Constructive Technology as the Key to Entering the Community of Learners

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ABSTRACT

From 1999 to 2002, the author was the principal investigator and one of three architects of an alternative learning environment operated inside The Maine Youth Center, the state's troubled juvenile detention facility. Guided by the learning theory of constructionism, a multi-age, interdisciplinary technology-rich learning environment was created to support the development of personally meaningful projects based on student interest, talent and experience.

Students in the Constructionist Learning Laboratory (CLL) often classified as learning disabled, engaged in rigorous learning adventures and developed positive personal behaviours in a context free from traditional curricula, behaviourism or other aspects of coercion. Personal and collaborative long-range student projects incorporated powerful ideas from mathematics, science, computer science, engineering and the arts. Sophisticated projects resulted from a more expansive view of technology that included programming, robotics, woodworking and communications via a variety of media. Completed projects and detailed explanations of both product and process demonstrate evidence of the construction of knowledge. Unlike many school projects, CLL students had to contend with what Seymour Papert calls the "resistance of reality." In other words, their projects had to work, not just pass. The intrinsic motivation and rigorous engagement at the heart of this process is of critical importance. Technology played an enormous role in not just improving self-esteem, but in affording students the chance to be mathematicians, scientists and engineers.

This research suggests the viability of Papert's constructionism as a foundation for designing productive learning environments, not only for a transient population of at-risk teens, but the broader learning community. This paper will also document new constructionist approaches to teaching and learning with computational materials. Future research might investigate if similar approaches to teaching and learning not only reverses the effects of school on at-risk learners, but may be used to design learning environments that place fewer students at-risk in the first place.

1. INTRODUCTION

In September 1999, Dr. David Cavallo, Dr. Seymour Papert of the Massachusetts Institute of Technology and I created the Constructionist Learning Laboratory (CLL) inside of the Maine Youth Center (MYC), the state prison for adjudicated teens. For three school years, the CLL offered the educational community a model of constructionist learning as an intervention strategy for educating a transient population of extremely at-risk adolescents. This paper shares a bit of the rich data collected as part of this research project. A more extensive portrait and analysis of this study will be published in a forthcoming doctoral thesis.

1.1 The setting for constructionism

In 1999, Maine Governor Angus King Jr. asked Dr. Papert to develop a model of what learning might look like in the future. Papert's seminal work with children and computing, as well as the societal impact of computational technology, required that this model for the future of learning would involve computers.

> "I have yet to meet or hear anybody who is opposed to productive learning. In all but a few instances the gulf between the policies they advocate and the results their actions produce exposes the emptiness of their rhetoric. Indeed, when they become aware of the failures of their policies, they are incapable of entertaining the possibility that their understanding of productive learning has no substance, and so they continue to come up with a new policy or diagnosis, again confirming the adage that the more things change, the more things stay the same." (Sarason 2002, page 243)

Sarason goes on to suggest that this is evidence of neurotic behaviour. The senior officials in the State of Maine clearly represented the exception to Sarason's characterization. The Governor and State Commissioner of Education recognized the futility of continuing to teach children with a long history of school failure in the same unsuccessful ways. The result of this acknowledgement was the suspension of all curriculum and assessment requirements for the CLL. This freedom[i] allowed us to make an effort at creating a truly unique learning environment to serve a population of students who had been ill-served or harmed by traditional schooling.

The intent of the CLL was to create a rich constructionist learning environment in which severely at-risk students were engaged in long-term projects based on personal interest, expertise and experience. Students used computational technologies, including programmable LEGO, and more traditional materials to construct knowledge through the act of constructing personally meaningful projects. The primary objective was to acquaint or reacquaint these at-risk learners with their power as learners and what Eleanor Duckworth called, "The Having of Wonderful Ideas."

The CLL built upon many elements found in various school reform efforts including: multi-age grouping; interdisciplinary curriculum; student/faculty collaboration; project based learning; hands-on activities; computer use and multiple ways for students to demonstrate understanding. However, we did not stop there. The CLL also featured a five-hour daily block of uninterrupted learning time, a computer for every child, radical notions of curriculum and assessment and a concerted effort to focus the life of the learning environment on supporting each student in the construction of personally meaningful long-term projects. It is both the focus on project development and the construction of knowledge resulting as a consequence of that activity, often in a computational context, that gives life to Papert's theory of constructionism and sets the CLL apart from any other experiment in school reform.

