesthetics. There were simple menus with places for text entry. Questions were unclear. Sometimes, answering something on one screen would cause (where they had no idea which answer was preferable or why it was important) a problem on a later screen. But there was no way to go back from the later screen to the earlier that caused the difficulty. Rather, they had to exit the whole registration program and begin again from scratch. This not only mortified them as users, but particularly bothered them as designers. they said they would never make their users suffer such madness. Even in the brief time that they had been programming, they had developed a better sense of how to interact with users than some professionals.

2.8.4 Working in Groups

From the beginning we worked with all the youth trying to help them develop according to their path. We talked with each one and encouraged them. But we also allowed them to work in groups whenever they saw fit. Because we had a workable ratio between them and staff, we knew we could pay attention to the needs of each one. If one only followed others and never worked by her or his self, then we could take the time to work individually with that one. Allowing them to work in groups not only help foster a more communal and cooperative spirit, but also helped pull the slower ones along in a non-degrading manner.

Michelle in particular helped quite a number of her colleagues to get started. At eighteen Michelle was the oldest of the participants. She was very bright and creative, but also very friendly, cheerful, and supportive. She immediately began creating an animated story of her wacky house. At first she took Pamela under her wing. Pamela had quite a troubled past and was currently in foster care after being homeless for a while. She had been victimized by others, and as she was rather young, had fallen into some rather socially and self destructive ways. But Michelle helped carry her into the project and helped her begin programming. Each one would create a room for the wacky house and then they would integrate the project. Perhaps Pamela would have taken off well on her own, but having Michelle to work with certainly facilitated matters. After Pamela, Michelle helped Jimmy, Mickey, and Ron. She organized and led the group in planning their end of summer celebration.

It was an ambitious effort (a group trip to Old Orchard Beach), but Michelle's strength, charm, intelligence, and leadership pulled the group together and overcame the reluctance from the staff. On Open House Michelle was demonstrating to her mother all of the projects she built during the summer. Michelle's mom had a typical pattern of many poor woman; married and pregnant in her teens and unable to finish a school career that was mediocre anyway. Later abandoned and poor. Michelle's work was a hope for escape. To their joy, in their coverage of the event, The Bangor Daily News pictured Michelle demonstrating to her Mom on their front page of the State section.

While a few of the kids worked alone the whole summer, most worked on group projects at various times. Even Ron, who at first would not even stay in the same room as his colleagues and who would stand as far away as he could from whomever was talking with him, eventually worked with Lego/Logo with Michelle and Pamela. After the Bucksport tour, Debbie, Spike and Jimmy built their Dunkin Donuts cop detector. Led by Debbie it was the primary Lego work done by any of the girls, and certainly different in character to the creatures and vehicles built by the boys. Brenda and Mickey together worked through many StarLogo projects. In fact, alone they probably would not have done it as they found the work very challenging. But together they had the strength to persevere.

2.8.5 Improvisation with Theatre Arts Works

Another program run through TDC was Theatre Arts Works (TAW), run by Bill Raiten and his wife Elena with the assistance of June Carter. This program had a similar mission to TWE except that it used theatre rather than technology as its starting point. Their participants were from the same social, economic, and educational background as ours. Unlike TWE, TAW had run for several years and had maintained a core group of participants. Also, the TAW participants were slightly older than ours, ranging in age from 18-23.

TAW was extremely successful in its mission. It is not that it developed highly successful actors or theatre professionals (although several participants were extremely talented). Rather, it provided a constructionist venue where young people could:
• perform meaningful activities of their own choosing
• take on real responsibilities
• accomplish goals of personal and group significance
• and thereby radically alter their typically poor views of themselves as intelligent and capable citizens of their communities

So even though there was not a direct path from TAW to theatre careers (although it is hoped that one of the participants will soon enter college to study photography), the constructionist participation led to positive changes in the lives of those who did the most at TAW. One participant got off drugs, earned his GED, and is working optimistically towards a future he had previously thought unreachable. Another, at 19, learned to read. Others learned math and language skills that through all of their previous schooling had eluded them. Others also had dramatic improvements in their overall lives. All this through the catalyst of their activities in taking full responsibility for all aspects of putting on plays and performances at TAW (with, of course, the loving support and interaction of Bill, Elena, and the staff).

Unfortunately, because the success of TAW does not fit the normal school and social program paradigm of direct cause and effect, TAW constantly fights for its existence and funding. Even though the direct cause and effect paradigm is largely a myth as learning and development is much more complex, bureaucratic funding and assessment relies upon testable, standardized methodology, whether the assessment gained by this methodology is accurate or not.

Thus, in order to better fit the standard model, TAW did not put on a play over their summer workshop. Instead, they created various little playlets organized around the theme of "Work Competencies." That is, they wrote, rehearsed, and staged various little scenarios designed to highlight the performance or lack of competencies necessary for successful participation in job settings. Since TAW and TWE were designed to help prepare youth who were lacking job skills, both academic and personal (e.g. respect, responsibility, cleanliness, orderliness, cooperative, etc.), the realization and acquisition of such skills was critical for their future work success.

In the spirit of Augusto Boal's Theatre of the Oppressed [Boal, xx], these scenarios were designed to be interactive. The TAW crew would perform a scenario, highlighting one performer's lack of competencies. The audience would then be invited to take over that role, and perform the tasks properly. The pedagogical goal was to convey certain pre-determined competencies, show how their lack poorly impacts the business and particularly the poor performer (in every scenario that performer was "fired" from the job), and then show how a different, competent performance would have a different effect for one and all. To truly drive home the point, the emcee would hand out a sheet to everyone in the audience, listing the competencies, each with several examples of their performance, and then lead the audience through a multiple choice question and answer period about which competencies were or were not displayed during the scenarios. These then were presented to various Youth Employment and Job Corps participants in order to help them learn these competencies.

This year's performances proved immensely popular with the administrators and social service workers. They saw work competencies displayed and the messages conveyed. They thought that this was quite worthwhile, and made the value of TAW more easily documentable. This direct, explicit conveyance was assumed to be effective. The lessons to be learned were clear, and certainly the audience had to hear them. If they did not act upon them now that they *know* would be their own fault. But it is this reasoning that brands the TAW and TWE participants as incapable of learning and unintelligent because they did not respond to the school way of educating and testing. (It also is reminiscent of a proposed solution to the financial scandals on Wall Street in the 80's, where it was suggested that the reason so many intelligent, well-educated people broke the securities laws was because they were not taught ethics in business schools and that such classes should be added to the curriculum. That is, it is as though they only broke the law because no one taught them that breaking the law was wrong.)

What is interesting is that behind the scenes, the older hands of the TAW crew had chosen the competencies they presented because of their frustration with the lack of these exact competencies among some of their colleagues. It was exactly these competencies that were causing trouble and consternation. They hoped that by highlighting these deficiencies in a subtle way, that the wayward ones might reform their ways.

So, if it were only a matter of being told the lessons to be learned, then all would have been well. The audience would have learned what was necessary to be successful at work, and the wayward TAW members would have seen the errors of their ways. But, obviously, it is not so simple. Because of the talent and creativity of the TAW performers, the audience enjoyed themselves and laughed at the poor competencies displayed. But was this sufficient for them to change their behavior at work? This is doubtful. For the TAW members whose behavior inspired the utilization of these topics did not change even though they were telling others not to do the exact things that they did.

What can explain this? They were lecturing others not to do things that they, in other, authentic situations (i.e. the operation of TAW itself) do. We know from common sense that this is not so unusual. But yet school situations and the assessment of them often operate as though telling were the main thing that mattered.

Again, part of the answer lies in the agency. When they are telling others, the agency is such that they are the agents of telling and the audience is the agent of lacking competency. During the TAW operation, the setting and agency are sufficiently different such that the lack of competencies, and perhaps the concept of competency, is not sufficiently explicit to overcome the patterned, and problematic, behavior. And again, as suggested by the Constructionist point of view, the ones who learned these lessons best are the ones who wrote the scenarios.

2.8.6 Michelle, Design, and some Affordances of the Tools

One afternoon towards the end of the summer, a friend and colleague who had worked with, studied, and helped disseminate Logo in the 70's paid us a visit. He had been away from people working with Logo for some time. He observed the activities and was truly amazed at how much they could do in such a short time.

He sat with Michelle, who with Mickey were the most accomplished and articulate programmers, and asked her about her animation. The visitor posed a number of design questions, asking why she made various choices, how she might have done things differently, what would happen if she tried this or that.

Rather than trying to explain her answers, Michelle rapidly prototyped responses to answer the questions. She felt that showing the modified programs would be a more powerful method of explanation than words. The visitor was totally incredulous. He remembered a time where he and Seymour were working on something, while Marvin Minsky and Danny Hillis were working hard together to get the proper motion of a Ferris wheel in Logo, where the wheel would rotate and the carriages would remain in their proper relationship to the ground. He also remembered working in a summer project twenty years ago with a group of teachers in graduate study. In this project, over the course of seven weeks (the same length as TWE except that the teachers only worked for two hours per day) the teachers struggled to create one animation. And here were a group of teenagers, who had not done well in school, rapidly creating one complex animation after another.

Clearly, there are trade-offs here. This group, with certain functions and objects built provided in the environment, do not necessarily have to think through certain issues that older versions of Logo forced upon them [Valente, 1996]. For instance, a child can use a geometric shape as a primitive rather than having to create a function to draw one. However, activities performed using newer versions of Microworlds and StarLogo still can require such thinking, and in fact all of the youth at TWE did at some point during the summer want and need to do this type of turtle geometry.

However, what was not possible before, was to use the environment as a rapid prototyping tool typical of modern Graphical User Interfaces (GUI) where software designers will quickly build prototypes to show ideas to users so that they can respond to the functionality of the concrete object rather than verbal or written descriptions of it. In other words, the activity that Michelle performed with the visitor is typical of how professionals perform software design and creation in the real world. She is operating at a different level of engagement with the tool and in the design process than was previously afforded. But she was able to produce so much more so much faster than was ever possible before. This use of technology mirrors the work world. Yes, something is potentially lost by providing this power. But other things are gained at the design level; at the customer level; and at the systems level.

