A holistic model for learning environments: technological saturation and school and community connections

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Abstract

The dominant modes of thinking about education in "developing countries" focus on inferiority that is to be remedied by transfer of superior methods from the "developed countries." This thesis is framed within a way of thinking that reverses this perception by identifying strengths of particular countries to develop specific models for learning environments. The spirit of reverse goes further: the particular models that will be discussed in this thesis, while rooted in rural Latin America, have "spin-off" application to the most advanced industrial countries.

Digital technologies play a critical role in the proposed model. But here too there is a reversal of the dominant approaches. Most attempts to bring technology to bear on the educational problems of developing countries attempt to address the degree of understanding the technology required by limiting the role of the teacher who uses it. This is clearest when the technology is primarily used to support "distance learning." They try to “teacher-proof” the technology use, and limit things to office applications or other superficial uses, which then limits the potential impact of the technology and the change in education.

The work proposed in this thesis is based on experiences that demonstrate the capacity of teachers to understand and use computational thinking on a deeper level. By extending the scope of these experiences it contributes to one of the fundamental issues in the dynamic of extending modern education on a global scale. This is the issue often identified as "the problem of the under-qualified teacher." The limiting factor in the rate of growth of education is seen as a bottle neck to knowledge created by the limited educational level of teachers. There is a prevailing assumption that what the teachers can not teach the students can not learn.

Constructionism challenges this apparently obvious assumption. It is possible to learn in action provided that the learning environment provides opportunity for the right kinds of action. In the model provided here this becomes the primary role of the technology. Pro-learning technologies make it possible to learn in action what might be impossible or at least greatly more difficult to learn in an academic way. However this does not mean that the mere presence of the technology is sufficient, and this is where this thesis makes its specific contribution. In the proposed project the technology is not only present but also present in sufficient quantity to constitute an immersion environment; experienced as socially and personally relevant;, linked to sources of social and cultural knowledge; linked to a source of *powerful ideas*; and reinforced by a knowledge network of personal and intellectual support.

One to one computer infra-structure and other technologies, including the requirements for LEGO-style robotics and net-based videoconferencing, will installed in two "one-teacher" rural schools in Costa Rica. Building on the foundation in Constructionist computer work already in place in Costa Rica, teachers will be trained to be able to learn more in the course of extensively project-based learning with participation by students of all ages and of community members. A unique feature will be an on-line knowledge network using MIT and other resources to transfer into the school environment ideas and

knowledge unfamiliar to the teachers. The scalability of this process is based on a concept of developing a self-sustaining network of similar schools and of support groups. Evaluation will examine (a) learning gains made by students (b) learning gains made by teachers (3) indications of the feasibility of the networking basis for sustainability.

1 Introduction

The increased global ubiquity of computers combined with high bandwidth connectivity has laid the technical groundwork for fundamental change in education. The technical infrastructure is arriving; however the most common patterns of use have been limited. What are needed now are new models for learning environments that can take full advantage of the new capabilities and the pervasive availability of computational devices, and of the properties of dense access to connected computational technologies.

The need to improve the quality and access to education in Latin America is well recognized, but current efforts to improve education fall far short of what is considered necessary. A large fraction of the population has no access to minimum levels of education, and most of those who enjoy access receive very low quality education, especially in rural areas, where there is even greater need.

One-teacher schools, found in most rural areas, provide a fertile ground for new models for learning environments as they do not fit traditional models but have characteristics where Constructionist principles can take hold. Moreover, these schools are not merely typical of Latin America; such conditions exist globally. Providing compelling models for such situations has potential impact on a global scale. One-teacher schools offer an exceptional context to implement a school model within the entire school, making possible technology saturation at a reasonable cost; making easier the fostering of connections between school and community; facilitating addressing teacher development issues; and providing an environment where collaboration among children from all ages, work across different disciplines, and relevant content to the community come more naturally.

The central questions to be addressed in this thesis are: what would be a model for learning environments for one-teacher schools? How well does the proposed model do in attempting to solve the specific problems of rural education? Three actions will be used to answer these questions: 1) designing a new model for learning environments that draws from both experiences based on technological saturated environments mostly in "developed countries", and experiences that integrate school and community in Latin America; 2) implementing the new model in two one-teacher school in Costa Rica. The actual process will be documented at through out the experience; and 3) assessing the new model in the schools and communities where it will be implemented.

Latin American education, especially in Costa Rica, presents an interesting ground for research and implementation of the work proposed in this thesis, based upon successful deployment and on-going support of computers for education, which could enable Costa Rica to repeat history by once more taking the lead in the new phase of development of educational technology.

In 1988 Costa Rica took a bold step towards using computer technology to enhance its schools. The Costa Rican program of introducing computers into schools and especially of providing support for teachers using these computers, places the country in the forefront among Latin American countries. The Omar Dengo Foundation, the institution which has implemented the computer initiative in Costa Rica, has created both in-service and computer-based training programs, which are conceived within a Constructionist philosophy (Anfossi & Fonseca, 1999). The Foundation has also created a support network of tutors who are teachers participating in the program; and a nationwide conference for children. Through these programs, Costa Rica has shown how to introduce a nationwide change that is both radical and sustainable, which gives the country a culture of educational innovation.

