# Climbing to Understanding: Lessons from an Experimental Learning Environment for Adjudicated Youth

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**Abstract:** We present lessons from an experimental educational intervention based in a residential facility for adjudicated youth. In this initiative we created a technologically immersive environment based upon constructionist learning. Rather than adjust one element of the learning environment at a time, we created a radically different environment not just for this particular setting, but for any setting. The youth worked in an age and grade integrated, inter-disciplinary, open, learner-centered, project-based way, investigating areas of their own choice, learning through design and construction. We found many results that far exceeded expectations and past performance. We analyze the factors behind these results to shed light on learning environments in general. We also discuss the limits exposed within this experience.

**Keywords:** Constructionism, Technological Fluency, Severely at-risk youth

## Introduction

We (1) present an educational intervention based in the Maine Youth Center, a residential facility for adjudicated youth. This intervention did not merely attempt to alter certain aspects of the learning environment, but was a radical reconfiguration of the process and epistemological basis of the school environment. It combined a number of elements we considered essential to a more open-ended, learner-centered approach, such as:

- A technologically-rich environment with a greater than 1:1 ratio of computational devices to students
- Activity based upon design and construction of personally-meaningful artifacts
- An inter-disciplinary, age/grade integrated, project-based approach
- Recognizing the learner's role and responsibility in guiding the learning process while not abdicating adults' roles and responsibilities in contributing to the learning environment

It is beyond the scope of this paper to present a final, definitive assessment of the entire endeavor (2). Instead, we offer examples to show how the combination of unusual uses of technology with unusual features of the learning environment results in interesting learning. While the nature of the population of students and the possibility of far-reaching re-design of the learning environment were obviously major contributing factors, we believe that this work demonstrates not only interesting ideas applicable to severely at-risk students, but also offers certain lessons about learning environments generally. We will present some background on the setting, describe the overall environment for our intervention, present a representative sample of the activities, and discuss a few of the cases, the limits within the model as applied in the setting, and the lessons learned.

## Background

The Maine Youth center is located in South Portland, Maine. At that time it was the only facility for adjudicated youth in the state of Maine, with on average 230 youth in the Center at one time. Over the course of our involvement, the youth ranged in age from 11-20, with the majority in the 14-16 year range. Thus, in addition to its correctional responsibilities, the state also has educational responsibilities for those of school-going age. All of the youth at the MYC were required to attend school, unless they had achieved their high school diploma or were eligible by state law to have dropped out due to age.

At the time the project described here began the school had a traditional structure. When individuals arrived at the center they were evaluated and assigned to a grade level. During their stay, they would attend classes as if they were in a regular middle or high school. It was however clear to most observes and to the management of the center that the school was ineffective for the majority of the students. Although the custodial and treatment wings of the organization tried to minimize disruption of the school there were frequent interruptions of class time and many incidents in which custodial staff intervened in disciplinary incidents. Moreover, students were not there for regular school terms. They can be sent there and released at any time. Thus, a two-semester approach with a set curriculum is not tenable, as a teacher could start even one semester with one group of kids and by the end of the semester have a totally different group. The school tried to adapt with 9-week quarters but this was far from providing sufficient continuity.

Other difficulties stemmed from the diverse and usually unsuccessful prior school life of these students. They came from different school systems throughout the state. Many of them were itinerant, moving from place to place for a variety of reasons. Many of them had simply stopped attending school. Thus, there could not be a common starting point regardless of their entry and exit dates. The vast majority was in special education and far from "working at grade-level." Indeed, some 15 and 16 year olds tested at first or second grade level in reading and/or school mathematics.