2.8.7 Writing in Work Diaries/Notebooks

We wanted the kids to keep diaries or notebooks of their activities. This was an endeavor we believed in for a number of reasons. Naturally, we knew that the activity could help develop their writing skills. We also thought it would be a good basis for reflection on what they had done and thereby provide another object to think with. It could also help document how much they progressed (or not) during the summer.

But when we proposed the activity, first in the beginning of the summer and again a few weeks into the project, the kids unanimously shot down the idea. To them it felt like school busy work. They could not see how it was in their interest to take the time to do the writing. Even when we explained our rationale, they did not agree to the proposal. They reasoned that it would not help them in their projects and thus was not worth doing. It was implicit, but to me it felt like a test of our intentions. If they truly had the autonomy we said they did, then they should not have to write. If this were like school as we said it was not, then we would force them to keep the notebooks. I asked them if they had to do things like this in school and did not like the experience, and they said that they had. I decided not force the issue and let it drop.

I myself kept a diary and would often write in it during project hours. The kids saw me do this, but did not really ask why I did it. When I tried to engage them in conversation about it, they did not care to discuss it. It was my thing and if I wanted to be geeky enough to keep a notebook, I could. They often delighted in teasing me about being nerdy and geeky for liking computers, for working on these projects, but this was all good natured. As they themselves changed over the summer, they too did some of the geeky things they teased me about. But their attitudes did not change regarding diaries and I still regretted the fact I could not find a way to help them see the benefit in such a practice.

We did have other activities that required writing to which they did consent as it was part of the organic flow of TFIP. For example, Antoine's writing of project memos to get an Internet connection, their writing of results from the Bucksport tour, writing leaflets promoting the Open House, etc., all required their writing. Often it was by committee or the whole group, and this obviated the need for those who felt ashamed of their writing proficiency to have it publicly displayed.

2.9 A Lego/Logo Experience at a Different Site

One way to highlight the approach at TWE is to contrast it with another project that utilized Lego/Logo. The other project was with eigth graders at a regular school. The teacher who ran the classroom viewed himself as a Constructionist. He had read some of the literature and truly believed he worked according to those principles.

Certainly working in a school placed numerous constraints upon his activities that were hardly conducive to producing as effective a learning environment as possible. This includes:

• only seeing the students for two one hour and forty minutes blocks over nine weeks

• not having enough Lego so that at the end of every period the students had to dismantle their Lego, sort it, and return it to its box, thus never having enough time to go deeply and create complex projects

• having so many students (around 140 per semester) so that he could not possibly know the vast majority of them on a personal level

• not having time or resources to learn how to use the new technology and how to leverage the technology for learning

Clearly, these constraints are incredibly difficult to overcome and provide a powerful learning environment. Given how obvious this conclusion appears when taken in this context, it is amazing that we do not change the structure of our schools, classrooms, and teacher training programs.

But even if this classroom utilized the benefits of a deeply immersive environment such as TWE, it is doubtful that the same results would have been achieved. This is primarily because of the lack of freedom and initiative afforded the youth so as to enable control and consistency for the teacher's benefit. The children were led through a step-wise process in order that they may be told and shown what was already deemed as the important lessons in a pre-ordained context. A brief example of a day at this class will illustrate why this is sadly true.

The children were given their Lego sets and worked two to a computer. They were given workbooks with a recipe on what to construct and how to construct it. In their workbooks there were specific questions at every step asking the children to respond. This is a pseudo-attempt at having the children do the scientific method. That is, they are told what steps to take and asked for what they observe. But the situation is so artificial that deep results rarely occur.

One group children became somewhat familiar with the Lego. They excitedly asked their science teacher (whose class this was but who was not the teacher for the Lego/Logo), "What would happen if we hooked up two motors to the interface box to control the fan?"

This is an exciting moment when working with children. They are showing real excitement over what they can do. They are thinking of possibilities for exploration. They have created project ideas and now want to implement them. Were it my group of children, my natural inclination would have been to repeat the question back to them: "Well, what do you think would happen?", have them make hypotheses about the situation, discuss their ideas, and then let them begin the exploration based upon their theories. This is what we did at TWE once we were able to engage them in the work. These two children needed no cajoling, coercing, or encouraging. They were curious, eager, and ready.

But this was not the response of the teacher. Rather, he asked them whether that was in the instructions. The answer was no. He then told the children to do only what was in the instructions. And then he moved on to ensure that order was maintained in the classroom.

This was not an isolated incident in this group. The children were not allowed to deviate from the cookbook exercises. It was pre-ordained what they should learn and how they should learn it. And, to top it off, even if they showed interest, curiosity and thought about the work by trying to engage in authentic activity with the technology, they were forbidden from doing so.

Another pair of children was trying to design simple circuits using AND, OR, and NOT gates. They were presented with word problems that expressed goals, and had to draw a proper logic design to accomplish the goals in the worksheets. These were bright children, but they were floundering. Successfully completing the logic design was prerequisite to working with Lego/Logo, which was treated as a reward. All their classmates had already moved on.

The problems were not that difficult, but were too abstract for the taste of these two. By talking to them, they demonstrated that they were using logic more complex than what was in the problem. They had no trouble following logic expressed in everyday language. But they could not bridge from this to their problems. When the same logic required by the problem was presented as conditions in a familiar context (under what conditions would someone buy lunch for a friend lunch), they immediately saw what was there and designed the circuit. We repeated the same process for the next two problems and they were on their way. What was a roadblock for three class periods dissolved when it was re-framed within their own language and experience. How we allow certain school exercise to turn children from curious and intelligent beings into beaten, sad and incompetent ones is almost criminal.

What was needed was a bridge from their own experience into the new domain to be learned (in this case, the language of formal logic). It is often not enough merely to present new material, logical and clear as it may seem to the presenter or curriculum designer. Children are not branching form nothing to the new material. New understandings must be based from current understandings. Constructing these bridges is particularly important for children from other backgrounds and cultures. Having a teacher who is familiar enough with the children, their cultures, their ways of seeing and expressing things, is critical to constructing such bridges. The bridge cannot only be rooted in the new domain, but also must be planted on the departing side.

An interesting question is how could this teacher consider himself a Constructionist. Constructionism is not merely using construction materials. The children must be able to be creative and engage in authentic activity. This classroom was no more constructionist than telling a child to go and turn on a light switch and to write down what they observed after turning on the switch. This is the same type of denigration that learning by doing has suffered since Dewey's time.

The group of teachers using Lego/Logo that we studied did not use the technology in interesting ways, preferring to follow the above instructor's use of cookbook instructions. They were unfamiliar with examples of how to use it in more creative and deeper ways. They were unfamiliar and uncomfortable with the programming side to the technology and thus avoided extending its use beyond the recipes. And they were constrained by the above factors imposed by current school structures.

But these same teachers, for the most part, worked in very different ways with the same children when it came to electronics. It was almost as though they were different people with different philosophies. These teachers themselves loved electronics. They were fluent, comfortable, and even excited by working with it. It was a labor of love for them. And this rubbed off with their students.

When it came to electronics, the teachers knew which of their students "lived at Radio Shack." They could push the students, help them, encourage them, help them find interesting projects and deeper understandings. And, of course, it had different effects for the students. The enthusiasm was contagious and the love was spread. Building with and learning about electronics was Constructionism at its best. That such a methodological dissonance could occur was sad, but certainly not a problem with the materials.

3. Discussion Section

The most salient point is that the youth at TFIP, who had not previously exhibited success in academic settings, performed sophisticated activities requiring intelligence and technical savvy. Conventional wisdom is that students in vocational educational should work in more tightly controlled, structured environments. We did the exact opposite with TFIP, providing these youth the same freedom, respect, and opportunities normally only afforded to advanced work classes. With the opportunities and support, and with open-ended malleable technological tools that could be used by people with various interests and learning styles, this group, who to a one believed they had no future, in the span of a few weeks demonstrated capabilities above and beyond what they had done previously. Also, in most vocational education programs, the focus is on narrow skills. This project instead focused on developing technological fluency which could then be utilized in a broad range of activities over the long term.

This section details which aspects of TFIP helped to produce such positive results. It also points out which aspects did not produce hoped for results. The aspects themselves are sorted into two broad categories, cultural aspects and technological aspects. Naturally, as is true with any real-life, integrated environment, the categories are not ideal nor is membership within one category or the other mutually exclusive. But, the categories could be thought of as aspects which could be true of any social learning environment (cultural aspects), and those that are particular to a computer-based project (technological aspects).

3.1 Cultural Aspects

This section details aspects of TFIP that we believe were critical to its success. Yet, these aspects could be true of any learning environment whether it incorporates technology or not. These aspects are the use of time for immersion experience, control of learning, high expectations of performance, and emergent project-based learning.

3.1.1 Time

We did not have to deal with artificial time constraints. We spent seven hours each day, five days per week for seven weeks working on projects. This provided the youth with sufficient time to explore issues deeply, and to add more attributes to their projects (and thus more complexity) until they were satisfied with what it did.

We had time for the staff to build relationships with each of the participants. In this way we could know each of them well enough to know what interests them, what motivates them, what experiences they have in order to help them develop and succeed in their projects. Since this group had not had success in school and therefore would not mobilize their intelligence and curiosity in a institutional setting, building solid relationships with them and knowing their preferences was critical to helping to engage them and interact with them. Without the time, perhaps the great success that they achieved, particularly Alan, Justin , Antoine, and Tom, would not have occurred.

We had time for each child to build familiarity with the tools and the work. With this familiarity they could explore and build relationships with the domains in which they worked. We did not have to be concerned with rapidly converging on the right answer. Because we had time, they could be stuck on a problem for a while and it did not matter. There was time for reflection, for puzzlement, for wonder and wondering, for imagination. There was time to be wrong, work through problems, and then have a better grounding.

The rhythm of time was more like work in science or engineering than in school. There were no artificial constraints of what had to happen within a fifty-minute block. There was time and room for multiple, simultaneous projects. This facilitated a natural clustering of knowledge as the threads of each project wove together into authentic coherent wholes. Powerful ideas were able to emerge as they saw that certain constructs or concepts re-appeared across the many projects (e.g. Alan noticing how gearing down could produce so many different results). Thus, there powerful ideas were not mere facts to be learned, but were allowed to emerge and appear in various contexts thereby displaying their power by their applicability across numerous problems. They were personally powerful because they filled lacunae felt individually. They were not isolated facts, but part of a web of knowing through doing.