The MIT Media Laboratory provides an ideal environment to carry out this research in many ways. First, there is a great history of collaboration between the Media Lab and Costa Rica. Seymour Papert and his research group at the Media Lab worked together with the government of Costa Rica in the computer for education project. This program is considered one of the most successful experiences in Latin America. It has had great deal of stability since it started, and has involved 50% of the student population[1]. The work proposed in this thesis could enable Costa Rica to repeat history by once more taking the lead in the new phase of development of educational technology. Second, members of the Future of Learning group have gained a great deal of experience by collaborating in projects with people from developing countries around the world (Cavallo, 2000; Urrea, 2001; Blikstein & Cavallo, 2003). This experience enables them to support the teachers in carrying out the proposed research project. And last, new research on low-cost computing at the Media Lab has tackled the lack of technology availability in learning environments by designing new technologies that can be produced at the local communities using local components (Sipitakiat, et al, 2002). This research provides a solution to the problem of technology acquisition that keeps most of the developing countries from implementing further innovations in the field of educational technology.

1.1 Rural education: problems and challenges

The current situation of the target environment has to be analyzed in order to propose a model for learning that can take full advantage of the new capabilities and the arriving ubiquity of computational devices. The following are some of the main problems and challenges in rural education (Reimers, 2003), which this thesis work is taking into consideration:

- Disconnected knowledge and skills. Students from rural areas have access to a limited amount of knowledge and skill compared to students from urban communities. They also learn the concepts in a disconnected way, missing the opportunity to make meaningful connections, therefore get the skills they need to improve the community where they live.
- Ineffective and unsuitable teaching methods. In the rural school, one teacher is in charge of instructing the students and delivering all the information. Within those conditions, teachers do not have the time to cover all the material they are supposed to, nor can they devote time to pay attention to the students' interests and needs.
- Limited learning resources and materials. Rural school teachers have access to limited materials and resources, if any; or the materials they get are outdated. Another related problem to the teaching materials is the fact that teachers do not know how to integrate and use them in the classroom.

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[1] http://www.esicm.cu/cejisoft/www.espanol/eve/1999/ponencia2.htm

- Isolated teachers. One of the main issues for teachers in rural areas is that they work in isolation. They do not get in contact with other teachers to discuss problems and challenges, to review their performance, and to exchange ideas and projects.
- Inadequate or insufficient teacher development. It is undeniable that there is a need for improving teacher training programs in Latin America (Lowden, 1999), but difficulties to establish general solutions are widely recognized (Navarro, 2000). Individual successful initiatives have been identified in the region. The common characteristic is that they respond to local needs and problems. Some of those problems are: failures in pedagogic methods used to train teachers, inappropriate content of training, and failure in the impact of training given limited support.

To illustrate how the proposed model would attempt to solve some of those problems, envision the following scenario:

> *Martha, a teacher from a one-teacher school, sets out to engage students in the solution of problems about scarce resources in the community, such as water and electricity. She introduces the topic to the students by reading an article she found on the library. The article tells the story of a city, in which citizens did not pay attention to how they used the water they had. One day the city ran out of water and its citizens were very preoccupied about the future of the city and its people. After reading the story, she posts the following question: "How can we help them solve the problem they have?" The teacher guides the discussion towards finding solutions and by using examples of their own community to propose concrete projects.*
>
> *A network of distant tutors from MIT will be available to support teachers. These tutors will help teachers identify places where the project can be deepened and further connections with powerful ideas. Martha, the teacher, sends email to the team at MIT to coordinate a meeting. She would like to get advice on how to deepen the discussion by introducing concepts and ideas from other disciplines. One of the suggestions of the MIT team is to have children record water usage and especially wasteful usage.*
>
> *Teachers face the challenge of establishing more connections with powerful ideas in mathematics, science, social sciences, as well as civil and human values. The problem of mathematics is particularly critical because of limited mathematical knowledge teachers have outside of the curriculum. Having students come up with their own ways to measure water usage introduces the use of arithmetic operations, such as multiplication. Multiplication is usually introduced as m times n, which refers to m sets of n things. Then children are confused when they see multiplication coming up in situations like:*
>
> *distance = speed times time.*
>
> *In the case of water usage, it can even get more confusing:*
>
> *quantity = rate of flow times time.*

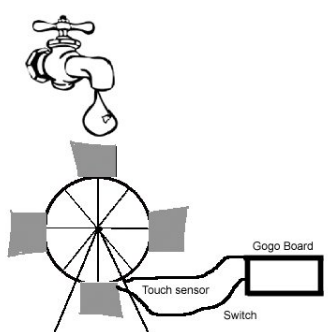
Having the students come up with their own ways to measure quantities of water usage and representing it over time, really helps them construct their own understanding of a concept such as multiplication.

After the meeting with the MIT team, Martha gets concrete ideas of how to coach the students into making deeper connections to arithmetic operations and data representation. She then asks the students to design their own ways to estimate the quantity of wasted water and also show this over time. Students from different ages create groups, and define the projects they want to work on. They decide the goals of the project, state their interests and capabilities, and choose the tools they want to use. They meet with the teacher in order to document their progress and discuss the feasibility of the ideas.

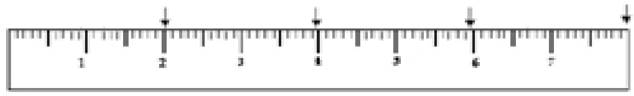
For example, one of the groups may design a system to measure the amount of water wasted. The system is a watermill with four containers –all the same size. They use plastic containers and parts they have recycled at their house to build it.