In its search for ways to correct these weaknesses, in 1999 the State awarded a contract to The Seymour Papert Institute (also known as The Learning Barn) to create a pilot version of an alternative learning environment called the "Constructionist Learning Lab" (CLL) and nicknamed the Lego Lab because one of its more visible features was extensive use of LEGO Mindstorms and RoboLab materials. The life of the CLL has had two phases. For the first two years it operated in parallel with the traditional school offering 10-12 students a full-time alternative. In the third year the State decided to convert the entire school to a form closer to the principles demonstrated in the CLL after which its development has been determined as much by the sociological factors of changing a school and by complications of doing so in the context of a correctional institutions as by issues related to how individuals learn. This paper bears only on the first phase during which the learning principles on which they were based were practiced in a relatively (though not entirely) pure form.

During the subsequent period an evolving design was influenced by a number of others in addition to the authors, in particular by Sue Finch, a gifted teacher at the MYC who as assigned to the CLL about six months after its beginning, and by John Stetson who had previously been a volunteer at the MYC and became a full time staff member of the project. The key ideas of the design were as follows:

1. Trying to pursue grade-linked curriculum goals was obviously futile and irrelevant to the needs of the majority of these students. Instead the primary goal was to develop the habits, attitudes and sense of self needed to be a disciplined and successful learner. A secondary goal was to develop very basic skills in the areas of language, numeracy, and technological fluency.
2. These two goals would be served by an interdisciplinary, project-based method, where learners' interests guide the areas of investigation, giving sufficient time for exploring projects, content, and ideas at length and depth.
3. There would be no segregation by age, grade level or knowledge level, nor division of the day into "periods" devoted to different "subjects." The diversity of experience, ages, and levels of expertise would become a strength instead of a fatal flaw.
4. A major emphasis would be on building a collaborative culture of "learning and doing" where students assumed the roles of teacher as well as learner (and teachers became learners as well), The culture was to value both independence and discipline. A basic rule would be not to tell a student what to do at each moment but everyone had to work on something.
5. The working of the learning environment should be sufficiently flexible not only to change to take account of experience but also to give students a *genuine* sense of participating in its creation.

## Constructing the Environment

The project began with ten students. A group including the school principal, the guidance counselor, the teacher, and ourselves interviewed the volunteer pool and chose students trying to have the widest possible range of diversity. We chose to work with only ten at first in order to test out the ideas within the setting with a manageable number. The project had two rooms. In one there was a high concentration of computers (at least one for each student) peripherals and building materials including a large supply of LEGO robotic, "technic" and "MINDSTORMS" materials. The other was equipped for work on projects such as making guitars and making powered flight devices. The staff consisted of one teacher permanently assigned by the facility and a variable number of people employed by SPI and volunteers; averaging a little under 1.5. This made the ratio of staff to students a little better than the average for the school where the average class size was six with one teacher and often another adult present.

However we feel that this does not invalidate the value of the intervention for several reasons. By providing sufficient resources for an unknown and challenging situation in order to enable a different form of working to take hold, for us to learn about what works and what does not in order to debug and refine the learning environment, and, most importantly, in order to demonstrate what this population of children could learn and accomplish given a setting different from the school experience with which they all had extremely bad associations, we felt it was proper to work with resources beyond typical levels. It is a fallacy to think that insight into the possibilities of change can only come from working under the exact conditions of the existing system. The idea is more a function of our paucity of models for change than a matter of scientific method or effectiveness of intervention [Cavallo, in press].

The fifth design principle was most pronounced at the start when students could participate in setting up the space in which we would work but was continued throughout the life of the project through frequent changes in physical layout as well as in procedures. Engaging the students in the design and decision process had a number of interesting outcomes. First and perhaps foremost, it demonstrated in a concrete way our seriousness when we said they would be part of the decision-making process. Too often in school, let alone in a juvenile facility, we only condescendingly permit students to express their point of view on issues of importance, and all too often their inputs are discarded. Students certainly understand the message behind such interactions.

A common belief among administrators at the MYC was that youth were typically in this situation because of a lack of taking responsibility for their actions combined with a lack of empathy for others. However, the traditional school setting is not conducive to young people developing a sense of responsibility by making real decisions of consequence and the “correctional culture” prevailing at the MYC did not help. Our plan to engage students by presenting designs for a common space and then critiquing their merits and collectively making decisions was another element that solidified the program in the eyes of the youth. Having a fair discussion, moderated by us as this was new and we did not want existing power structures and culture among them to be the primary determining factor, also enabled a more positive atmosphere in our room. The program had to have an air where everyone’s ideas were valid, and that together we could decide on what was best for all.