While constructivism defines learning as the building of knowledge structures inside of one's head, *constructionism* suggests that the best way to ensure that such intellectual structures form is through the active construction of something outside of one's head, that is something tangible, something shareable. (Stager 2001, 2002) The Constructionist Learning Environment's emphasis on building, crafting, making and doing gave life to the theory of constructionism. Although there had been several previous educational projects built upon Papert's theory, principally by Papert and this students, the CLL represented the first learning environment built entirely from the ground-up to support constructionism. The project at the Maine Youth Center also represents the most recent experiments in school reform led by Seymour Papert. The independence from any existing school structure, both physically and philosophically, also adds to the significance of the CLL.

1.2 Contexts for Productive Learning

While constructionism acknowledges that knowledge is socially constructed and best achieved through the act of making something shareable, prior work by Papert and his colleagues has contributed little specific guidance towards creating the environments in which such learning might occur. Psychologist, author and Yale Professor Emeritus, Seymour Sarason, has made significant contributions to thinking about school reform in numerous book over the past five decades. His highly critical predictions of failed reform efforts are similar in many ways to those of Seymour Papert. A large part of Papert's singular genius is manifest in his ability to propose a theory of learning; suggest a vision of what that theory would look like in practice; and predict the ways in which the existing system of schooling would neutralize that innovation. Sarason skips the theory and practice to explore the variables that lead to what he calls the "predictable failure of educational reform." (Sarason 1996)

It would be a grave disservice to Dr. Sarason's fifty years of scholarship to try and reduce it to the space of this paper. However, his recent work has been concerned with a powerful idea that overlaps with the work of the Constructionist Learning Center. Sarason states that a major problem plaguing efforts at educational reform is based on a failure to identify contexts for productive and unproductive learning. Educators, policy-makers and citizens have refrained from describing appropriate contexts for productive learning and have failed to even define what they mean by "learning." Sarason points out that in but a few rare cases the discussion of contexts for learning and what we mean by learning have yet to even exist. Sarason argues that the absence of agreement on such basic terminology dooms all efforts at reforming schools. (Sarason 1996, 1998, 2001, 2002)

> *The initial problem in educational reform is not one of subject matter but rather gaining clarity and consensus about the distinguishing features between contexts of productive and unproductive learning.* (Sarason 2002, page 247)

My colleagues and the students in the Constructionist Learning Laboratory spent several years attempting to build a context of productive learning for without it, the types of constructionist learning desired would have been impossible. In short, our definition of a context for productive learning is an environment and set of experiences that would lead students to construct knowledge through the act of engaging in long-term personally meaningful project work.

This practice required changes in approaches to curriculum, pedagogy and assessment. In fact, very little emphasis was given to assessment of any kind. This represents a radical departure from the mainstream educational community in an age when assessment and externally determined outcomes drive nearly everything that happens in schools. The CLL celebrated and valued that which students found interesting. Educational success was not measured by a rubric, quiz or test. Student learning was represented by a desire to learn more, an ability to share knowledge with another person or inherent in a project artefact containing evidence of mastery. The fundamental belief that knowledge is the consequence of experience laid a foundation for the construction of a context for productive learning.

> "Willy-nilly children learn, but we are not satisfied with that because we believe, indeed our rhetoric insists, that schools must achieve several goals; (a) to mine, exploit, sustain the motivation to learn; (b) to learn those skills and that knowledge that make the world, past and present, meaningfully comprehensible; (c) to instil the sense of personal competence and social responsibility. That does not describe willy-nilly learning in which chance is a dominant factor. It begins, and only begins to describe what we think we mean by productive. William James, always the pragmatist, said the litmus of the efficacy of what we

> do is its "cash value": how much of what we wanted to achieve we have achieved. The cash value of educational reform is written in red ink." (Sarason 2004, page 242)

The CLL did not concern itself with traditional notions of curriculum, particularly the seemingly random hierarchy and sequence of skills, topics and concepts prescribed by textbooks and standardized tests. Therefore, critics might suggest that our efforts did not produce much educational value. However, our students made significant process towards the three process goals Sarason describes above. In fact, Sarason's goals do a very nice job of describing the educational objectives of the CLL, despite the fact that his writing does not discuss the role computers may play in learning.