Carlos, a 12 year old child working on the watermill project guides the development of the project. He explains his ideas to the rest of the group. He proposes to use the GogoBoard to program a system that keeps track of the water usage. The idea is to use a touch sensor and a switch. The touch sensor activates the system: reset a timer and a counter for the number of containers used; and the switch detects every time a new container fills, so that the counter is incremented by one.

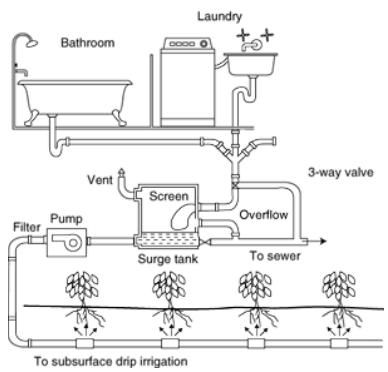
To *reduce the burden on the teacher, in the proposed learning environment, students collaborate among themselves. They work in projects and help each other as they need to. Two younger children working on the project understand the idea behind the design and how the board and the sensors work together, but they have a hard time writing a program that controls all of the components. Carlos spends time with them writing the program.*



To represent the amount of water runs over time, the group uses a measuring tape on increments of one minute. They record the "wasting a new container" event on the tape to get a sense of the amount of water wasted over time.



Collaborative projects will be established with people who share similar interests, and who follow similar principles and philosophy. Support provided through these collaborations will allow sharing and refining ideas among the different sites; discussing project issues among kids in different places; and combining these projects to overcome limitations in local solutions and to seize global aggregation. Other group(s) joined a collaborative project. They worked together with a school in Mexico, which is part of the Schlumberger Excellence in Educational Development (SEED) network[2]. They proposed a system to recycle and reuse grey waters at home. They use the internet to research some of the available solutions and propose a system that seemed the most appropriate for the local conditions of the community.



At the end of the session students present their projects to all the students in the classroom. They reflect on the design process. All of the students documented their projects with pictures they took with a digital camera and wrote their own reflections on their individual portfolios.

2 Approach

The central questions to be addressed in this thesis are: how does a model for learning environments in such school look like? How well does the proposed model do in attempting to solve the specific problems of the situation of rural education? Three actions will be used to answer these questions: 1) designing a new model for learning environments that draws from both experiences based on technological saturated environments mostly in “developed countries”, and experiences that integrate school and community in Latin America; 2) implementing the new model in two one-teacher school in Costa Rica. The actual process will be documented at through out the experience; and 3) assessing the new model in the schools and communities where it will be implemented.

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[2] http://www.seed.slb.com/en/things_to_do/projects/index.htm

2.1 *Designing a new model for learning environments*

In order to answer the question: how does a model for learning environments in such school look like? This thesis proposes a new model for learning environments that draws from both experiences based on technological saturated environments mostly in "developed countries", and experiences that integrate school and community in Latin America.

2.1.1 Technological saturated learning environments

Looking at voluminous literature on computers in school, I draw on three examples. The first, a highly publicized research study by Angrist and Lavy (2001), which use data from a test given to children from 905 school in Israel to examine the relationship between computer:student ratio and student achievement. Schools were equipped with computers at a 1:10 ratio. The results of the study show no effect between computers and achievement. However, it is not surprising that technology had no impact on student achievement given limited access students had to the computer, no attempt at connection with children's real lives or interests, and no connection with powerful ideas. Moreover, in this study only computer-based activities were evaluated from the point of view of the teacher (i.e. how the use the technology to teach), as though only having the computer was sufficient without paying attention to the activities the students engaged in or how students use the computer.

A second experience study performed by a group of researchers at Boston University on a South Elementary School, located in Andover, Massachusetts, compared two types of classrooms: classrooms with a temporary 1:1 environment, and classroom with a 1:1environment on permanent basis (Russell, 2004). The findings resulted on higher use of technology, higher level of motivation and engagement in classrooms with full access to laptops, but still there were no connections with students' lives or interests, and no connections with powerful ideas.

A third experience by Idit Harel at the Hennigan Elementary School in Boston (Harel, 1991). Idit Harel worked with seventeen 4th grade students for about 70 hours over the course of four months in designing instructional mathematics software. Although there was not a 1:1 computer:student ratio, students spent significantly meaningful time using the computer and making connection to powerful ideas in math. This experience resulted in student engagement and math improvement in the regular math curriculum, but still did not connect with students' lives and interests. From these studies it can be concluded that while the technology is a necessary condition for change it is insufficient, if the learning does not happen in the context of learners' lives and interests and does not connect to powerful ideas.

2.1.2 School and Community Connections in Latin America

Escuela Nueva (New School) and Fe y Alegria (Faith and Joy), are previous initiatives aimed at addressing the problems of rural education in Latin America, which inspire the work proposed in this thesis. The goal of the Fe y Alegria program is to provide quality education to children in underserved and rural communities (Reimers, 1992; Reimers, 1993). The program is a collaboration effort between the Ministry of Education of the country where the project is implemented, which pays teachers' salaries; and the community members, who help build and maintain the schools (Reimers, 1993). The main goals of the program are: to provide teacher training and support, to create materials that are relevant material to the community, and to foster state and community involvement.

The Escuela Nueva model for rural settings fosters connection between school and community by having one or two teachers teach up to five grades, encouraging collaboration between children of different ages, developing a curriculum around rural life, emphasizing project-based learning, and allowing students to follow their own schedules, so they can help their families if they need to (Reimers, 1993). The Escuela Nueva program was introduced in the rural schools of Colombia in 1975 and has expanded, having incorporated by 1992, 27,000 Colombian rural schools (Colbert & Arboleda, 1990).

