CREATE:
Opportunities for Technology Appropriation

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ABSTRACT
The "Create" research program proposes a holistic model for learning environments that draws from experiences based on technologically saturated environments. This paper presents the first pilot experience of the research program, which implemented a one-to-one computer infrastructure in a small rural community in Costa Rica. While the majority of experiences have been done in developed countries, the experience in Costa Rica is the first to concretely look at the idea of using one to one computer infrastructure in a developing country, and to analyze its implications. The case study of this experience will be used to suggest that "appropriation" is the most powerful theoretical lens for studying the effects of the computer presence in learning environments. The details of the model, the case study, and some examples that illustrate the students' appropriation of technology are described.

Keywords
One-to-one computing, Laptops, Constructionism, Technology appropriation.

1. A HOLISTIC MODEL FOR LEARNING ENVIRONMENTS
Motivating this research program is the underlying philosophy of Constructionism, in which the computer is seen as more than just a tool, but rather as a potential carrier of new ways of thinking about teaching, learning, and education ([1]). Interventions afforded by Constructionism will take into consideration the local knowledge and culture, people's interests, and different learning styles; consequently, they have the potential of leading to appropriate actions in rural education. Constructionism also proposes the use of computational tools to support learners' construction of knowledge, but it states that not all tools are equal and some are more conducive than others to help people construct knowledge about the world. Therefore, it encourages the design of new models for learning environments ([2],[3],[4],[5],[6],[7]) and construction toolkits that engage learners in designing and creating things, both on the screen and in the physical world ([8]); and in making epistemological as well as personal connections ([9]).

The "Create" research program makes its specific contribution in those regards by proposing a new model for learning environments that takes experiences that integrate school and community from Latin American Countries ([10]), and combines them with technological saturated environments where technology is not simply present, but rather 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 network of personal and intellectual support.

The proposed new model for learning environments is a holistic one; it involves looking at interactions between elements within the learning environment rather than just concentrating on individual elements. In the proposed model there are no boundaries between teachers and students, students' ages and grades, school and community, local and remote places, or among disciplines; and technology becomes the glue that holds all these elements together. Students collaborate with the teacher, and experts and family members, on projects that are meaningful to them and to their communities, and at the same time integrate powerful ideas from different disciplines.

2. PILOT EXPERIENCE
The pilot experience of the "Create" research program took place in a one-teacher rural school in Costa Rica, between September 2005 and May 2006. It was conducted with the support of a team of advisors from MIT and a local team from the Omar Dengo Foundation, institution which has implemented the computer initiative in Costa Rica along with the Department of Education ([11]). The pilot experience had forty one participants: twenty students (1st to 6th grade) and their parents (at least one parent had to participate in the pilot experience).

The first day of the pilot experience, laptop computers with wireless network capabilities, robotics technology, and other materials were handed to the students. A meeting with the teacher, the students, the families and other members of the community was celebrated at the school to explain the details of the pilot experience, which involved not only the use of laptop computers and other digital technologies, but also a change on the learning methodology. After listening to comments and answering questions, the pilot experience officially started.

Several changes were proposed and implemented at the school. Fist, the learning environment was adjusted to support project-based learning. Instead of dividing the day into math, science, social science and Spanish classes, the work has been organized in

activities, which encourage students to propose, design and create the projects they are interested in doing. During any given day, the students gather to read their compositions or present their projects, to listen to a presentation by the teacher, or to discuss an activity. Second, two different construction toolkits were introduced: Microworlds[1] and GoGo boards. Microworlds is a Logo-based construction kit that makes the process of creating a project a rich, learning experience. By allowing children to program their own simulations, games and videos, MicroWorlds fosters the development of problem-solving strategies, critical thinking skills and creativity. Similar kinds of constructionist toolkits are the GoGo boards ([12]), which are tiny, portable computers that can be used to build all sorts of artifacts and program them to interact with the world through sensors and motors. Both construction toolkits, Microworlds and GoGo boards, were designed to build a great variety of different kinds of projects and to support different learning styles. And third, a new curriculum was designed and facilitated. This new curriculum consists of activities that integrate powerful ideas in math, science, and social science, as well as civic and human values. Some examples of the kind of activities developed with the children are described below.