2. CREATING CONTEXTS FOR PRODUCTIVE LEARNING

Early in the life of the project, Seymour Papert prepared the following information sheet describing the powerful ideas behind the creation of the Constructionist Learning Laboratory.

Eight Big Ideas Behind the Constructionist Learning Lab
By Seymour Papert

The first big idea is learning by doing. We all learn better when learning is part of doing something we find really interesting. We learn best of all when we use what we learn to make something we really want.

The second big idea is technology as building material. If you can use technology to make things you can make a lot more interesting things. And you can learn a lot more by making them. This is especially true of digital technology: computers of all sorts including the computer-controlled Lego in our Lab.

The third big idea is hard fun. We learn best and we work best if we enjoy what we are doing. But fun and enjoying doesn't mean "easy." The best fun is hard fun. Our sports heroes work very hard at getting better at their sports. The most successful carpenter enjoys doing carpentry. The successful businessman enjoys working hard at making deals.

The fourth big idea is learning to learn. Many students get the idea that "the only way to learn is by being taught." This is what makes them fail in school and in life. Nobody can teach you everything you need to know. You have to take charge of your own learning.

The fifth big idea is taking time – the proper time for the job. Many students at school get used to being told every five minutes or every hour: do this, then do that, now do the next thing. If someone isn't telling them what to do they get bored. *Life is not like that*. To do anything important you have to learn to manage time for yourself. This is the hardest lesson for many of our students.

The sixth big idea is the biggest of all: you can't get it right without getting it wrong. Nothing important works the first time. The only way to get it right is to look carefully at what happened when it went wrong. To succeed you need the freedom to goof on the way.

The seventh big idea is do unto ourselves what we do unto our students. We are learning all the time. We have a lot of experience of other similar projects but each one is different. We do not have a pre-conceived idea of exactly how this will work out. We enjoy what we are doing but we expect it to be hard. We expect to take the time we need to get this right. Every difficulty we run into is an opportunity to learn. The best lesson we can give our students is to let them see us struggle to learn.

The eighth big idea is we are entering a digital world where knowing about digital technology is as important as reading and writing. So learning about computers is essential for our students' futures BUT the most important purpose is using them NOW to learn about everything else.

Idea number six resonated with a number of our students whose reaction to the idea of getting things wrong ranged from surprise to affirmation. The idea of being wrong being all right, ran counter to the students' experience with traditional schooling.

While Papert's eight big ideas do not specifically address the three educational goals presented by Sarason there is substantial overlap. Let us explore how Sarason's goals were addressed in the Constructionist Learning Laboratory. The examples provided are far from exhaustive and intended as either a model for your own innovation or as a prelude to the forthcoming research thesis on this project.

2.1 Goal A: to mine, exploit, sustain the motivation to learn

A principal objective of our work was to create an environment in which there were sufficient objects to think with, materials to build with and people to work with. The CLL was a beehive of activity with as many as ten different projects underway at any given time. Students might be programming robots they constructed out of LEGO, building a telescope, handcrafting a classical guitar over several hundred hours, writing a sequel to Othello, designing a videogame in MicroWorlds, conducting research related to a project, directing a movie, developing film exposed with a pinhole camera, flying an ultralight airplane just assembled, reading a book of poetry, attempting to reduce friction so that a machine can achieve its objective, animating a claymation video or producing a radio program. Any given student might have been engaged in multiple projects in various states of completion and they would undoubtedly spend some time each day mentoring a classmate or engaged in discussion with one of the adults (teachers or volunteers) in the Lab.

The widespread access to interesting construction materials, tools, books, a personal computer and interesting adults within reach inspired students to engage in project work. The excitement generated by peers engaged in similar pursuits added to the desire to work on a project. Challenges, those foreseen and unexpected, are inherent in project work. The popular use of robotics in the CLL inspired a great deal of interest. You cannot resist the attraction of handmade machines zipping about the classroom. These activities invariably inspire discussion, inquiry or competitive impulses among students.