Although both these experiences have notably bridged the gap between school and community by encouraging new ways of learning and proposing a relevant curriculum, they have paid less attention to the uses of media and technology for those purposes. In the case of Escuela Nueva for example, static materials, and lack of comprehensive teacher development and support have been recognized as some of the reasons for the model to have begun to deteriorate over the last years (Kline, 2000), which consequently push teachers to use materials as recipes and kept them from facilitating connections to powerful ideas.

2.1.3 A holistic model for learning environments

Experiences such as "Con-science" and the "City That We Want" present interesting characteristics: Con-science project attempts to integrate learning about technology and values by providing tools and methodologies, including the construction of robotic devices (Bers & Urrea, 2000); and The City that We Want project (Cavallo et al., 2004) "enabled the constructionist use of technology within a generative theme to enable students to design and construct their ideas about how to improve life in their communities." Both of these experiences use technology rich environments, facilitate learning from school and community connections, and connect to powerful ideas; but they are isolated experiences.

Motivating both of these projects is the underlying philosophy of Constructionism, in which the computer are seen as more than just a tool, but rather as a potential carrier of new ways of thinking about teaching, learning, and education (Papert, 1980). Interventions afforded by Constructionism will take into consideration the local knowledge and culture, people's interests, and different learning styles, and therefore have the potential of leading to appropriate actions in rural education. This thesis makes its specific contribution in those regards by proposing a new model for learning that takes these experiences that integrate school and community, and combines them with technological saturated environments where technology is not only present but also: present in sufficient quantity to constitute an immersion environment, experienced as socially and personally relevant, linked to sources of social and cultural knowledge, linked to a source of *ideas*, and reinforce by a network of personal and intellectual support.

My definition of holistic model involves looking at interactions between elements within the learning environment rather than just concentrating on individual elements. I am taking into consideration all the elements when defining the new model of learning environments. I am proposing a new model that does not impose boundaries between teachers and students, children's ages and grades, school and community, local and remote places, or disciplines among each other, and in which technology becomes the glue that helps integrate all the elements. In the new model for learning environments:

- learning is not limited to the school, but it happens in the context of their community. Students use the computer and other digital technologies to develop projects that are relevant to the local conditions, interests and problems; and make connections to powerful ideas in math, science, and social science, as well as civic and human values[3]. They acquire the knowledge and skills they need, when they need them.
- the teacher learns along with the students and vice versa. The teacher acts as a collaborator and facilitator rather than an instructor. Students also collaborate among themselves. They create groups, work in projects and help each other as they need to.
- teachers can get the resources and support needed to develop and propose activities. Teachers and students can access materials and information by working on collaborative projects with people who share similar interests, and who are developing related activities. Support provided through these collaborations will allow sharing and refining ideas among the different sites; discussing project issues among kids in different places; and combining these projects to overcome limitations in local solutions and to seize global aggregation.
- teachers can use the internet to communicate and collaborate with other teachers who have similar interests, problems and ideas due to the availability of computers and other technologies,. They can use videoconferencing to review their own methods and hold meetings, use email to exchange ideas for projects and solution to problems, and use new web-based multimedia contextual support we are developing for ideas, explanations, support, and discussion.
- teacher capacity will be built by: 1) hands-on training to introduce teachers to Constructionist learning: to get teachers engaged with the technology and to get them motivated to develop their own methodology; 2) in-service training: to review teacher practices and review progress of the project; and 3) constant support though knowledge network: to help teachers identify places where projects can be deepened and further connections with concepts in mathematics, science, social sciences can be explored.

2.2 Implementation

In order to implement this work, I will work with one or two schools in Costa Rica during a school semester. Several activities will be performed as part of the implementation:

[3] Costa Rica is interested in a holistic education of the citizens. They promote equilibrium between the cognitive, emotional and the environmental aspects of the human being by promoting: education in values, education for peace, civic education and responsibility, and promotion of environmental biodiversity, among others. Further information can be found http://www.mep.go.cr/

schools preparation, deployment of technology, content creation, teacher development, and support and follow-up. All of these activities will be in collaboration with the Omar Dengo Foundation, institution which has implemented the computer initiative in Costa Rica along with the Costa Rican Ministry of Public Education.

2.2.1 Preliminary activities

In order to prepare for the pilot experience, important groundwork needs to be done. Members from the Omar Dengo Foundation and the Media Laboratory (Media Lab) will meet to make decisions regarding the schools where the pilot program will be implemented, and the computers and other technology that needs to be prepared.

A team of people will be created with members from the Omar Dengo Foundation, the Media Lab and teachers from the participating schools. The team will be in charge of getting information about the school to finalize the details of the implementation; and details about the community to prepare the initial content.

Initial data will be collected for the evaluation. First, teachers will complete a survey that focuses on uses of technology, content and content design, learning approaches, student and teacher engagement, and community involvement. Second, observations will be conducted at the schools twice before the pilot experience starts. Each observation will be conducted over a day period and will be recorded for further analysis. The observations will focus on teaching/learning approaches, student-student interactions, and uses of technology (if any).