Despite the relative luxury of time, it was apparent that seven weeks was insufficient to enable them to mobilize their intelligence and newfound confidence in every context they encountered. They were still at a loss when they went touring the town and needed to interview the store owners. Thus, even though there were dramatic improvements within TFIP, there was not enough to carry over in every circumstance outside. This is not surprising, but what happens outside the friendly confines remains as an issue. We originally conceived of TWE as a year-round program where involvement could span multiple years. Whether the added time could help produce this effect is an open issue for further research.

3.1.2 Control

Control is a complex issue. We wanted the kids to be in control of their own learning (how could it be otherwise?). Yet, we knew that, given their history, interventions were clearly necessary. We wanted an environment where the participants had a voice about issues, but where we could use our natural position as more experienced adults in order to ensure that we could maintain a just and equitable environment. We did not want either extreme of the teacher having all the power not only in determining what everyone would do but also in determining what was right, true or legitimate, or the other extreme associated with free schools where whatever the kids did, including nothing, was fine. We looked for a balance among all the interests of everyone within the community.

That we were operating a training program facilitated this. It was not legally mandated compulsory education. The participants were there by choice. Since they were attending voluntarily, we felt we had the right to insist that if they were there, then they had to do something. But that something was of their own choosing.

The process of engagement with Antoine was a clear of example of how this worked. Enabling Antoine to take control of his own learning was not merely a viable long-term strategy, but was exactly the goal. Antoine arrived at TFIP alienated from his own learning, unwilling to mobilize his intelligence, curiosity, and energy for positive results. Unless and until we found a way to intervene to jump start the learning process, he would have continued to drift in educational settings. But merely trying to trick him into performing school chores, or giving him short, controlled minor tasks would keep the control of his learning away from him and with the educational authorities. Antoine asserted his control over his life by trying to subvert any effort to make him do anything that he did not want to do. Our goal then was to create an environment, and deal with Antoine in such a way that he could feel that there was no contradiction between actively performing in learning situations and maintain control of his sense of identity and independence.

Every structure we created within TFIP had to navigate the inherent conflict between the rights of the individual and the desires of the community. While we wanted each person to feel free to pursue each one's own interests, at times this could conflict with the wishes of others in the community. We utilized group meetings to help make the issues explicit and then settle the issues when conflicts arose. Meetings were open for all to participate. Whenever we could, decisions were made by consensus. We attempted to make every issue open for discussion. How we should spend our time; who should do what; how to organize the room; whatever the decision the group would discuss and decide. As described above, by the end of the summer, they were chairing, running, and deciding through our group meetings. Their decisions were not merely window dressing or on trivial issues. We wanted the program to be theirs; the learning to be theirs; and the success to be theirs. If the emphasis was on our teaching, or the control were ours, then their accomplishment, and their sense of accomplishment, would have been limited.

Yet, by enabling this control, we did not abdicate our responsibility. We too had a stake in the activities. We too had a legitimate role to play. But this role was to use our experience, in life, with the technology, and in the domains of exploration, to help facilitate their learning and performing.

Control was not about eliminating surprises, for it is often the surprises that provide the richest learning experiences (e.g. Alan and the serendipitous effect when trying to gear down his maze car to enable turning also enabled climbing). TFIP was about exploring and learning by working on projects that were interesting, unknown, challenging, and fun. What those turned out to be was as varied as the experiences and interests of the individuals. Enabling and facilitating such explorations in a supportive atmosphere was our mission. By having each one working towards their own goals was empowering. And by having such an environment, the need for dominating control, force, coercion, co-optation was eliminated.

3.1.3 Expectations

I had high expectations of what each child could achieve. I did not look into their previous records as I did not want to be prejudiced for or against them. As we came to know each other, we could build an environment in which all of us could thrive and develop. They came to realize that I believed in them, supported them, knew that they were intelligent, and expected that they would perform well even in difficult tasks. As they accomplished these tasks, their belief in themselves also grew.

3.1.4 Emergent Projects

The level of engagement at TFIP was at the project level, not at the skill, problem, or subject level as is typical in many educational settings. Project-based activities is gaining popularity within educational circles,[10] with good reason, and therefore I will not delve in depth into the issue here except to delineate how the approach at TFIP was unique.

Having an open-ended project basis enabled them to pursue their own interests. In this way the learning was connected to their own lacunae. This not only provided a motivational basis but also helped to connect what they learned to what they knew. Facts and activities were not in isolation and thus had better potential for retention, use, and depth via connection. Allowing projects to have an individual basis and an emergent flow based upon the interests of the participants, which naturally change over time, is perhaps the most salient difference between TFIP and other project-based environments. In most project-based environments, there is only one project and everyone participates in it. This belies the individual nature of learning, interests, and lacunae.

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[10]See Papert, 1996, Tinker, 1993, and xxx for more on projects and their roles.

The projects were allowed to flow and develop based upon the interests and activities of the individuals and the group. It was not decided a priori what the projects would be, how they should unfold, what the key learnings should be, nor what the sequencing of events should be. Each project had a complex, non-predictable emergence, and it was impossible to know beforehand what would or would not resonate with a child or with the group. Rather, we tried to guide and mold, to probe and push, so that the youth would look deeper and add more to their work. But what they would accept or find interesting was unknown. So, by having a familiarity with the domains, the tools and the participants we could help them search for interesting possibilities.

As mentioned in the story with Alan, his placing of a brick in front of his car and his car climbing it was totally random and serendipitous. Yet it was one his most profound learning experiences as it showed the power and span of the idea of mechanical advantage. Only by working for a long time in a number of related projects did the breadth of the idea become apparent to him. One cannot necessarily plan what will be a moving experience for everyone. The best one can do is to try to set the climate where such discoveries are more likely to occur.

Projects also created whole, organic entities, and do not get sliced or de-natured as often happens. For example, the slow car projects had aspects of engineering, physics, mechanics, and mathematics in them. As they wrote about their projects, language became connected as they needed to express and communicate their ideas. The project was an organizing center for activities in each of the subject so that these subjects could be connected to and supportive of each other.

3.2 Technological Aspects

The above aspects could be beneficial in any type of program. Treating adolescents with respect, having democratic control and responsibility, allowing time for deep ideas and projects to develop, having high expectations for everyone's intelligence are all necessities no matter what the project, whether Technology Works, Basket-Weaving Works, or Gene-Splicing Works. And without doubt, anyone could gain a tremendous amount working in any project that contained the aspects detailed above. However, the technology of the Technological Fluency Immersion Project also made a significant contribution. Some aspects of what the technology afforded are listed below.

3.2.1 Cultural Capital/Cultural Resonance

The ability to work with technology carries a certain cachet in our society. The participants believed that if you could work with computer technology then you must be smart. While they exhibited their intelligence in other aspects of their lives, because cultural value may not have been attached to these activities their was not a strong feedback effect into their self-images. Successfully attacking difficult projects of their own choosing and thus carrying personal import, projects that utilized programming, mechanics, and new technology, helped to begin to change their views of their intelligence.

This was especially evident in their changed behavior between the beginning of the summer and the end. At the beginning the least little obstacle would cause them to quit. They needed a lot of support and encouragement in order to keep working. They displayed considerable evasive behavior, apparently attempting to conceal their self-doubts and to avoid situations where their felt stupidity would become visible to others. By the end of the summer most had a true *hacker* mentality. They may not know how to solve a problem initially, but they would work until they could find a way. The contrast between the Alan at the onset of the project and the Alan refusing to compromise in having a robust, perfected maze navigating vehicle is an example of this.

Poor or disadvantaged adolescents are often bereft of *cultural capital* [West, 1994]. That is, there are few experiences in their lives that they can use as a foundation from which to build and leverage from in order to attempt seemingly difficult activities (thus the metaphor of capital). Schools for these adolescents also typically do not afford opportunities for creative and open-ended work so again they do not have the opportunity to build from this [Anyon, 1980, Apple, 1979]. Thus, by gaining proficiency with and an enjoyment of working with technology that affords the cultural capital, the youth inherited the feeling of intelligence.

A critical factor in their inheriting this value was that we did not de-nature the projects by pre-determining them or slicing them into tiny, bite-size pieces. The danger of this, also an unfortunate prevalent practice in many schools, particularly for the poor, is that the difficulty and challenge are removed and thus there is no great satisfaction of achievement.

This does not mean that we should intentionally make things difficult. Quite the contrary, a major benefit of the software environments the group used at TFIP is that they make otherwise difficult domains to learn more approachable and tractable by providing different ports of entry than were previously available. But by using technology, (which they believed that they had to be smart to do), to successfully complete projects (that were difficult and thus they had to be smart to accomplish) of their own choosing, (which thus had meaning and significance), they gave themselves evidence in a meaningful way that helped show them their own intelligence in a way that words and encouragement, though helpful, could not do by themselves.

3.2.2 Individuation

By utilizing open-ended, malleable technology at TFIP, the youth were free to pursue projects of personal interest. Because the tools we used were programmable, they were adaptable to investigation of wide variety of projects and open to many styles of acting and ways of expression. This meant that we were not bound to only investigating particular phenomena or particular projects as we might have been had we used technology that was only for investigating particular problems. This provided multiple ports of entry based upon the interests of the child.

For example, Justin loved to play video games and building his own games became his port of entry into the technology. Alan, on the other hand, only wanted to work with the Programmable Brick. Tom was able to parlay his love of sports with his encyclopedia and sample project browsing to create his geography quiz. Michelle built her graphical animation stories. Most of the girls stayed away from the Lego at first while the boys were building vehicles. But once we embarked upon the Bucksport tour, the girls modelled artifacts of their own choosing (e.g. the Dunkin Donuts cop detector).

The point is that each could work on projects that resonated with her or his interests. There was not one overall project on which everyone had to work. Still, because Logo was the underlying technology, there still was sufficient commonalty of experiences upon which to build the emergent learning culture. That is, a good idea or innovation by one could be adapted by all into their own projects. This happened with the spread of procedural abstraction from Justin; the spread of cutting and pasting images from Tom; the spread of animation techniques from Michelle; the spread of Brick Logo and Lego construction from Alan, etc.