The absence of grades in the CLL and our best attempts at eliminating coercion of any sort went a long way to contributing to a culture of risk-taking, sharing and learning for the right (personal) reasons. Students read books because the adults talked about reading, recommended books and purchased a steady stream of new books for the classroom library. There were no requirements to read a specific number of pages and answer comprehension questions associated with reading. Students read for the same reason "real" people do – for information or pleasure. Book club luncheons in which students discussed books they read with peers mirrored what literate adults do for fun. There were no threats, bribes or rewards required. The simple act of asking what seemed like standard comprehension questions might cause one of our students who often struggled with low literacy skills to stop reading.

Project rubrics would cause this population of students to do the minimum required or nothing at all. Efforts to force students to keep project journals, designer's notebooks or portfolios was more difficult than it had been in previous projects, but it was difficult to motivate students to do so even in more advantaged school settings. Once we had arranged for the Director of Admissions for a local community college to come speak with the CLL students about the possibility of attending college, one student spontaneously said, “I have an idea! I should assemble examples of all my work so he can look at it, see what I can do and then let me go to his college.” From that moment on, more students took greater care to maintain work portfolios for themselves, not a teacher.

One page in a student portfolio says a lot about the CLL. There is a digital photo of a robot he has engineered and will program. The idea is to build a robotic bird feeder that will snap a photo of a bird when it comes to eat. The machine is made of LEGO, a disposable film camera and LEGO’s programmable brick. Beneath the photo is a caption typed by the student that says, “When I get this to work I’m gonna get me some Langston Hughes.”[ii] While it is unclear if one of us made such a deal with this student, the fact that a fifteen year-old Caucasian “troublemaker” was inspired to work hard, solve problems and learn because it would grant him access to a book of poetry offers a rousing endorsement of the CLL’s context for learning.

Employing an approach to documentation using drawings, text, digital images and video in the spirit of Reggio Emilia schools was a much more successful strategy in the CLL than traditional private notebooks or journals. The public display of thinking represented in images not only eliminated obstacles to self-expression caused by low literacy levels, but engaged more students in problem solving and thinking about other students’ thinking. (Figure 1) Students repeatedly made reference to how much their portfolios meant to them when they left the Youth Center. They were able to look back on their efforts with a sense of pride and accomplishment.

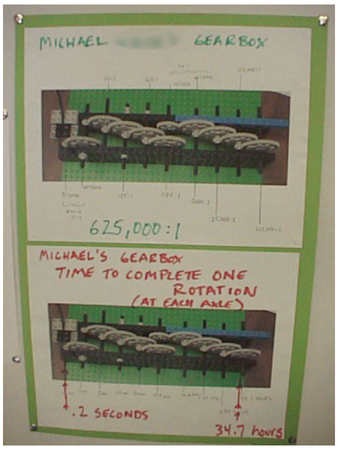

Figure 1. Student documentation of experience with gear ratios

2.2 Goal B: to learn those skills and that knowledge that make the world, past and present, meaningfully comprehensible

A unique approach to curriculum was required by the CLL since it was far less important to determine that a student had learned X than it was that they were learning something.

> While traditional models of curriculum are based on a desire for kids to develop certain skills or possess a body of knowledge, teachers in the CLL were challenged by Dr. Papert to evaluate classroom practice through the prism of "what can they DO with that?" In other words, the concept being taught or explored must have a reasonable likelihood of leading to the construction of a larger theory or bigger question. It is the role of the teacher and the

purpose of the highly casual flexible curriculum to guide children in the direction of authentic learning gained through purposeful activities of their own choosing. This was not just an academic ideal, but a pedagogical reality. Our students rejected any methodology that smelled of school. As one fantastic young engineer, poet and raconteur in the CLL said, "I just don't learn from the fat guy in the suit." (Stager 2002)

Therefore, we turned the traditional nature of curriculum on its head. (Figure 2) While most schools use themes and projects as a way to get students to learn a specific skill or concept, the CLL flipped the pyramid. (Figure 3)Since the theory of constructionism suggests that the best way to learning is through the construction of something shareable, projects were not a means to an end, but the goal itself. Projects possess a narrative comprised of debugging, experimentation, serendipity, research, collaboration, perspective, creativity and ingenuity. Projects also exhibit habits of mind. A student's ability to complete a project and explain its creation or how it works represents sophisticated understanding.