2.2.2 Technology deployment

Besides the computers, other technologies and construction toolkits will be available in the classroom. Some of the possibilities are: GoGo boards and other programmable bricks (Mindstorms bricks, Crickets, Handy Crickets), Micromundos, HDL, etc. In addition to digital technologies, the use of other building materials, such as scrap and found materials and tools is encouraged (Urrea, 2001; Sipitakiat et al, 2004). For example, digital cameras, art materials, building supplies, recycled objects, soldering tools, and other resources will be accessible as natural tools for work. [4]

In order to accommodate the technology and the new approaches for learning, the physical environment should be changed. I propose the transformation of the physical space into an atmosphere that fosters collaboration and openness. It should be a functional setting, which can be easily customized according to specific activities. Digital technologies and other resources will be accessible to students at all times.

The proposed physical environment should have specific areas: 1) resources and library area, where students have free access to different materials and mechanisms they need to develop their work; 2) teacher's area, where the teacher can develop her/his projects and plan her/his work. They can also use this area to meet with students and to give individualized attention to students; 3) computer area, which is not necessarily a separated area, but a specific place where computers are located and available for teacher

[4] A complete list of suggested materials and equipment is included at the end of the document

and students to use; and 4) students' work area, which will be used by the students to collaborate and develop their projects.

The existing layout and local conditions should be identified first in order to design and propose a new layout. This new layout should also be designed in collaboration with the entire team of people already selected. The following layout is suggested as one way to start brainstorming and further develop according to specific needs and conditions (see Fig 1).

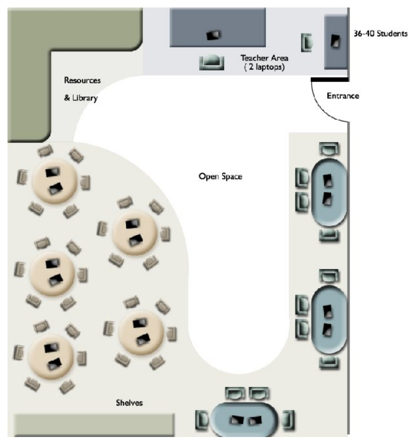

Figure 1. Classroom layout

2.2.3 Introducing teachers to Constructionist learning

Over the last years of work I have developed my own methodology to introduce teachers and students to Constructionist learning. This methodology will be used as a way to get teachers engaged with the technology and to get them motivated to develop their own methodology (based on the same general principles). The teachers will work on projects around content development, which they will use in their classrooms.

This methodology of work is organized as follows:

- Discussion about specific aspects of the activity (content). It is important to create a context of work when introducing a particular technology, not just learn about technology as such, but also learn about the technology because you have the need and the interest to explore a specific idea(s). There is a discussion about the specific content and some related ideas that learners would like to use to create projects.

- Introduction to the use of technology. This is a hands-on experience with the technology. This session is a discovering process. There is some explanation about what the technology does, but more importantly, there are activities that help the learners discover its functionality and applicability.

- Creation of groups and discussion. After discovering the possibilities of working with a particular technology, learners choose the building blocks of their projects. They make decisions about particular ideas they would like to explore, specific aspects of the technology and materials they may need to use.

- Cycle of design, building and test. This cycle becomes one of the most important parts of the work. Learners may devote a lot of time to construct and deconstruct concrete projects to the point where they are satisfied and feel that they have accomplished their goals.
- Final presentation. It is important to review the process that took place during the design and construction of projects. By externalizing and telling others about their learning experiences learners are able to reflect about their own learning process (and develop potential improvements).

2.2.4 Content development

The proposed content for this research project is based upon the local conditions, interests and problems. The idea is to have students learn concepts and skills by working on projects that are relevant to the community. Contrary to the way they learn today, students would acquire knowledge as they need it. The teacher would be in charge of developing activities/lessons that are rich in the three dimensions: engage students, connect with local issues, and connect with powerful ideas in mathematics, science, social sciences, as well as civic and human values; all of them afforded by the technology at hand.

In order to develop those activities/lessons, teachers need support. Providing this support presents a deep dilemma. On one hand, Constructionism requires that educational ideas have to come from the teachers themselves and have to connect to the local issues[5]. On the other hand, teachers lack the required knowledge to make deeper connections with powerful ideas. A central component of this thesis is developing strategies to deal with this conflict. First, I will use the knowledge and expertise of the Media Lab team, which has accumulated examples of using technology in the form of "robotic" artifacts and "Microworlds" projects to engage children with problems of social concern. I will use those examples to help teachers find connections with community issues and get started proposing lessons. Second, I will conduct teacher development sessions to help teachers become technologically fluent (Papert & Resnick, 95) as they propose new lessons, and guide students in the development of projects. And third and most original, the teacher's isolation will be replaced by being in a "knowledge network"[6]. The common way to bring new ideas into teaching is by supporting the development of lesson, but I proposed a support that goes step further. The idea is that the network will help teachers identify places where the project can be deepened and further connections with powerful ideas can be explored.

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[5] Constructionism affirms that the construction of knowledge happens especially in an opportune context in which the learner is designing and building an artifact or project that is meaningful to him or her (Papert, 84). The idea is that the teacher guides the discussion to help students come up with their own projects and explore their own interests within the context of a given lesson. In the same way, a similar experience will be laid out for the teachers, in which they can become the designers of the school content, using different technological tools.

[6] The knowledge network concept will be elaborated further in section 2.2.6

Activities/lessons will be organized in themes, which are major important aspects of the community. Within each lesson, students can explore one or more powerful ideas. Some examples are presented in the following table.