3.2.3 Bricolage

A related and also significant advantage to using malleable, programmable technology was that it afforded the participants the ability to do bricolage [Papert, 1980]. A major tactic for me was to help them when they were stuck was to have them try to pull analogies and related cases from their experiences and try to apply them to the current situation. If it were not possible or straightforward to make an easy translation from their experiences into operable expressions in the technology then the difficulty of approaching the problems would have been much greater. For example, as the group struggled with the concepts connected to gearing and mechanical advantage we used bicycles, automobiles, and other familiar objects as exemplars. While searching for salient examples I would have in mind classes of objects that could be of use, and depending upon the preferences and experiences of the child, we would pull from ones they knew. They used these to understand their new work and also became more familiar with the familiar objects.

Another aspect to youth as bricoleurs was that the bricolage could not only be applied in their expressions, but also that the projects themselves could move and grow in various directions based upon the experiences, tastes, and idiosyncrasies of each child. That is, because the technology and the scope of the projects was open, they could take advantage of serendipity or momentary inspiration or even being stuck to re-direct their project, add something from somewhere else, and still produce something meaningful and often beautiful. In essence the youth were not stuck in rigid, pre-defined experiments where what they would discover was pre-ordained, nor were they stuck using tools that tightly controlled how ideas could be expressed. This was exemplified with the resonance of truck and tractor pulls and other Brick Olympic activities.

3.2.4 Technological Fluency and Critical Thinking

One of the greatest differentiators between TFIP from other programs aimed at job preparedness and vocational training was our belief in and efforts towards building a technological fluency rather than aiming at specific skills [Papert & Resnick, 1994]. Indeed, we received much questioning and criticism from other administrators and teachers involved in this type of endeavor. "Why are you working with Lego rather than teaching word processing or keyboarding. Where is someone going to get a job working with Lego?" went the refrain. And indeed, unless one is going to work for Lego (or be a professor at MIT) the jobs working with Lego are extremely scarce. Yet, it is our belief that this was a better, more fruitful path towards preparedness than directly teaching any software package. There are a number of reasons for this belief.

First, most any specific skill one could teach today will almost certainly be obsolete soon. Not long ago significant effort was spent training people to keypunch. Not only is this obsolete, but even the underlying skill of typing is barely in demand now as office automation products and desktop publishing have delivered the ability to create professional quality documents to each user. Only knowing a particular skill or tool is at best a short-term panacea. For the optimal long-term effect we can better serve learners by facilitating the development of capabilities for conceiving, designing, constructing, debugging, and deploying technology projects.

This is the basis for fluency. According to Papert and Resnick:

> ...a technologically fluent person should be able to go from the germ of an idea to the realization of a technological project. Fluency involves the ability to express, explore, and realize ideas.
>
> Why is this type of technological fluency important? Some reasons are apparent. As more complex technological media enter the workplace, the gap between those who know how to use them and those who do not (the haves and the have-nots of technological fluency) will increasingly show itself in quality and productivity of work.

> But there is an even more important reason for students to develop fluency with new technological media. Technological knowledge is useful not only in its own right, but also as a means of access to knowledge and a facilitator of learning. [Papert and Resnick, 94]

TFIP was an existence proof of this philosophy.

An important element of Constructionism is the development of critical thinking through the building of projects. Children conceive of projects in which they are interested and excited. They build these projects and they either work or they do not. In order to get them to work, the projects must be robust and they must employ critical thinking to find and resolve the problems. When they work, and often when they work in unexpected ways, the learners can then extend or modify their designs. A special benefit to working with Lego/Logo robotics projects is that it introduces a real-world uncertainty into the operation of the project, and this uncertainty must be handled. In digital software boundaries are clear. With robots acting in and interacting with the real world, so much is inexact. Turning for a particular time may produce different results based upon numerous factors. Perhaps there is a pebble in the way. Perhaps the gears slip. Perhaps it is uphill. If this movement is part of a complex program, then the state of the robot is different. This uncertainty adds a real-world complexity and depth to the projects, and requires sophisticated thought to produce the desired results.

In arguing for a re-design of introductory computer science, Lynn Stein points out how computing exists in the world today, and how that is different from how we normally introduce students to computational ideas.

> But this model of computation [computation as calculation and algorithmic] doesn't really correspond to the way that computation exists in the world at large. Most computation these days is not algorithmic question-answering in desktop boxes. Instead, most computation takes place in automobiles and in toaster ovens. It is a parallel, distributed, embedded, continuous, condition-monitoring, event- driven, ongoing, interactive process. It is computation as a living, breathing thing that exists and coexists in a dynamic continuous parallel world. Even the computation that does occur in traditional computers is largely of this sort -- it is spreadsheets and word processors and network access protocols, distributed databases and graphical visualization tools and computer games, rather than mathematical problem-solving per se. [Stein, 96]

Because their projects were interactive, they had to consider what and how their users might act in the situations they designed. Based upon this, they had to put themselves into the minds of their users to imagine what and how they might act, and then base their programs upon this evaluation. This has an interesting relationship to where Scribner and Cole found benefits from literacy. In their study on the effects of literacy,[11] they discovered a greater effect from socialization than from literacy per se, except in one glaring instance. Those literate in Vai script often wrote letters for other non-literate neighbors. In order to successfully write such letters, they had to place themselves in the minds of the receivers of the letters so as to know what and what not to include and describe. The letter writers significantly outperformed other groups in the logic tests that Scribner and Cole presented. It was clear that the literacy (fluency) this constructionist experience helped develop had leverage into an area that its lack did not afford. The same could be deduced for technological fluency when building interactive environments.

Another critical aspect to developing technological fluency is nicely expressed by Thurston's view of mathematical practice. He writes:

> In other words, 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, 94]

Substitute computation for mathematics and this describes the process of how the youth at TFIP developed. Together we created a culture where they could construct computational thinking and fluency and apply it to real situations in the world and to real projects about which they cared. This helped provide them with more tools for their repertoire for being in the world.

[11] Flawed as such a phrasing of the research question might be, the study had numerous benefits and insights.

3.2.5 Technology as Enabler

One extremely significant aspect of the use of technology in the real world is how technology, and in particular computer technology, fundamentally altered by orders of magnitude what could be accomplished. The quality and amount of work can be dramatically increased through effective utilization of computers. The ensuing displacement and need for more technological skills in the work world is one of the causes of the social needs that TFIP addresses. But the manner in which the use of technology can fundamentally change what and how a person performs is a critical element in our program and in work environments.

The example of how Michelle was able to rapidly re-design and alter her program based upon the questions of a visitor illustrates this. Michelle was demonstrating her animated story of her "Crazy House" where different wacky actions happened as a guest traversed her various rooms. Her visitor, familiar with Logo from decades ago, asked her various questions about how to achieve different effects or create other scenarios.

While the visitor was expecting a verbal answer, Michelle surprised him by rapidly implementing examples responding to each of his suggestions and questions. The tool, Microworlds Logo, afforded her the potential to interact at a level where she, after her experiences through the summer, could respond to verbal descriptions and questions and rapidly transform those into functioning code. The visitor was especially impressed because he had worked in a similar summer project approximately twenty years ago where it took professional teachers in graduate school the complete summer to program only one such project. And here was a young woman of eighteen, who had not done well in school, rapidly turning verbal project requests into functioning code!

This is not a trivial question. There are computer tools that better facilitate the rapid creation of beautiful graphical objects than the ones we used at TFIP (although after developing their fluency with our suite of tools the group could and did go on to using other software such as PhotoShop and Director for specific projects). But these tools, particularly the drawing tools, are not designed for creating dynamic programmable objects that can interact with users and each other. Michelle demonstrated capabilities of design thinking and creating functioning interactive artifacts based upon user specifications essential for a software engineer. The issue is not whether any one tool is best, but having the ability to utilize the proper tools at the proper times. And to develop this level of understanding, technological fluency is valuable.

One can view this as a question of levels of engagement which vary according to circumstance. For this group of adolescents the ability to quickly engage in a variety of meaningful projects was critical to overcoming their resistance to difficult tasks. Still, these tasks had to have not merely a technological interface but also a degree of difficulty such that they could modify their view of themselves as intelligent human beings.

Michelle enjoyed creating many different projects. Users interacted with each project in different ways based upon the nature of the subject. To work with her Crazy House you had to navigate the layout of the rooms and do things with the various objects in the house. She drew these objects in, creatively giving each one character. For example, in her bathroom there was a fish that jumped out of its bowl, into the bathtub, and then onto the floor with drops of water flying off to die a colorful death, only to be reincarnated; upon certain user actions the medicine cabinet would open and the bottles would spill on the floor making large puddles; handles would operate other bathroom fixtures, and so on. In a geography quiz you could drive your car across a map of the United States but need to answer certain factual questions about the states you were in so as to proceed.

There were different levels of engagement for her in the creation of these projects. The tool afforded her the ability to rapidly create these interactive narrative animations. Because there was clip art of U. S. geography, she did not have to draw the outline of the states. She could use primitive graphic turtle objects and stamp other pre-determined shapes on them. She did not have to deal with the geometric primitives required to build these shapes. She could deal with Logo programming primitives and thus did not need to do lower-level programming. Carrying this argument to the extreme, she could use an existing computer and did not have to design and build one.

The point here is that there are trade-offs no matter at what level of engagement one enters into working on technology projects. There are benefits and drawbacks, particular affordances, and what tool is better to use is totally dependent upon the goals. Understanding a subject is relative to how one needs to exercise one's understanding. Michelle was able to cover a tremendous amount of ground by having a tool that facilitated the creation of a great number of varied, yet technically sophisticated, interactive projects. This afforded her the development of higher-level design and implementation skills, while hiding some of the tedious, lower-level implementation details that slow productivity. This helps prepare her for work at a particular level in today's, and probably tomorrow's, economy.

3.2.6 Leverage

Leveraging experiences were a primary goal of TFIP. We wanted to provide an environment where the youth could build technological fluency by having experience building projects with computer-based tools. Not only would this provide them with real-world experience on the projects themselves, but also we believed that these experiences would provide leverage for them in future endeavors. By gaining fluency in working on projects, understanding problems, expressing ideas, and employing computational ideas, the youth built not only a stronger sense of self but also a strong repertoire of experiences from which to apply in new endeavors.