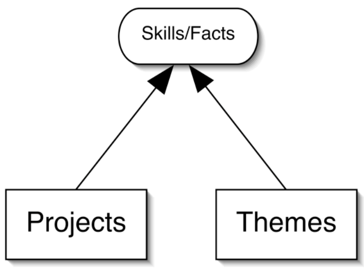

Figure 2. Graphic representation of traditional approaches to curriculum

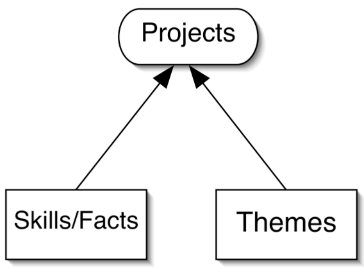

Figure 3. The CLL Curricular Pyramid

Limiting student expression to pencil and paper makes the demonstration of understanding difficult for many students, particularly the population of students with a history of school failure and special education classification found at the Maine Youth Center. The availability of tape recorders, digital cameras and digital video cameras made it possible for CLL students to tell the story of their learning during the project development process and when the project was competed. This served as evidence of concept mastery and understanding. Anyone who witnesses the video of a thirteen year-old student explaining his invention that graphs fluctuations in temperature over a period of several days or the student who constructed a working phonograph entirely out of LEGO, a paper cone and a sewing needle. Not only was he able to understand gear ratios sufficiently to get LEGO geared to 37 1/2 RPM (the goal was 33 1/3), but he also used a digital microscope to explain the way in which the cone amplifies the sounds generated when the needle vibrates in the grooves on the record. (Figure 4) Not only did this student recreate the historic work of Edison within a few days of entering the CLL, he demonstrated an understanding of gears, ratios, the use of a microscope, Logo programming and innumerable other concepts.

Figure 4. LEGO phongraph invented by CLL student

Students capable of using MicroWorlds to program a video game or an animation in the style of *Fantasia* demonstrate the application of numerous mathematical and computer science concepts. The sense of personal accomplishment that accompanies a job well done when coupled with the respect of peers and teachers can not help but inspire a student to learn more.

2.2 Goal C: to instil the sense of personal competence and social responsibility

Successful solving of one problem inevitably led to a greater sense of personal competence and inspired further more sophisticated explorations. Bugs led to debugging, the rethinking of your approach and attempts at different strategies. Bugs and success both lead to greater intellectual development and engagement.

The majority of students served by the CLL had been classified as in need of special education services. Many of them had dropped out during the fifth or sixth grade. Papert remarked that they suffered from the "curious epidemic of learning disability." Yet, most of these students demonstrated remarkable creative or intellectual gifts while in our classroom.

Students claimed to be more curious or better thinkers as a result of their tenure in the CLL. One seventeen year-old student, Tony, reported that he was more curious since he entered the CLL. He had fallen in love with black and white photography, the darkroom and robotics. His robotics mentor was thirteen years old with a few months seniority in the CLL. A few weeks before Tony's release from the Youth Center, he and I engaged in the following exchange.

Tony: *I think about doing things totally different now? I looked at the groundhog hole and wanted to go down it. Before I would just look at it and stick a stick down it.*
Interviewer: *What makes you want to go down it?*
Tony: *Because I can.*
Interviewer: *Because you can?*
Tony: *Yeah, because I want to.*
Interviewer: *Why do you want to go down there?*
Tony: *I don't know - just to see what's down there.*
Interviewer: *So, do you think you are more curious now?*
Tony: *Yeah*

> With a bit of my assistance and an assortment of USB webcams, flashlights and other materials, Tony and his new assistant, Craig, spent the next few weeks building a series of what came to be known as "Gopher-cams." This work captured the imagination of the entire Maine Youth Center. Staff members hostile to our project and kids across the facility wanted regular updates on the Gopher-cam team's progress. Tony and Craig learned a great deal about how simple unanticipated obstacles like a twig could derail days of planning and require new programming or engineering. These students engaged in a process of