Themes	**Lesson/Activities**	**Powerful Ideas**
Environment (water, electricity, nature, etc).	Measuring water quality	Data collection and representation: Children can study the quality of water by analyzing samples they collect in their community. They can make a sense of the data because they connect the reading to concrete samples of the water they have collected. They can make speculations and come up with meaningful ways to represent the results. (SEED project - http://www.seed.slb.com/)
	Recording water usage and especially wasteful usage	Multiplication: Having the students come up with their own ways to measure quantities of water usage and representing it over time, really helps them construct their own understanding of a concept such as multiplication. For example, a group of children can design a watermill to keep count of the amount of water used over time. They can also design their own ways to represent the event of one container used at a given time.
	Animal behavior	Randomness: Children can learn about this concept by building and simulating animal behavior using digital technologies (Martin, 1988). For example, they can build a robotic fly and use randomness to simulate how it flies.
My community	Where is my community located?	Geometry: Children can build a map of the community where they live. They can calculate distances by taking a walk between places, counting steps and scaling them on a map. They can use Microworlds and the concept of "body syntonic" (Papert, 1980) to draw the map and explore further concepts of geometry as they travel between places.
	Living in peace and harmony	Human values: In the same spirit of Con-Science project, children can build robotic artifacts to explore human values (Bers & Urrea, 2000). They can also use narratives to complement their projects. For example, a group of children can build a conveyor belt that transports actions, and have people play with it to reflect about the good and bad things they have done and how they can improve their behavior

	Recreation (Games)	Probability: There is a lot of probability embedded in games. Students can explore the concept of probably by designing their own games and having community members play with them at a school fair. A group of students can design a contraption that gives yes/no/maybe type answers to people's questions. They assign a probability of 50/30/20 to each of the possibilities.

2.2.5 Teacher/Community development

Further hands-on activities will be organized during the school year, which involve teacher, families and other members of the community. The intent is to create connection between school and community by facilitating these kinds of activities, in which not only community initiatives can emerge, but also new ideas for content development.

School and family

Parents and families are important players on the education and development of the children (Bers & Urrea, 2000). There are many issues related to children's education and development that cannot be left to the schools alone. I propose the organization and implementation of different activities that include students' families. I believe that their involvement is essential for the success of these pilot programs. By including them in different activities related to the school initiative of change, they can not only understand and learn, but also participate and support students, teachers and schools in the process.

School and community

I propose to organize activities in which experts from the community collaborate with the students and teachers by working on projects related to the community. There are skills and assets either present at the community or being identified as important to develop at the community level in order to improve the well being of its members.

2.2.6 Elaboration of knowledge network concept

In order to achieve and sustain the desired changes, and to collaborate with teachers from rural communities, otherwise working in isolation, support and communication mechanisms need to be provided. The initial idea is to create a knowledge network of distant tutors from MIT including Seymour Papert, David Cavallo, as well as Claudia Urrea, and tutors from the Omar Dengo Foundation team, who will support teachers at all times. This support will be not only on the technical and practical aspects of the project, but also on the theoretical aspects and ideas behind the work. Several support channels would be established:

- Permanent email and instant messaging access.
- A conference call with teachers, the Omar Dengo Foundation and the Media Lab team once a week to review project progress. If there is connectivity, videoconferences can be coordinated instead of phone calls.

- Communication with local and distant tutors will help teachers identify areas where the project can be deepened and where further connections with powerful ideas (Papert, 80) in mathematics, science, and social sciences can be explored.
- Collaborative projects will be established with people who share similar interests, and who follow similar principles and philosophy. Two concrete examples of projects are: the Schlumberger Excellence in Educational Development (SEED)[7], and Escuela Virtual (Virtual School)[8]. Support provided through these collaborations will allow sharing and refining ideas among the different sites; discussing project issues among kids in different places; and combining these projects to overcome limitations in local solutions and to seize global aggregation.

Sustainability beyond the thesis period will be provided not only through the distant tutors, but also though the documentation of the actual projects, which will be written up as case studies and used for education of future teachers and for guidance of in-service teachers. The implementation depends on access to scarce resources such as MIT team. However, my working hypothesis is that an extended network of teachers becomes self sustained as more teachers and local tutors join the network.

2.3 Evaluation

It is necessary before discussing what can be done under the heading "evaluation" to note some intrinsic limitations which are frequently not faced by innovators in education. To situate the issue I present an example of a successful educational action as described by Marc Tucker (2004), president of the National Center for Education and the Economy.

Danish story.

> *Change does not happen in a vacuum. What makes the educational actions taken in Denmark successful is not measured by short term, change in preparedness of individual to pass a test, but by relatively long term change in preparedness of the population to meet needs of the economy. Indeed, the situation is even more complicated when we recognize that even this manner of judging success does not rigorously isolate the educational part of a national program from economic and other components of national policy.*

In a similar spirit the real measure of success of the work to be reported in this thesis will be its contribution to a long term social development. Although the time-frame of a doctoral thesis, and indeed of most studies of educational actions, does not permit the use of such criteria it is appropriate to look for indicators of their plausibility.

Categories of evaluation criteria:

1. The lowest level questions have to do with the workability of the procedures independently of their consequences. These questions are not trivial. There are many ways in which attempts to introduce robotics-based projects into schools can, and often do, fail.

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[7] http://www.seed.slb.com/en/about/index.htm
[8] http://recintodelpensamiento.com/escuelavirtual/index.htm

2. Certain consequences can be continuously over the experimental period. Some of these have been studied in other settings thus opening a set of comparative questions. For example, there have been numerous studies in different kinds of social settings of achieving an unusually high level of student engagement as a result of implementing individual components of the conditions that will be combined in this project: high level of computer access; use of robotics as a basis for projects, and connections with community issues have each separately been shown to produce higher levels of engagements. I can conjecture but cannot know with any certainty in advance that combining these conditions and doing so in a very different social/cultural context will produce at least equal and probably much higher consequences of this kind. I also conjecture that while such effects will be comparable in general form to what has been seen in schools in the USA, Australia, France and other countries, the details of how they play will be interestingly different.