The initial tendency for most of them was to create their designs on paper. However, when we introduced making the designs both in software with which they had become familiar in our project (MicroWorlds Logo), as well as other applicable software such as Corel Draw and free design software, everyone moved to this as they came to see that the software provided flexibility and power lacking in paper and pencil approaches. This helped build upon and cement the immersive computer culture of the program. An aim was to help develop technological fluency as a path to learning in a variety of areas and fitting a variety of styles [Papert & Resnick, 1995, Cavallo, 2000, Sipitakiat, 2002].

The contrast in cultural representation of learning was reflected in the evolution of the valence attached to the use of the term “LEGO LAB” for what was officially called the Constructionist Learning Lab (CLL), At first this was not a complimentary term, as outsiders thought we were just playing and many students thought this was an easy way to get out of a boring school experience. However, the connotation of “LEGO” gradually changed as students came to appreciate both the work involved and the value of participating, and administrators saw the change in behavior and accomplishment of the students.

Project work was the basic unit of endeavor. Sometimes we presented challenges for everyone to do, at other times there were themes for work, and there were also projects of an individual nature. A student would typically have two or three projects of different kinds going at once. All students worked on a variety of projects using a variety of materials, computational, mechanical, and crafts, simultaneously. Some were very traditional craftsmanship: for example many students worked for well over a hundred hours on building a high quality guitar from scratch – and, as John Stetson (who was responsible for introducing this kind of work,) noted, invariably went on to learn to play it. Many projects were purely computer-based, such as creating animations, making games, building simulations, managing stock portfolios, etc. Perhaps the most popular projects were based upon Lego robotics. Some were challenges such as getting weight across a divide or throwing objects over barriers (especially compelling to adjudicated youth), while others involved more complex control structures using programming and sensing (e.g. locating objects and moving them to specified places, automatic Lego sorters, or even a soft drink dispenser that charged more or less depending upon the temperature, inspired by a news item and inspiring the creator to author a letter to a cola company offering his design). More complicated challenges were rallies where vehicles had to follow a path laid out in tape throughout the room, avoid obstacles, and hit certain markers at particular times. This required algebra in an authentic way to determine gear ratios and speeds. After they accomplished this, they laid out a path that would require changing gears and differentials by not having a constant relationship between distance and time

## Two Exemplary Projects

### Exemplary Project Theme 1: Lego Vehicles on Ramps

Going Down

In order to introduce the way of working and some of the materials, we used a challenge project that has become part of the "LEGO robotics culture." The goal is to make a non-powered vehicle to run down a ramp and run as far as possible on the ground with the momentum acquired. Before beginning, students are challenged to get a theory about what design will work best. They produce many: Heavy or light? Many wheels or a few wheels? High center of gravity or low? A nice feature of this type of methodology is that there can be a rapid design-develop-test cycle, and one has multiple opportunities to test one's theories by trying multiple approaches. Moreover, one can also use the material to reliably test the ideas. For example, most associated longer distance on the floor with faster speed on the ramp. Measuring the speed opens new challenges: sensors can be used to get a numerical measure or two vehicles can be run together to get a qualitative measure. One student broke off onto a side project of designing a building general purpose speedometers for LEGO vehicles and became successfully involved in some mathematics far ahead of what one would imagine he could do judging from his schools scores!

But although theorizing about vehicles running down slopes leads to some intellectual excitement and some learning it was disappointing as an area to work on with the materials and level of experimental sophistication we encountered and indeed would be found in most schools. Theories were abundantly produced but too many factors influence the speed of a LEGO vehicle for clean experiments to support clear results with any degree of rigor. We were rescued from this dilemma by a suggestion to switch from running gravity powered vehicles down the slope to running powered vehicles up the slope. This proved to be an extremely rich project when working under the conditions of sufficient time for exploration and a culture that values it.