> exploration not unlike the men who sailed the high seas or landed on the moon. While they never *really* found out what was down the hole, they learned a great many much more important lessons. (Stager 2002)

Michael, the student who spent the most time in the CLL was so gifted building mechanical inventions and programming them that Dr. Papert proclaimed him a genius. However, his school records indicated that he was illiterate. Michael had been incarcerated for all but eleven months of the time between the ages of eleven and eighteen years old. Shortly before his release on his eighteenth birthday, he sat down and typed a 12,000 word autobiography. When confronted with the surprise accompanying his opus, Michael remarked, "*I knew how to read and write. On the reading, like, the books I wanted to read were too high for my level. So there would be bigger words. I like reading about NASA, how they figure things out, but some of the words I couldn't read. So I just didn't read, because I didn't want to read about cute little puppies…*" In a productive context for learning a teacher would have had a similar conversation in a safe supportive classroom at least a decade before.

Press accounts report a growing concern with issues of student discipline and school safety. Entire industries are built upon school security, classroom management and student discipline. In fact, one of the fastest growing uses of technology in schools is not for the types of rich learning experiences found in the CLL, but rather for surveillance. Therefore, one way to assess the CLL's success at increasing social responsibility is by looking at the behaviour of our students. It is worth remembering that these students were condemned as a threat to society, yet we found that the students were remarkably kind, empathetic and supportive of each other..

> 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. (Cavallo, Papert & Stager, 2004)

In three years, we did not experience a broken computer, a stolen computer, a lost mouse ball or a single student who had to be removed from the classroom for discipline reasons. The finest prep schools cannot claim such a record of positive student behaviour. Such evidence of pro-social behaviour along with examples of student work, eyewitness accounts and student interviews is a testament to the context for productive learning produced in the Constructionist Learning Laboratory.

3. THE TECHNOLOGY ECONOMY

The CLL departed from traditional classroom practice by viewing technology as a system. Students used technology to write, record, edit and broadcast radio programs that they listened to on the crystal radio they also constructed. Building a pinhole camera out of a shoebox allowed students to develop photosensitive paper and then produce prints via a scanner, printer and digital editing software. That same camera might also be used to snap an aerial photo or collect evidence from an underground expedition. The temperature-plotting machine could be used to conduct more sophisticated science experiments. Much was learned building a guitar, but ownership of that instrument required that you learn to play it. That guitar and newly acquired musical knowledge might be used to score another student's claymation film.

CLL Students used technology to build tools useful in constructing other things. Their projects formed a technology ecology in which one application led to other uses and more complete understanding. This represents a new standard for educational technology.

4. CONCLUSION

CLL students often revelled in the realization that they possessed so much talent. Adults who put the needs of each child ahead of an arbitrary curriculum nurtured individual gifts, interests and aptitudes. Other educational interventions for at-risk children tend to limit options and present the same material in a slower fashion. The frenetic research and development environment of the CLL assumed that students could engage in serious intellectual work.

The ubiquitous access to computers and computationally rich building materials made a significant contribution to both the learning process and the learning environment. We could have baked cookies, sang songs, read stories to the children or gave them rewards for positive behaviour and their self-esteem may have been elevated or test scores increased. However, the routine use of the computer and related technologies allowed our students to engage in serious intellectual work, perhaps for the first time in their lives. The computer allowed them to experience the feeling associated with being a mathematician, a scientist, an engineer or a filmmaker. This "feeling of wonderful ideas" is profound and absent from even the most successful school reform efforts. Imagine a school system in which every child felt as Tony did that he had the personal power, potential and intellect required to meet any challenge.

Papert's constructionist learning theory combined with the daily work of wonderful children and caring adults represents a large step towards asking Sarason's critical question of "What do you mean by learning?" and offers inspiration for others interested in creating productive contexts for learning in the digital age.

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[i] The use of the term, freedom, in association with this project is tragically ironic since the students were incarcerated and denied basic freedoms in an institution found to be abusing children by Amnesty International.

[ii] Langston Hughes was an African American poet, writer and activist associated with the Harlem Renaissance of the early Twentieth Century. He was later dubbed the "Poet Laureate of the Negro Race."