3. Other consequences will be seen only at the end of the experimental period. Among these are advances in test performances in standard school subjects. A battery of tests will be developed during the course of the project but will at least include versions of the TIMSS (Trends in International Mathematics and Science Study) tests modified for administration in computational media. A larger matched group will be used as a control. It should be noted that any significant effects established on this level will have great importance for thinking about the way computers are used in all countries including, very especially, the USA.

4. A very different kind of question on which the project has an important bearing concerns the development not of students but of teachers. Although our sample size for this is even smaller than the student sample, qualitative phenomena might still be observed and make further studies plausible.

Given the background presented in the previous section, a framework analysis is proposed (Ritchie and Spencer, 1994). A framework analysis seems the most appropriate methodology given the nature of the specific questions to be address, and the limited amount of time available to implement and evaluate the experience.

The general question of “How well does the proposed model do in attempting to solve the specific problems of the situation of rural education?” gets divided on the following ones, according to the specific problems of rural education:

- Do students use the computer and other digital technologies to develop projects? Do the students make connections to powerful ideas by developing project? Do students collaborate with other students?
- Are projects relevant to local conditions, interests and problems? Do other members of the community get involved with school matters?
- Do teachers learn along with the students and vice versa? Is the teacher a facilitator? Can teachers propose and document their own lessons?
- Do the teachers use digital technologies to communicate and collaborate with other teachers who share similar interests, problems and ideas? Do the teachers use technology to document projects?

- Do teachers learn to make the connections to powerful ideas (e.g. the powerful mathematical ideas useful for the projects based in the community)? Does this then have lasting impact on the students? Does the knowledge network grow over the course of the project?

2.3.1 Methodology

The study will focus on looking at teacher practices and learning activities experienced at the one-teacher school. The school will be permanently equipped with a computer per every student, as well as other digital technologies. It is expected that the total number of students, teachers and community members will participate in the study. The implementation process provides also systematic and visible stages to the analysis process (e.g. introducing teachers to Constructionist learning, content development, teacher/community development, etc.)

2.3.2 Data collection

Three types of data will be collected through out the experience. First, semi-structured interviews will be conducted with the teachers, students and community members. Semi-structured interviews will be conducted with a fairly open framework which allow for focused, conversational, two-way communication. Semi structured interviewing starts with more general questions or topics. Relevant topics (student engagement, technology use) are initially identified and the possible relationship between these topics and the issues such as (availability, nature of use) become the basis for more specific questions which do not need to be prepared in advance.

Second, the activities occurring throughout a given observation period will be recorded. Specific emphasis will be paid to teacher-student interactions, student-student interactions, uses of technology, and student engagement.

In addition to the interview and observations, documentation of the actual projects written up as case studies will be collected. These case studies will be used as a source of further interview and observations.

2.3.3 Analysis

Analysis of the interview, observations, and surveys data will be done in an iterative process typically employed in qualitative studies (Miles and Huberman, 1994). This process typically includes: transcription (total or partial) and reading of the data; identification a thematic framework (a priori issues and from emerging issues from the transcription stage); coding: the process of applying the thematic framework to the data, using numerical or textual codes to identify specific pieces of data which correspond to differing themes; charting: using headings from the thematic framework to create charts of your data so that you can easily read across the whole dataset; and mapping and interpretation: this means searching for patterns, associations, concepts, and explanations in data, aided by visual displays and including excerpts from original data if appropriate (i.e. quotes from interviews).

The process becomes iterative because I will have the opportunity to conduct more interviews, observations and surveys in order to confirm, elaborate, and clarify the emerging data.

The a priori issues that have been identified are:

- Student engagement: student motivation and readiness to participate in school activities, to design, construct, modify and share projects; to imagine, express and realize their ideas; and to share projects with others.
- Teacher capacity: ability to carry out the research program by creating and documenting new project ideas, by engaging the students in meaningful projects, by collaborating and communicating with a group of experts at the local and international level.
- Relationship with community: emergent curriculum around community life; increased participation of parents and community members in school activities; and after-school programs for both parents and children.
- Technology use: nature of technology use, both by teachers and students (e.g. frequency, meaningful, support, etc).

3 Original contributions

The main contribution I made in this thesis is bringing together in a holistic, integrated way, a number of educational themes that have been shown to have value but only limited value separately, these are:

- the Colombian and other Latin American countries methodologies of community/school and rural school;
- the Costa Rican national culture of educational innovation though the computer for education program, w: teacher preparation, student empowerment, organizational support;
- Constructionist methodologies using computers and robotics;
- distanced methodologies and collaboration with projects such as SEED and Escuela Nueva;
- a strategy for achieving sustainability through a knowledge network based at MIT.

4 Relevant Literature

4.1 School improvement and implementation

Proposing an innovation in school is as important as implementing it. Different types of school require different strategies for development. The strategies for school development need to fit the grow state, or particular context of the school (Hopkins, 98; Cavallo, 2004). The work proposed in this thesis follow the same principles by designing a model for learning environments based upon the strengths and needs of the particular contexts of rural education.