But how this works is hard to pin down. We believe that there are such things as powerful ideas, key concepts in domains, important heuristics, etc., but how they function and how they can help leverage into other domains or new problems is not fully explained. How this could possibly work requires further research.

The project did not work absolutely in that when the participants interviewed the store owners they were unable to utilize their newfound self-confidence nor their technological fluency in a productive and timely manner. Thus, the experiences of the first five weeks before that project did not provide leverage in this particular endeavor.

However, leverage was exhibited in how they were able to more rapidly build multiple projects and approach new and difficult questions based upon their technological fluency and computational experience. In fact, through their project constructions they mastered many of the important core computational concepts that academics now believe are a good basis in the education of computer scientists [Stein, 1996]. This basis (e.g. interactivity, control, differential responses, parallelism, state, object orientation, etc.) then can provide leverage into deeper computational concepts. How these particular adolescents ably performed projects that are a basis for university-level computer science through projects, Logo, Lego/Logo, and StarLogo, demonstrates the power of the methodology we used at TFIP.

3.3 Role of the Facilitator--Or, 1001 Tricks

Naturally, the role of the facilitator is critical. It was not the aim nor a long-term goal at TFIP to try to replace the role of humans or adults or more experienced peers in the learning process. Yet, despite this it is important to address the oft repeated criticism of this type of project that the technology is of no matter and the only factor is having good people as though the position was advocated that only the technology mattered. The criticism that "These projects work fine so long as Papert, Resnick, or their students run them, but if not then good results do not occur" needs to be re-framed. This criticism focuses on the people almost as though it were genetic (i.e. the people in this group can do it but others cannot). It is not a matter of people per se, but rather it is very definitely a matter of what these people do. It is further explication of what to do that is the aim of this section.

Perhaps the most important characteristic of a good facilitator for this type of project is a love of life. Enjoying doing things and, through this doing, learning about things and others is infectious and cannot really be faked. Over time learners can easily see through any facade and can tell who is interested in this type of doing, and who is truly interested in them as people. By enjoying experimenting, discussing, questioning and searching through interesting ideas and mysteries, and thus learning all the time, the youth become part of this culture and can develop this type of love as well. John Holt beautifully expressed this type of love of doing and how learning is intimately tied up in this and should never be separated from it [Holt, 1989].

Most of the wonderful breakthrough moments at TFIP were at the end of long and arduous journeys. But these journeys perhaps would have been abandoned if the journey itself were not in some way enjoyable. The answers or finished projects were not the only important matters. The process of getting there also mattered. We enjoyed posing interesting questions, attempting challenges, hypothesizing about alternatives, building projects, evaluating, debugging and modifying them. This was our life at TFIP and the youth responded to this.

Intrinsic to any group-based learning environment is the development of relationships among the facilitator, the participants, the material, and the tools. Just as there is no one right way to raise children, there is no one right way to work with children. But how the facilitator feels about the domains being investigated and the tools being used will be crystal clear to the participants. If the facilitator enjoys the subjects, enjoys using the tools than this can be contagious. If the work is burdensome, the tools frightening, or the participants held at a distance or in disregard, then it is unrealistic to believe that good results will ensue. And because developing relationships is the key activity in any learning environment, and because these relationships are as varied as the people and settings involved, there can be no formulaic, cookbook approach to what to do. It will be bound up in the circumstances of the time.

The bandwidth is not merely the teacher communication knowledge to a child. This type of focus is obsolete. The perception and understanding of the terms surrounding learning environments, be it teacher, knowledge, learning, are bound up in cultural models of schools and learning that need to be re-examined. The teacher as dispenser and arbiter of knowledge and knowing never was accurate. Yet, it is the myth so deeply embedded in our society, and so customary in everyone's educational experiences, that it often subtly operates even when educational practitioners profess a different outlook. In **Kinds of Power**, James Hillman argues that many of the terms used in human institutions(and schools are certainly one such major institution) need to be re-assessed and re-defined given new organizational structures and operations [Hillman, 1995]. While Hillman was addressing economic concerns, this is no less is true when applied to education.

Because our activities at TFIP were project-based, chosen by the participants, and utilized computer-based technology, the role of the facilitator had to fit within those constraints. There are many qualities that could be important in other settings that were de-emphasized here (e.g. being a good lecturer, having to have familiarity about lots of things in lots of subjects, etc.). What was important then was familiarity with the tools, with powerful ideas that help use the tools, with the types of activities that can be attempted with the tools, with working with youth and drawing out their thoughts and helping them appropriate the use of the tools. Given the lack of success in schooling our group at TFIP had, it was also important to know them well enough to have a feel for when and when not to push, as well as how to provide support in a non-condescending and non-belittling way where they could maintain the sense of accomplishment.

A major goal of TFIP was that becoming more adept and self-reliant at being a learner/doer was as important as learning any particular thing. Accomplishing this required a major shift of agency. In this view the primary agent is not the teacher. Nor is the primary focus on the material. Rather it is the agency of the child that is primary. While this might seem trivial and obvious, and perhaps everyone involved in education might claim this as the goal, when one examines the process utilized in most educational settings other foci become apparent.

Even when teachers view their roles as coaches or facilitators, even when their is a belief in discovery learning (how could learning be anything but a discovery?), often the agency still lies with the teacher. Discovery learning can functionally be practiced as discovery that is pre-ordained and expressed in pre-ordained terms thereby losing any authenticity, meaning or personal connection. Facilitating can devolve into merely manipulating or seducing someone into a pre-determined practice. It is practically a cliché now for teachers to orate about how they are coaches yet still dominate the discourse and life of their environments.

The power inherent in a teacher's role is potentially dangerous. The teacher as final arbiter of what is true and what counts for knowledge is seductive for the teacher and possibly harmful for all involved. There is a higher bandwidth among teachers and learners than the mere transfer of information and subject matter. The extra features transmitted have been detailed in the previous environmental section, and is referred to in other writings as the "hidden curriculum" [Bowles & Gintis, 1976, Giroux, 1981]. The bias of what the teacher finds interesting, who the teacher likes, what the teacher likes, etc. invariably enters into the atmosphere. It cannot be otherwise. Learners are going to sense it and react to it. It is critical that this power is acknowledged and open and the realization that learning is more than the transfer of information.

This is not to say that power should be abdicated or ignored. Nor is it to say that while the adolescents had autonomy and freedom within projects, that there was a spirit of anything goes and that the adult had no role or no authority. Dennison beautifully illustrated the natural authority the adult has in these environments that emerges from the adult's experience and the youth's desires to participate in society [Dennison, 1969]. At TFIP I could be respected because I knew how to do things that they came to want to know how to do. Because I respected them the door was opened to working with them. At times I might show them exactly how to do something. At other times I would challenge them to try to figure it out on their own. Sometimes I knew they were misguided about their belief in something or other (e.g. whether a program would work, whether a gear train was adequate to power their vehicle), but believed that if I told them what was wrong and what was the answer that I would be robbing them of something: that concretely experiencing something was wrong, and then having to figure out what and why it was wrong, would help them to build a better theoretical foundation for a long-term understanding. That negative cases, so long as there was support and hope for eventually achieving positive results and that the temporarily negative results did not mean they were negative or stupid as people, could be formative as well.

In this way some of the events and tools at TFIP were pre-set. I had a familiarity with programming in particular, but also with working with LEGO/Logo and StarLogo, and with children attempting to build projects with these tools. I had a relatively rich experience base both of how to program professionally on a wide variety of projects, but also on how children work on projects with these tools and how they can go right or wrong. From this case base, while I never knew exactly what would happen, nor on what a child might want to work, nor how things might develop, I could still have a large bag of tricks from which to pull in a context-based way.

For example, when the size and complexity of Justin's program had grown so that he was having difficulty debugging his code and understanding the control logic, it was the perfect time to introduce procedural abstraction. Procedural abstraction is a powerful idea precisely because, among other reasons, it addresses exactly this need. He keenly felt the problem with his project, and thus had a deep attraction for the solution. That he had absorbed and assimilated the concept was apparent as he explained the basis of the concept to our visitors and demonstrated it to his colleagues so that they might utilize its power, even though he did not yet use the term procedural abstraction.

Similarly, this was true with other programming and mechanical concepts. Needs arose constantly when they were building their projects. We could introduce powerful concepts (e.g. variables, mechanical advantage, concurrent programming, processes, etc.) as the needs presented themselves. Sometimes it was to address existing problems. Sometimes it was to extend a project in an interesting new way. In this way the ideas had power embedded in concrete experience and had attachments to real functionality.

Contrast this to how powerful ideas and key concepts are normally taught. Which ideas are important is pre-determined. The best explanations are concocted. Examples are pre-set. And then problems are selected that can highlight the idea and provide exercise for the child in their use. The curriculum is composed of what others think is important to know. And the role of pedagogy is to transfer this to the child.

This type of use of curriculum turns the power of key concepts on its head. Key concepts are key precisely because they deliver power thinking about real situations. Thus, when the facilitator has a familiarity with the concepts and where and how they might apply, then so long as the projects have sufficient depth and complexity the opportunities for the key concepts will inevitably arise in their natural contexts.

In line with keeping the focus on the youth and not just the material, another critical skill for the facilitator is the ability to elicit what they would like to do and what they are thinking. In my life there were two important threads that helped me develop my style for doing this. No doubt there are others, but for me these two were key. One was an exposure to a Piagetian style of clinical interviewing in order to draw out what a child might be thinking while trying to accomplish a task. the other is knowledge acquisition and engineering for building knowledge-based (or expert) systems.