Going Up

The challenge is to find out how steep a ramp a LEGO vehicle can climb. As opposed to the quick action and frequent accidents in the races down, here things move slowly enough to be studied carefully and lend themselves to developing in students a sense of using scientific understanding to get practical results. The method of work is as follows:

A ramp with variable slope is built and provided with a protractor for measuring the slope. Incidentally, we note that even at this stage several students "got the point" of measuring angles for the first time! A vehicle is built and tested on increasing slopes until it fails. Often first attempts at building fail at quite small angles – for example fifteen or twenty degrees. But the point of the project is not to regard this the vehicles failure as a personal failure but on the contrary by understanding *why* the vehicle failed to gain insight into how to redesign a better one. In order to facilitate their thinking, students are required to enter on a writing board next to the ramp what they diagnose as the limiting factor responsible for the failure. What makes the project educationally valuable is that almost all cases are covered by one of a small number of *limiting factors* each of leads to a scientifically important concept, which can be studied and then used to improve the vehicle. These factors are:

1. The wheels slip. The relevant concept is FRICTION.
2. The vehicle topples. Relevant concepts are STABILITY and CENTER OF GRAVITY.
3. The vehicle stalls. Relevant concepts are FORCE, TORQUE, and MECHANICAL ADVANTAGE.
4. The vehicle breaks. Relevant concepts include FORCE and FRICTION but especially concepts of STRUCTURAL ENGINEERING.

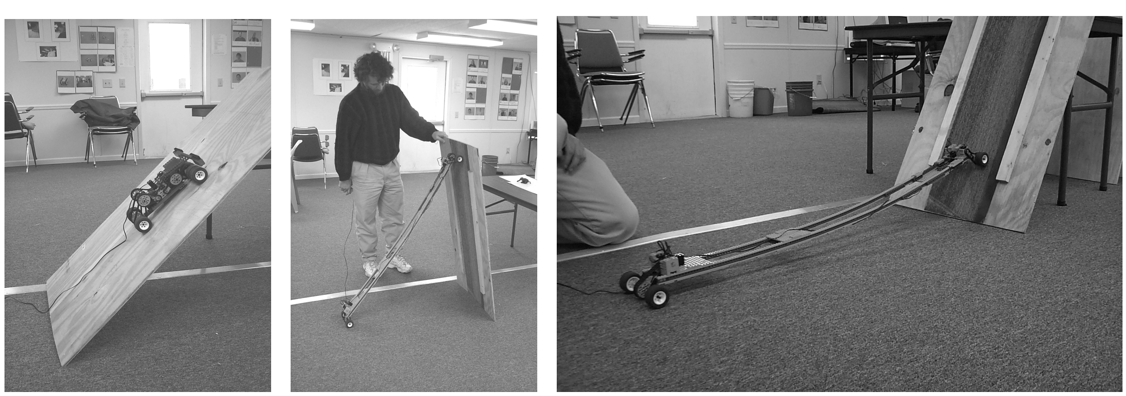
This procedure gave a way to introduce powerful ideas such as mechanical advantage and torque not in an abstract way but in a concrete, connected way. The students found the ideas powerful because they enabled them to achieve what they wanted. A procedure that directs attention to the limiting factors not only models a productive process in context but also enables the introduction of terminology and powerful ideas. We do not expect everyone to invent important scientific content out of nothing. We do not fabricate toy situations to teach specific concepts, but rather the concepts emerge due to need to make their own projects succeed. *Their* projects are *their* expression of *their* thinking about how to accomplish what *they* choose. Our approach trivializes neither constructivism nor discovery. The world provides the feedback and if their thinking does not achieve what they expect, either their expression or their ideas need re-doing. We do not do nothing and expect them to discover everything. However, we are not under the illusion that if we merely tell them an answer then that means they understand it fully. The project serves as the most important metric of understanding. It either works or it does not. Multiple projects surface scientific principles as the same idea can work in a variety of situations. The methodology, and the development of a culture built upon such exploration, investigation, and verification, potentially carries the learning past simply making something work as one uses the same approach and tools to verify whether the ideas are robust, complete, and have aesthetic value.