Several strategies have been used to introduce change in educational settings: top-down and bottom-up approaches (Gardner & Lewis, 1996). While the dominant modes of thinking about education in "developing countries" focus on inferiority that is to be remedied by transfer of superior methods from the "developed countries", I strongly believe that what is required is a more sophisticated blend of the two (Fullan, 1992) that reverses this perception by identifying strengths of particular countries to develop specific models for learning environments. The spirit of reverse goes further: the particular models that will be discussed in this thesis, while rooted in the rural Latin America, have "spin-off" application to the most advanced industrial countries.

4.2 Constructionist learning

Motivating this thesis work is the underlying philosophy of Constructionism. According to Seymour Papert, Constructionism is both a theory of learning and a strategy for education (Papert, 1980), which builds on the *constructivist* theories of Jean Piaget, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed by the mind of the learner.

- The teacher acts as a facilitator and collaborator as opposed to being the one and only provider of information in control of instruction. The teacher becomes a mentor that doesn't necessary holds the absolute truth but recognizes and accommodates different kind of learning styles, what Papert and Turkle refers as to "Epistemological Pluralism" (1991).

- Knowledge acquisition is viewed as being particularly facilitated when children are engaged in personally meaningful projects and explorations (Papert 1980). Epistemological and personal connections play an important role in learning (Resnick et al, 1996).
- Classroom activities are more focused on self-directed, personally meaningful projects and less on verbal lessons by the teacher.
- Constructionist learning experiences cannot be evaluated with traditional techniques (Bers & Urrea, 2000). Assessment is focused on the processes of learning rather than pre-established educational outcomes and curriculum objectives. They require a more creative way of documentation, assessment and observation (i.e. portfolios, presentation, etc.)

4.3 School and Community

There are solutions to the problems of education in Latin America, which inspire the work proposed in this thesis: Escuela Nueva (New School) and Fe y Alegria (Faith and Joy), which are widely documented of models of rural education. The goal of the Fe y Alegria program is to provide quality education to children in underserved and rural communities (Reimers, 1992; Reimers, 1993). It has been implemented in twelve countries and it involves several levels of education, from day care to high secondary. The program is a collaboration effort between the ministries of education, which pays teachers' salaries, and the community members, who help build and maintain the schools (Reimers, 1993).

Along the same lines, the Escuela Nueva model for rural settings has fostered connection between school and community by having one or two teachers teach up to five grades, encouraging collaboration between children of different ages, developing a curriculum around rural life, and allowing students to follow their own schedules, so they can help their families if they need to (Reimers, 1993). The Escuela Nueva program was introduced in the rural schools of Colombia in 1975 and has expanded, having incorporated by 1992, 27,000 Colombian rural schools (Colbert & Arboleda, 1990).

Although both these experiences have successfully bridged the gap between school and community by encouraging new ways of learning and proposing a relevant curriculum, they have paid less attention to the uses of media and technology for those purposes. In the case of Escuela Nueva, static materials and lack of support have been recognized as some of the reasons for the model to have begun to deteriorate over the last years (Kline, 2000). This thesis makes its specific contribution in those regards by proposing a new model for learning that takes these experiences that integrate school and community and combines them with technological saturated environments where technology is not only present but also: present in sufficient quantity to constitute an immersion environment, experienced as socially and personally relevant, linked to sources of social and cultural knowledge, linked to a source of *ideas*, and reinforce by a network of personal and intellectual support.

4.4 Teacher development

It is undeniable that there is a need for improve teacher training programs in Latin America (Lowden, 1999), but difficulties to establish general solutions are widely recognized (Navarro, 2000). Individual successful initiatives have been identified in the region. The common characteristic is that they respond to local needs and problems. Some of those problems are: failures in pedagogic methods used to teach teachers, inappropriate content of training, and failure in the impact of training given limited support.

The work proposed in this thesis is based on experiences that demonstrate the capacity of teachers to understand and use computational thinking on a deeper level (Fullan, 1992; Reimers, *; Urrea 2002). By extending the scope of these experiences it contributes to one of the fundamental issues in the dynamic of extending modern education on a global scale. This is the issue often identified as "the problem of the under-qualified teacher" (Navarro, 2000). The limiting factor in the rate of growth of education is seen as a bottle neck to knowledge created by the limited educational level of teachers. Constructionism challenges this seemingly axiomatic assumption. It is possible to learn in action provided that the learning environment provides opportunity for the right kinds of action.

5 Timeline

Activities	Nov to Jan	Feb	Marc	April	May	June	July	Aug
1. Preliminary activities								
2. Technology deployment								
3. Introducing teachers to Constructionist Learning								
4. Content development								
5. Teacher/Community development								
6. Elaboration of knowledge network concept								
7. Assessment								

	Claudia Urrea in Boston		Claudia Urrea in Costa Rica

6 Requirements

In the same way as the design of classroom layout, decisions regarding the materials and equipment included in the classroom should be made by the whole project team and after the schools have been chosen. It is important to take into consideration the current situation and characteristics of the school. The following framework is suggested given past experiences:

- Digital technologies: one computer per child, programmable bricks (Mindstorms bricks, Crickets, Handy Crickets, GogoBoards), Micromundos, etc. It is important to mention that I will be using the expertise and on-going work on low-cost robotics being done by the Omar Dengo Foundation with the support of the Future of Learning group from the Media Lab.
- Building materials: scrap and found materials collected by the students.
- Building tools: solder tools, scissors, glue gun, etc.
- Furniture: round tables, shelves, desks, etc.

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