It is not possible to be absolutely objective and engage children in dialogues about what they are thinking without biasing the process. Both types of interview and engagement share certain features. In each the subject is in the process of doing something. In each it is not the goal to try to teach the subject or reform how they do the activity, but rather the interviewer is trying to find out what the subject is thinking about while doing the activity while biasing this as little as possible. And, in using these methodologies in a Constructionist setting, it is a learner-centered way to making internal thoughts more explicit in order to facilitate the learners developing a better understanding of their ideas through the production of an artifact.[12]

The last point about the role of the facilitator is illustrated by the difference in activity among the other group of teachers that used Lego/Logo mentioned earlier in this paper. Those teachers viewed themselves as Constructionists, used the same materials (Lego/Logo), worked on projects (though this differed in a fundamental way), and had vastly different results. They also had vastly different results with some of their students when they worked in electronics, a

[12]An interesting side issue is the failure of the type of knowledge representation used in most expert systems and for those in Intelligent Tutoring Systems (ITS). The type of knowledge representation, with declarative, factual knowledge, and procedural knowledge encoded in situation-action rules, was fitting with a formal trend in epistemology that was prevalent earlier in this century. These types of systems failed primarily for one of two reasons. Either the knowledge was brittle, in that while an expert can easily resolve a new situation that is similar to known situations, these systems could not. Or the system was incapable of learning. yet, despite this last significant reason for failure, much of pedagogy functions along this line of knowledge representation, with the role of pedagogy as the transfer of these representations. And thus the learners suffer from some of the same problems as the systems.

familiar domain to the teacher, as opposed to the relatively unfamiliar Lego/Logo. The programming side of Lego/Logo was particularly unfamiliar.

In the areas where the teachers were on unfamiliar terrain (in this case, Lego/Logo), they resorted to canned exercises with pre-determined lessons. The children were forced to follow cookbook-like instructions about what to perform. The underlying assumption was that simply by performing the construction steps, they would automatically infer the proper lessons. Much of science curriculum is similarly designed.

But of course it does not usually work that way even though when it is convenient we pretend that it does. For various reasons the pre-planned exercises did not engage the children and did not produce leveraging experiences. Significantly, neither did these exercises engage the teachers nor lead to a deeper understanding among them so that the next time they would use the materials in a more profound way. It is not that the exercises were inappropriate and merely needed to be replaced by better ones because there is no possibility that any one set of exercises, no matter how well planned, thought out, and explained, will be sufficient to engage all learners and connect to what each learner brings to bear on a situation.

How these same teachers dealt with working with their motivated students using electronics illuminates the key differences. The teachers liked building electronic devices. They were comfortable with it. They were fluent in how to go about designing and creating artifacts to satisfy some project goal. They could work with their children in this type of endeavor. And the children not only could learn electronics by building components to satisfy a need or curiosity, but also they could develop such a fluency and such an enjoyment from this type of work, just as the teachers did at some point during their formative periods.

3.4 Assessment

In part because we know so little about how the mind works, as well as so little about not only how people learn particular things but also about how early learnings impact subsequent learnings, true assessment is virtually impossible. Nevertheless, motivated not only by a sincere desire to determine effectiveness of learning but also, sometimes, by a desire to appear "scientific," assessment, particularly quantitative assessment is rampant in education even though it often has little scientific validity. Many misguided efforts resemble the old Sufi story of searching for lost keys under the streetlights not because they were lost there but because that is where the light is better. Unfortunately, so much of educational assessment is similar. What can be easily measured is measured, even though it does not signify what it is purported to. It would not be so bad if it did not have such desultory effects on the lives of these children.

The success of the children at TFIP belies previous assessments of their capabilities. For the most part they were assessed as being incapable of performing the type of work that they demonstrated they could perform given a different environment in which to work. Previous assessments were virtually tautological in that they assessed that the children could not perform in the existing settings. The assessment off-loaded the responsibility for this onto the children themselves rather than onto the learning environments. The proof of their true capabilities lies within their performance at TFIP, where they successfully completed the majority of a college-level introduction to computer science curriculum.

The judgment about the efficacy of programs is skewed in a similar manner. For example, the youngsters who participated in Theatre Arts Works achieved dramatic improvements in their lives by the totality of their involvement in putting on plays. Learning to read, finishing high school, going to college, weaning oneself from drugs, all of these are major accomplishments triggered by their involvement in TAW. Yet the benefits achieved did not appeal to the assessors in the same way that performing little playlets about competencies did. If the basis for assessment is the impact on the real lives of the children, then the first years of TAW were a resounding success. Yet, the apparent, surface-level appeal of competency playlets to the administrators, as though the only way to gain competency is to be told about it, was more compelling than the more authentic activities of the previous years staging plays, **despite the fact of the demonstrable dramatic differences in their lives.** If the proof is not in the change in their lives, then where else could it be?

Corporate training is undergoing a assessment re-structuring to account for just this type of issue. The need for training is rapidly growing as the nature of work evolves and businesses need to constantly and rapidly adjust. Yet, for all the billions of dollars spent in training, corporations discovered that training that assessed and rated itself and its students as successful most often did not translate into improved performance or demonstrable learning where it mattered most, in performance on the job with the allegedly newly learned skills. Thus, many forward thinking companies adjusted their means of assessment, dispensing with traditional testing and quantitative methods and concentrating solely in terms of ensuing work performance.

The reaction to Tom's geography quiz displays another example of the inadequacy of traditional school-type, large, standardized programs and assessment. Tom's geography quiz was extremely popular with our visitors and social program administrators. I was curious about this, as although it certainly was a very nice project, other projects were more difficult, intricate, complex, creative, or artistic. Yet, without exception, Tom's attracted the most attention. Why was this?

It occurred to me that Tom's project was the most *school-like*. It had questions and correct answers. It was about explicit facts. What was underneath and what thought and activity was involved was not as important. Almost every admirer commented that others could learn from Tom's project. Perhaps this was true, but without doubt the one who learned most was Tom when he constructed the project and pulled together the facts. This subtle point, key to Constructionism [Papert, 1990], is so often missed in conventional schooling where telling is privileged.

3.5 The TFIP Experiment

Given the broad goals and short duration of TFIP, the project can be taken as an interesting and valid success that still requires more time to fully establish its more particular goals. With the broad mission of testing whether an open-ended, deeply immersive technology program that, rather than training on specific skills, instead attempts to build a technological fluency through working on projects, TFIP is an existence proof to providing such an environment successfully for children as a long-term vocational program is not only feasible, but also in many ways desirable. It is especially compelling given our participants, who had not previously excelled academically.

The children did build technological fluency and capably constructed many complex projects requiring sophisticated reasoning and technical skills. Even though the program was only seven weeks long, and functionally only five weeks, the difference in the children's performance from the beginning of TFIP to the end was dramatic. By the end of the summer, the children had projects building web pages for outside groups. They were capable of installing and maintaining hardware and networks, and we envisioned them providing this service back to the school systems. This would be especially powerful as it not only serves a critical and often unmet need within the schools, but is especially empowering for the children themselves to return to the site of where they were viewed as unsuccessful, and performing a difficult task that requires a significant amount of skill. They were also capable of building these sophisticated projects not by following someone's recipe, but by taking a broad goal or description and working their way through to a solution.

Still, despite the successes, TFIP fell short on some levels. As demonstrated when the children, for the most part, withdrew into shells when interviewing the store owners, the new behavior they demonstrated at TFIP did not necessarily carry over into all other settings. Clearly, seven weeks is insufficient time to change, but how the program would work over an extended period of time is an open issue.

Another critical point that TFIP did not meet was how to extend to, involve and assimilate other teachers in the process. Eleonora Badilla, coordinator of the

Computers in Education project in the Ministry of Education of Costa Rica, mentioned that this was a more critical problem in their effort in Costa Rica than running pilot projects with the children.[13] There were three other teachers involved at TFIP. Two worked in the first two weeks of the project due to coordination factors, and then participated on a visiting basis afterwards. Both of them had experience with the technology and the philosophy and both contributed a tremendous amount to the project and the children. Another participant came into the project at the end of the second week, and did not have the opportunity to be familiar with the goals, tools, or methodology employed. As the work with the children was intensive, there was not much time to also work on this person's development except through "on the job training." For various reasons, this did not work well at all. How to integrate others into an existing program is an open issue that requires development. While it was not a goal of the TFIP summer pilot project, it is crucial for the long term success of such programs.

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[13]Personal communication.

4. Relation to Other Work

In this section I describe the relationship between the TFIP project philosophy and other related research. I first review research on constructionism and social constructionism, particularly as applied with at-risk youth. Next I review aspects of learning by programming. This leads into a discussion on textual literacy and technological fluency. I conclude with a comparison of the ideas expressed in this work with ideas of situated learning and cognitive apprenticeship.

4.1 Constructionism, Social Constructionism and At-Risk Youth

This project falls into the Constructionist line of research developed over time in the Epistemology and Learning group at the MIT Media Lab [Papert, 1980, 1990, 1994, Kafai and Resnick, 1996]. Constructivist Learning [Piaget, 1952a, 1952b] posits that rather than receiving new knowledge in tact from an outside source, as in the "conduit metaphor" [Reddy, 1993], humans actively construct new knowledge based upon their prior experiences and own knowledge schemas. Constructionist learning adds to this that this process of knowledge construction is facilitated when actually constructing artifacts in the world.

> We understand "constructionism" as including, but going beyond, what Piaget would call "constructivism." The word with the v expresses the theory that knowledge is built by the learner, not supplied by the teacher. The word with the n expresses the further idea that this happens especially felicitously when the learner is engaged in the construction of something external or at least shareable ... a sand castle, a machine, a computer program, a book. This leads us to a model using a cycle of internalization of what is outside, then externalization of what is inside and so on [Papert, 1990].

This thesis adds to that body of work by applying the ideas of Constructionism and technological fluency [Papert & Resnick, 1994] in the domain of youth work preparedness. The urgency to address the needs of this segment of the population is described earlier in this work. But research into effective means of applying Constructionist principles and ideas of technological fluency for teenage children in difficulties for vocational preparedness has not been done. This thesis extends the body of research into this area.

This work shares its goals and basic approach with a project run by Alan Shaw with his wife Michelle [Shaw, 1995]. This project also applied Constructionist principles in working with teenagers subjected to economically deprived situations. While Shaw's work describes several projects, one in particular, working with neighborhood teenagers, many of them former gang members, to help them build appliance repair businesses, bears the most resemblance to the explicit aims of TFIP.

In the appliance repair project Shaw worked with these teens, who were part outcast and part objects of fear in their own communities. As in the TFIP project the opportunities for the participants were extremely limited. Without summer jobs and in their normal environment, many of the youths "seemed to be in a persistent cycle of dangerous activity." The primary explicit goal was "to develop meaningful projects that helped them find employment in their own neighborhood during the months while school was out."