### Side-Effect Richness

Following the laid down process leads all students to engage with key concepts and methods of thinking. The richness of the project shows up in the number of idiosyncratic side-paths followed by individuals. Space here permits mentioning only one.

A student we shall call Michael cunningly (as you will see!) turned the discussion in a class meeting to offering a more precise definition of the criterion for success. Everyone agreed to draw a line near the top of the ramp and define success by the front wheels of the vehicle crossing the line. For the next few days nobody could understand what Michael was doing until he unveiled the vehicle shown in figures 2 and 3. The front wheels climbed and the rear wheels pushed the vehicle against the ramp! The vehicle was able to “climb” (according to the definition Michael had led everyone to accept) a slope of 110 degrees! Cries of “cheating” from the other students had three answers. First, Michael had already built a “standard” vehicle like the one shown in figure 1 which had achieved a respectable climb over sixty-five degrees. So he was not evading the challenge. Second, it gave rise for an opportunity to discuss the difference between “dumb plain cheating” and “thinking out of the box.” Indeed, we wanted the students to see it as an example of innovative, out of the box, thinking we try to inculcate. Third, Michael actually presented some technically interesting ideas – length alone was not sufficient to achieve his result!

Michael’s academic history makes this story more remarkable. According to school records he had left school at age 11 showing virtually no achievement. In basic schools kills he tested at first and second grade levels even though at the time he was fourteen, which means that he could not really read or write. We had been advised not to admit him into our program because school administrators felt he was not sufficiently capable to benefit from it. Yet, he developed into our star student and truly showed brilliance in his work. His means of working was to take an idea and try to apply it in every means he could conceive. He wanted to understand things deeply and thoroughly. He would work for weeks on ideas and projects. It is easy to see how his approach does not work in a school environment where one can only work on things for short periods of time, where a curriculum is pre-determined, where subject matter is divided into the disciplines, where the projects are not one’s own.



Figures 1, 2, and 3 (left to right): Lego Climbers

### Ramp Climbing Extended

After achieving their remarkable feat, this boy and his partner decided to fortify their vehicle, as it was long and thin, and, by this time having gained structural expertise, knew that it was a rather brittle construction. So, they braced the structure, which required additional expertise. When they first attempted their reinforced climber, they were stunned to see that not only would it not climb at all, but also it vibrated severely and broke apart exactly where they had braced the structure. The vehicle needed flexibility so as to bend to climb at a greater than 90 degree angle. They discovered that rigidity did not always equal strength. This discovery led to a whole new range of extensions and ideas. We could study how bridges work, how flexible structures can be stronger for certain purposes, why how stress and load can be carried, why buildings do not fall under their own weight, and so on. A student created another interesting connection by using a digital microscope to examine whether she could match the surface of the ramp (as well as materials such as sandpaper that she would attach to the ramp) and the tread of the various tires available. She determined that there were better matches to get appropriate friction and could increase the incline. She built according to her theories in order to validate them.

It is easy to see why following the innovations and ideas of the students led to a rich and engaged learning experience. The content that they covered in their pursuit of succeeding with their projects is rich. It is organically inter-disciplinary, where the knowledge in the fields supports their quest, and thus is situated both in the context as well as in their construction of their thoughts. The math or physics is not abstract and isolated, but is put to use by the learners. Since their ideas were truly innovative, we could not plan beforehand what should follow what. However, we did not sit by idly either. When they began the ramp climbing, we introduced the methodology of looking for limiting factors, we brought in the language and concepts of force, torque, friction, etc., and when the innovative braced ramp climber fell apart, we suggested other connecting themes. As students needed concepts for use in their projects, or for extensions, or they expressed curiosity, we offered mini-lessons to demonstrate the necessary technique or idea. The ratio of teachers presenting to students doing is virtually the inverse of traditional classroom settings. We spoke little and in context and they led and accomplished more. We use an *emergent* approach to follow interests, introduce themes, and connect to important ideas [Cavallo, 2000].

### Exemplary Project 2: Using Radio to Develop the Skills Underlying Writing

Our second exemplary project is in the area of language skills. We begin by using Michael to give an idea of how expression was handled in general.

All students were required to keep design journals of their projects. However, as Michael did not read or write, and naturally did not like being exposed to public humiliation, he refused to write in his journal. Despite his enjoyment of the program, he was making a stand on his principle and would have returned to the regular school if we insisted on forcing him to write.

However, we chose to re-assess the underlying assumptions of why we cared about journals in the first place. It certainly was not merely to practice the mechanics of making marks on paper. Rather, the journals serve as a vehicle for reflection through documentation. In this sense what is important is the ability to note one's ideas, designs efforts, observations, and assessments. Once these are noted, then one uses the notes as a basis for reflection, debugging, discussion, modification, and further thought. Examining the process at this level demonstrates that the writing is not the essential element and that other media could suffice just as well. Taking him outside we offered Michael to record his notes by dictating onto a computer, and then use software to review and edit his recorded speech. He felt this was acceptable and remained in the program. During the course of the program, he decided to learn to read and write, and by the time of his release he was completing his autobiography of 129 pages (we have no idea why he decided beforehand that had to be its length) to give advice to younger children why they should not follow his path on the "outside."

The particular project we want to mention was made possible by an offer from a local radio station to broadcast a short weekly program made by the CLL students. Our interest was in pursuing the idea that most of the skills that are developed in "language arts classes" could be developed as well using other media than writing (3). For example, the use of digital technology allows skills such as editing or structuring a composition to be used in media such as sound, film and music. In this case students created audio journals, spoken narratives on subjects of their own choosing, backed by music they layered into the files. Here again, many of the youth who created such journals could barely read and write and would not have even begun to write anything let alone create something with meaning, nuance, depth, and texture, created compelling narratives, primarily autobiographical. Their thoughtful creations gave evidence to their intelligence and capabilities that had not surfaced in traditional school settings. And in the long run it reduced the obstacle to learning to write by developing skills that would reduce the painful and inhibiting time between first writing and being able to write something interesting enough to be proud of.

Similar effects were obtained in relation to producing portfolios. Just as we had tried to get the kids to maintain journals, we also wanted them to create portfolios of their work. Since this felt too much like school busywork and therefore not of interest, it was a constant struggle where the teacher felt she had to resort to coercion through grades and credits to get them to comply. Upon their release some of our early graduates went on to Southern Maine Technical College. We subsequently were visited by officials from the school, and one of the students announced to the class how much easier it might be to gain admission if they could show the collection of all of their project work at the CLL. They thus decided that their [re-]invention of portfolios was quite useful and meaningful.

## Limits

Our initial effort had some limits as the first teacher assigned to us, while certainly friendly and supportive, viewed his task as making sure the kids stayed out of trouble. He did not engage in the activities with the youth nor did he really mentor or monitor their work. The class functioned well as we had a heavy presence in the early months, but clearly this approach would not be sustainable. After the first 9-week session, another teacher, Sue Finch, whose approach to life, learning and teaching was more compatible with ours, replaced the first teacher. Even though she had no technical or science background, she dived into the projects with the kids and took it upon herself to learn programming. She set up a process of individual work plans and reviewed them daily with each student. She created a number of new challenges and projects. As we withdrew, at first she was apprehensive about whether she could manage. She told us that at every moment she felt like picking up the phone and calling for help. But she did not call and felt all the stronger because she did not. We discussed how this was the exact manner in which we challenged the students and how their attitude changed once they overcame the obstacles and achieved their objectives.