The goals of TFIP and this project were quite similar, that of providing a means to help enable these "left-outs" to utilize technological tools to build from within a means of participating in and developing the legitimate life of their community and preparing for meaningful work. However, the methodology applied was different. At TFIP we took a longer-term approach; building technological fluency so that it could be applied in other situations. Shaw's approach was more direct; building specific technical skills that the teenagers could apply in earning situations in a relatively short period of time.

Even though both projects worked for a mere seven or eight summer weeks with youth who had experienced much difficulty in their lives, even the modest successes achieved are incredible and indicative of the possibilities in their lives. A comparison of the merits of the two approaches is not possible, however, because TFIP enjoyed the luxury of many more resources than were available to Shaw. Indeed, Shaw writes:

> ...there were simply not enough adults involved in this project to give the teenagers adequate support in creating local services. Furthermore, we decided we would try to do other services in addition to appliance repair to better represent the range of interests and talents among the youth involved... Yet, this just increased our need for greater involvement by other adults who could take on some of the apprenticeships. [p. 108]

TDC provided TFIP with sufficient resources, both technical and people, to work in an technically immersive environment where each child could pursue projects of personal import. Because our environment was principally computer-based, the protean nature of the machine enabled pursuit of a wide variety of interests without requiring a mentor for every apprenticeship area. Shaw's project did not have this luxury and thus necessitated a shift in direction where they worked on constructing a community network and database to help compile and disseminate information about the skills in the neighborhood. Through this construction they helped to build a better sense of community and helped take better control over their own environment. Still, both projects illustrated that when working with teenagers who have been pushed into these destructive patterns, a fair amount of initial adult presence is required. At TFIP we did not progress as we would have liked with Jimmy and Spike. At Shaw's project they felt an acute need for more adults to help with the wider range of interests among his group. Starting with fewer participants and running for a longer period of time might solve this problem, and in ensuing TWE work we hope to prove this.

The social contribution of Shaw's work is undeniable and critically important. The major theoretical contribution of Shaw's work is a deep one, and is implicit in the appliance repair project, though made explicit and explained beautifully in his thesis. The criticality of the point is evidenced by how often many well meaning projects that do not take Shaw's aspect into consideration fail when working with adolescents from backgrounds similar to those with whom the Shaws worked. This contribution is the idea of "Social Constructionism."

> Social constructionism takes constructionism out of the classroom and out of the realm of educational priorities. In so doing, it takes the constructivist viewpoint even further into sociocultural perspectives bringing with it the same insights concerning the cycle of internalization and externalization. Through this lens, a group of subjects serve as active agents in the construction of outcomes and artifacts that produce a developmental cycle in the social setting, and this view explicitly includes as *social* constructions the social relations and social activities embedded in the social setting. To social constructionism, the social setting itself is an evolving construction. When the members of a social setting develop external and shareable social constructs, they engage the setting in a cycle of development which is critical to determining its ultimate form. [p. 40]

In social constructionism the youth are no longer merely either pushed to the side and relegated to their easily accessible destructive cycle, nor are they sitting in an artificial setting being fed information about the world around them. Rather , they are learning about their world by acting upon their world, or paraphrasing Shaw, they are learning by doing but also doing by learning. This style of work, while desirable when working with anyone, is particularly important for youth in disadvantaged circumstances, as written about by Freire (Freire, 1972, 1989, 1995].

The active role in working in their communities parallels the active role always advocated for learners, but difficult to achieve. In Shaw's work and at TFIP, to be truly effective it was critical for the participants not to be in the passive, donee role of acceptance, whether of knowledge or of change in their community or of change in themselves. It is a contradiction for empowerment to be a gift. So, in order for them to become less alienated from their environment, or no longer passive in the face of unpleasant social conditions, they needed to take charge in their lives by acting upon their environment, and simultaneously acting upon their environment by taking charge in their lives and learning.

Freire relates a story about how when giving a lecture on moral judgments based upon his study of Piaget that he was taken to task by a peasant worker. While Freire attempted to make the peasants understand his points about disciplining children, the peasant explained to him how Freire did not understand their conditions. Freire later complained to his wife that "I though I'd been so clear...I don't think they understood me," only for his wife to respond that "Could it have been you that did not understand them?" Freire relates how this incident has remained with him, guiding his work even though it occurred almost forty years ago [Freire, 1995].

Much mainstream educational research focuses solely on the nature of the material to be learned. This neglects the cultural aspects of learning embodied in the learners' views, and often is why seemingly promising educational efforts fail when working with children who are poor or from minority cultures. (Other aspects about how the worldviews and interests of the researchers influence what they see, write about, claim, and advocate are detailed nicely in Jackson [199x] or in Latour [1987].) Piaget long ago pointed out how our learning is bound in what we already know and how we know it. This is the essence of Constructivism. Yet, this allowance for ways of knowing is often neglected as it applies to people not from the cultural majority. Either it is ignored by a sole focus on the subject area, or it is ignored as though the privileged framework is the only framework. What is needed is not to merely attempt to make problems and examples relevant to different experiences on the surface, but rather to connect to and draw from the deep structures of anyone, which by definition must be deeply cultural. In other words, obvious as it is, we must try to connect to each one's frameworks and build from that. Merely trying to layer new knowledge on rarely works well no matter how cogent the explanation.

4.2 Learning by Programming

This gets to the essence of trying to build fluency in that the goal is to provide the tools and environment by which a learner can build, express, and debug concepts in a preferred area. This approach is very different from other current research focusing on what is called "end-user programming" [Guzdial, 1994]. Believing that programming is "too hard," and that because nobody will continue to program after "class" ends, then the goal should be to construct end-user environments where the primary activity is editing as that is what people tend to prefer to do with computers.

In the same way that "learning by doing" can be denigrated by mindless activities, so too can learning through construction be denigrated by removing expressiveness from construction materials. Learning to use language in a formal way by writing and reading is hard, as is learning to speak for a baby. Yet, no one would argue that because it is hard that it should be avoided. On the other hand this does not mean that we should only have learners do tasks that are hard. We should not make anything more difficult than it inherently is. But removing difficulty is not a goal. Because the tasks at TFIP were difficult the youth were able to create a sense of satisfaction and achievement and thus change their view of themselves as stupid. Programming and computers are used in almost all fields in order to make the complexity of those fields more tractable. Tools that try to reduce the complexity and hide the actual content for users and merely provide editable items or settable parameters (e.g. CAD or other design systems, 4GL environments, knowledge acquisition tools for expert systems, etc.) do not work even for domain experts let alone for learners.

Similarly, just because the majority of those exposed to programming in school do not program for fun at home does not necessarily lead to the conclusion that programming languages, as opposed to end-user programming, are not useful. People do not go home and use word processors or spreadsheets or other "end-user environments" for fun either, but that does not diminish their utility for the tasks for which they were designed.

Even the term end-user programming is misleading. Unless one builds one's own computer from raw materials one is an end-user of something. The question then is not programming languages versus end-user programming versus tool using, but rather what levels of engagement and expression are appropriate not only for the tasks at hand but also for what is appropriated for future use and expression.

TFIP illustrated some of the potential power in programming and engineering. Still, existing computers, languages and interfaces need to evolve to become more expressive, evocative, and accessible for all. Natural languages evolve to fit to human needs. It is natural that computer languages must evolve as well so as to improve as tools for understanding domains difficult to approach or comprehend without them.

However, the primary distinction between the approach of end-user programming and the approach adopted at TFIP may be characterized as providing tools for easily accomplishing narrow tasks in constrained environments (end-user programming approach) and providing more general tools that the user can configure for particular situations. As in any design situation, there are trade-offs. When the possible tasks are highly constrained and the steps are provided, then it is easier to get started (providing one understands the overall computational metaphor), is easier to perform particular high-level actions without significant prior preparation, and is perhaps easier to quickly create polished final products. But the trade-off is that one cannot easily create or customize one's own product because of the constraints.

Perhaps the biggest trade-off is the loss of future leverage. Because the situation is so constrained, there is no way to build a fluency to apply to future problems except within the affordances of the system itself. Certainly, end-user programming has a place (as this thesis is being written with a commercially available word processing program and not one built from scratch). The question is what approach can provide more long-term benefits, which is still an open question and very difficult to determine.

A different direction in introducing computation, and one consistent with the approach taken here, is the one expressed by Lynn Stein. Stating that given how computation has changed in the real world she advocates that the introduction to computing should change accordingly.

> Introductory computer science education is entrenched in an outdated computational model. Although it corresponds neither to our computing environments nor to our work, we insist on teaching our introductory students computation-as-calculation, a mathematical problem-solving view of the role of the computer program. We can dramatically improve this situation -- and, as a corollary, all of undergraduate computer science -- by focusing on the kind of dynamic, interactive, inherently parallel computation that occurs in spreadsheets and video games, web applications and robots.
>
> Traditionally, computer science education has begun from the perspective of von Neumann serial computing.[1] We teach people the following model of computation: Begin with a question. Describe the answer in terms of the question. Programming is the process of writing down the sequence of calculations required to get from a particular instance of the question to the corresponding instance of the answer. Computation is the process of executing those steps -- the algorithm -- to deduce the answer to a particular question.
>
> But this model of computation doesn't really correspond to the way that computation exists in the world at large. Most computation these days is not algorithmic question-answering in desktop boxes. Instead, most computation takes place in automobiles and in toaster ovens. It is a parallel, distributed, embedded, continuous, condition-monitoring, event- driven, ongoing, interactive process. It is computation as a living, breathing thing that exists and coexists in a dynamic continuous parallel world. Even the computation that does occur in traditional computers is largely of this sort -- it is spreadsheets and word processors and network access protocols, distributed databases and graphical visualization tools and

> computer games, rather than mathematical problem-solving per se. [Stein, 96]

Although the uses of the computer at TFIP were not based upon Stein's writings, note the similarity between the activities.[1] Because the participants chose projects of interest to them, projects based upon the real world or based upon doing computation in fun and intriguing ways rather than in decontextualized school-like ways, the nature of computation had to afford performing authentic activities. And because the formal practice of computation has the same goals, Stein proposes a similar change in the method of introduction. In a good engineering tradition the most effective learning is through practice. The next step is to begin using computational languages as a meta-language. That is, again contrary to the end-user approach, using the computational languages to build special purpose languages to fit to the task at hand [Abelson & Sussman, 1985]. This provides the protean ability in computing where end-user approaches never could. This also supplies a level of Constructionism not easily available in other media. Lastly, this very much fits the fluency approach and could provide the basis for cultural benefits from computing and computational technology akin to those provided by the technology of printing [Eisenstein, 1979].