Just as in the journal-writing example, the punitive side of the overall climate also had unfortunate, and at times ironic, impact on our program. One of the more egregious examples was the confiscation of “contraband” material brought to the cottage from the classroom. What was the material? It was the *Wall Street Journal* which the student was using for research on his stock portfolio project. Some administrators often punished students by removing the “privilege” of reading. Indeed, the popularity of our lab made participation in it a prime candidate for being withheld as a means of punishment. While at first many of the correctional administrators viewed our initiative warily, as they came to see how participants in our program caused fewer problems than those individuals had in the past, and how our population as a whole caused fewer problems, they became enthusiastically supportive.

Before our project the state engaged in planning for a new building on the site as the existing facilities were old and some had structural problems. However, the new building itself caused problems. The original facility had aspects of a college campus. Students walked between buildings. They resided in cottages. With the new, more prison-like building, the spirit of the place was drastically altered. Many of the youth did not even get outside for months. The inside was whitewashed, institutional concrete. Only staff with keycards could open the doors. There were no windows. The setting caused great problems and diminished the possibilities for an atmosphere that inspired the imagination. What was particularly unfortunate was that our successful program did not justify the type of concern for security breaches that necessitated the type of facility ultimately built. Yet the bureaucratic mindset determined the design of the facility. Form triumphed over function.

## Discussion

A center for adjudicated youth is not a typical setting for technologically rich, innovative learning environments. Metrics for success were varied. Naturally, we desired that the students learn, however what was also critical was that the attitude of the youth improve and that they become more capable of living productive lives on the outside. Moreover, as we chose not to take the existing environment and incrementally add selected features and test for their differences, but rather created a radically different learning culture with many features changed at once, we can only take a qualitative approach to examining the elements of the endeavor. We are not attempting to claim that the whole effort, or any piece of the effort, is measurably better than other alternatives. Rather, we are trying to demonstrate the potential and possibilities from a radically different approach by achieving notable results.

On one level it was undeniable that something important was occurring in the MYC Constructionist Learning Lab. On average in the MYC school there was one incident per day. An incident is an act of violence or destruction. In our lab there were **zero** incidents over four years. The recidivism rate of the facility was 70%. The rate of those engaged in our program over the first 2 years was 14%, where even that number was inflated by two youth who returned for 1 day and one weekend respectively.

Another indicator of attitudinal change was how the youth did not want to leave the lab to return for their free time in their living quarters. Many preferred staying to work on projects to playing basketball and other activities. They worked hard in our program. Their attitude was not different on their first day with us. Getting it to change was one of the key goals of our work. Finding a way to make working hard and succeeding acceptable within their own value system, that cooperating in our program did not mean they were weak, submissive to authority, or geeky. Watching their attitude change with their achievements was one of the joys of working there.

The interesting results were not limited to social and behavioral aspects. As the students observed their achievements in tasks they knew to be difficult, many changed their views of themselves as learners. They became more daring and more expert in their work in a self-reinforcing virtuous circle. As Michael remarked just before his release, "Who knew I had such talent?" Not just Michael, but many others had a similar style of work, that is, wanting to work on things of their own choosing for extended periods. The majority of the students were in special education classes both inside the facility and in regular school. Typically, in special education the process stays within the standard school epistemological framework, often presenting much the same material just slower and with more personal attention. We were trying to make a more fundamental change by focusing on the *design* and *construction* of personally meaningful *projects* determined by the learners and not pre-set by others, by allowing extended periods of *time* for depth and robustness of exploration, by not just focusing on articulation of knowledge primarily through text but rather by facilitating hands-on creation of concrete artifacts and thereby facilitating multiple learning styles and by having a better than 1:1 ratio of computational materials so that each student could create multiple projects simultaneously and express their ideas in forms more closely resembling their own conceptions.

## Endnotes

(1) The personal pronoun in this paper sometimes refers to the three authors, sometimes to a larger team. In later and more discursive publications, specific roles of individuals will be made more explicit.
(2) Other publications are in preparation, including a doctoral thesis by Stager.
(3) Papert's student Tara Shankar is developing this kind of thinking more deeply in a doctoral project.

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