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[1] This is perhaps even less surprising given that Stein's work evolved within the computing culture at the AI Lab at MIT, where the ideas of LOGO, learning by programming, and building meta-languages to apply to the task at hand are deeply embedded.

4.3 Textual Literacy and Technological Fluency

In a seminal work Eisenstein documented the role of the printing press as an agent of societal change. The printing press provided an instrument of standardization, accumulation, and dissemination. Previously, when writing by pen was the only available method of creating books, literacy remained the privilege of only the elite. The practice of science remained with the Church, who were also guardians of truth and religious knowledge. As the printing press enabled the exact copying not only of texts, but also of maps, charts, diagrams, and observations, a broader set of people began the practice of science, and enabled a new tradition of research. The rise of democracy (as well as the rise of bureaucracies), the spread of the practice of science, the use of mathematics and reasoning as opposed to reliance on divine interpretation, the spread of knowledge and authority from the royal courts and church hierarchies throughout the populace, while not pre-ordained by the technology, were certainly afforded by the technology.

The new technology not only enabled cultural changes, but also altered the view of what knowledge is (particularly in the West) [page 687]. As knowledge came to be viewed as embedded in texts, the world itself and minds became objects to be read from and written to. Intelligence became synonymous with literacy.

While Eisenstein herself focused on the effects from the use of printing technology, particularly its role in the rise of Protestantism and Early Modern Science, she did not argue that the ensuing literacy fundamentally altered the way people think. Others however, notably, Olson, Goody, and Watt, did [Olson, 94, Goody and Watt, 64]. Scribner and Cole studied this the "cognitive effects" of literacy and found the idea wanting [Scribner and Cole, 1981]. They studied the Vai in Liberia, who had a traditional written script (Vai), used English in schools and for official business, and also had a relatively large population not literate in either of the two languages. Therefore, they had a sample population that was literate in Vai script, but not schooled, and another sample literate in English and schooled. Also, as Islam is the primary religion, They hoped to differentiate cognitive effects from schooling and from literacy.

Scribner and Cole used a number of types of tests with the Vai, including abstraction, logical syllogisms, memory, taxonomic categorization, constrained classification, and free association of objects. Perhaps some of their most salient findings, following in the tradition of Vygotsky and Luria, are based upon tests of logical syllogisms.[2] Luria, working with Russian peasants, found that the non-

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[2]For example, they would provide the following problems, "All women who live in Monrovia are married. Kemu is not married. Does Kemu live in Monrovia?" To deal with the effect that many people, particularly the non-literate, would respond, something of the order of, "I do not know Kemu so I cannot say whether she is married or not." To help remove the situation from a known one (i.e. away from issues about the area in which the subjects lived so that whether someone

literate people he studied had difficulty with syllogistic reasoning tasks. The implication was that literacy itself was the cause of the ability to perform this type of reasoning.

Scribner and Cole challenged this assumption and, *within the constraints of their premises and their view of cognition*, conclusively demonstrated that the increased performance exhibited on the reasoning tasks was due to schooling rather than to literacy. They found that those literate in Vai script but unschooled, performed no better than their non-literate brethren. Likewise, they found that with some elementary training, all non-literates could quickly perform on a par with those that were literate. They conclude:

> In summary, all groups, including nonliterates, could achieve at least one successful abstraction (dimensional sort) and all were equally good or poor at breaking up one classification and achieving another. All literacies affected dimensional preferences, but only schooling enhanced ability to formulate verbally the basis for preferential selections. [page 121]
>
> Why does school improve performance on some tasks and not on others that presumably qualify as tasks of the same type? ... school fosters abilities in expository talk in contrived situations. [p. 244]

Since this work is built upon the premise of the value of a technological fluency, the value of literacy is of critical importance. If a textual literacy provides no significant value, then it is unlikely that a computational literacy will either. But there are several key points that shed different light on the findings.

One of the most interesting points that relates to this thesis is Scribner's and Cole's description of the Vai letter writers. One of the services performed by the Vai script writers is to write letters to relatives in other villages for other non-literate villagers. These letter writers scored no better on most tests administered by Scribner and Cole, except on the tests that relied upon an awareness of what another person might be thinking and how to interact with that (for example, one test that the letter writers outperformed their countrymen was in teaching another person how to play a game).

The implications of this are enormous. Most tests demonstrated experience with a school-like discourse on non-real problems. This result is more a reflection on how we do assessment and what was thought to be intelligent. But the related practices to letter writing did enable the practitioners to consistently perform better when the need to put oneself in other's shoes and find a means to effectively communicate to them.

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knew Kemu or not became irrelevant), they asked questions like: "All stones on the moon are blue. The man who went to the moon saw a stone. Was the stone he saw blue?"

This is similar to what is demanded of programmers of software environments, though not necessarily of end-user programmers. The software designer/programmer must imagine what is in the minds of the potential users; what they might do; what they need to know; what are the possible interactions, etc. Then, given these assumptions, the writer/programmer must find ways to allow the reader/user to navigate the environment to create meaning and perform actions.

The practice of letter writing enabled the Vai script literates to develop their abilities in a context that provided demonstrable leverage into other contexts in a way that non-literates and even schooled literates did not. The fact that schooled literates did worse on these tests as a group than did the Vai script literates illustrates the importance of authentic constructionist activity.

Eisenstein's work showed beyond doubt how the technology of the printing press enabled societal change through the faster reproduction of documents, maps, diagrams, etc. This tremendously increased the number of people with access to materials, and enabled these materials to be shared and discussed. However, these effects played out in historical time. Testing for the cognitive effects of printing among the first new readers might not have shown anything substantial. Yet, over time and as culture developed, the effects are tremendous and indisputable. The non-literate Vai still lived in a literate culture and spoke and shared meanings among their literate brethren. Thus, though while individually not literate, they were part of a literate culture and shared in the developments.

4.4 Situated Learning and Cognitive Apprenticeship

The results obtained by Scribner and Cole helped launch them towards a view of the situated nature of knowledge. Working from this point of view, many have begun to pay attention to what is called *cognitive apprenticeships* [Brown, Collins, & Duguid, 1989]. Cognitive apprenticeships borrow from the metaphor of an apprentice learning a craft. Central to this concept is that the apprentice is always engaging in the actual activity to be learned. Traditionally for crafts, this would mean someone learns carpentry by doing carpentry, under the watchful gaze of more experienced carpenters, who would help guide the apprentice through the learning process. The apprentice would begin with the simpler tasks, e.g. measuring, cutting, fastening, and gradually move towards performing the more complicated actions until gaining mastery of the craft. This metaphor is extended to the learning of more cognitive tasks, e.g. mathematics, in that the learner should perform the actual activity while more experienced practitioners help guide them through.

As it is coming into practice, key concepts within cognitive apprenticeships are:

• communicating process -- the master demonstrates how to perform the process to be learned, often with verbal annotation to highlight key points
• coaching -- when the learner is stuck, the master watches and provides hints, makes comments, reminds the apprentice about how the process was demonstrated, etc.
• eliciting articulation -- the master occasionally asks about the apprentice's actions or goals

Important within this practice is the idea of *scaffolding*. The master provides more support for the learner at first, gradually withdrawing it as the learner becomes more and more proficient. This lessening of support is referred to as *fading* [Guzdial, 94].

Researchers and practitioners have produced many promising results using the idea of cognitive apprenticeship. And certainly basing more educational practice in activity is productive and important. While it is important to bear in mind that cognitive apprenticeship is basically a guiding metaphor, and that the practice is merely beginning, there are aspects about cognitive apprenticeship that are troubling. A contrast between it and the framework at TWE will help highlight this.

Cognitive apprenticeship attempts to utilize authentic activity. It too attempts to provide an environment where learners can actively construct knowledge through such meaningful activity, rejecting the common practice in U.S. schools of attempting to teach knowledge out of the context in which it is embedded and practiced. Unfortunately, in various examples the emphasis can still placed on the domain to be learned, and not on what the learner is constructing. The metaphor of apprenticeship highlights this. There is a correct way to do a craft. The master knows and demonstrates it. The apprentice, through repeated work, gradually comes to acquire this accepted way of doing things. The apprentice performs the small, beginning tasks (perhaps simple stitching for tailors; or cutting for carpenters, etc.) and as the apprentice demonstrates proficiency gradually moves on to the more complex tasks.

The difficulty in effectively providing scaffolding is perhaps the key to why it is difficult to transition from the existing models of schooling and teaching to the models advocated in this thesis and in the papers on cognitive apprenticeship. This thesis utilized case studies to provide examples of how learners could move towards fluency and competency. There is no way known to this author to make this into a prescriptive practice. There are too many variables when dealing with human learning and experience. Scaffolding was certainly provided for the children, but, as described, it varied from person to person, project to project, and even day to day depending upon circumstance. When trying to automate scaffolding in end-user environments, or when providing scaffolding in person, it is easy to fall back upon traditional school and curriculum models of what should come first to enable acquisition of "more advanced" skills. This is when cognitive apprenticeship, or any new model of learning environment, could revert back to the sequential stepping stone model

Jean Lave, although among the group helping to originally formulate the ideas of cognitive apprenticeship and situated learning, later wrote about trying "to rescue the idea of cognitive apprenticeship" [Lave and Wegner, 1991, p. 29]. They reformulate the idea as *legitimate peripheral participation in communities of practice*. 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 generative social practice in the lived-in world...Legitimate peripheral participation is proposed as a descriptor of engagement in social practice that entails learning as an integral constituent. [page 35]

TFIP was very much in accordance with this view in that we were building a community of practice. The youth at TFIP were always performing activities and while they were always learning, this was also always through practice.

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