3. STUDY BACKGROUND

The breadth of focus of the study considers changes on individuals as well as the learning environment. It pays attention to the impact of technologically saturated environments on students, on parents, on teachers and on the learning environment itself. Two examples are used to situate the work. On the one hand, a highly publicized research study by Angrist & Lavy [13], which studies the impact of computerization on both the instructional use of computers and pupil achievement. The study was conducted on 122 schools from Tomorrow-98 program in Israel. The classrooms were equipped with computers at a 1:10 ratio. The focus of this study is narrower than the one proposed in this paper since it centered its attention on teachers' use of computer-aided instruction (CAI), which was the main use of the computer identified on a teacher survey. According to the authors, many existing studies are qualitative and gather impressions of the participants, therefore a very rigorous study was performed, which looks in details at the impact of CAI on students' performance. On the other hand, a 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 classrooms with a 1:1 environment on a permanent basis ([14]). The scope of the study is slightly wider since it paid attention to changes on teaching as well as learning practices, but it does not look in-depth to any of the findings. The scope of the proposed study is wider, but it also pays attention to salient outcomes, for example appropriation of technology. Data collected over the course of the study is used to understand in detail what happened over time.

It is also important to mention two fundamental differences between initiatives that bring laptop computers into the classroom and the experience described in this paper. First, the kind of technologies available to the students: Besides using word processors, spreadsheets, PowerPoint and Internet browsers ([13],[14],[15],[16],[17],[18], [19]), students at the pilot experience also used construction toolkits such as Microworlds and GoGo boards; and second, the way in which technology is introduced. Instead of teaching some kind a technology class ([15],[16],[17]), students learned about the technology as they use it to build their projects.

The premise is that the students express themselves fluently with the new technology by using it to design and build projects that are meaningful to them. The term technological fluency refers to the ability to use and apply technology in a fluent way, easily and smoothly, as one does with language ([20]). However, in order to become fluent, students have to come in contact with the technology and appropriate it in a meaningful way. Thinking too quickly about fluency without an opportunity to appropriate the technology can be dangerous. In the same sense Papert in his book The Children's machine [22] introduced the term "letteracy" to refer to the superficial sense of knowing to read; fluency can become equivalent to acquiring the mechanical skills involved in using the technology. If attention is paid only to teaching and evaluating how much the students know about the technology, there is a risk of loosing the opportunity for them to appropriate the technology to become independent learners.

4. EVALUATION

Three types of data have been collected throughout the pilot experience. First, semi-structured interviews have been conducted with the teachers, students and family members. Semi-structured interviews have been conducted with a fairly open framework which allows for focused, conversational, two-way communication. Second, the activities occurring throughout a given observation period have been recorded. Specific emphasis has been paid to teacher-student interactions, teacher-parent interactions, student interaction and uses of technology, and student engagement. In addition to the interview and observations, documentation of the actual projects written up as case studies have been collected. These case studies have also been used as a source of additional interviews and observations.

Analysis of the interview, observations, and surveys data have been done in an iterative process typically employed in qualitative studies ([21]). This process included: transcription and reading of the data; identification of 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; charting: using headings from the thematic framework to create charts of the 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). Because this process is iterative, it has given an opportunity to conduct more interviews, observations and surveys in order to confirm, elaborate, and clarify the emerging data.

5. APPROPRIATION OF TECHNOLOGY

Analysis of the available data revealed one of the significant findings of the study, which is the students' promptness to appropriate the technology. Several levels of appropriation of the technology have been identified, which have been grouped in three categories according to the use given to the technology: the first level of appropriation is with the computer itself, which was the first technological object used by the students; the second

[1] http://www.microworlds.com

level is the appropriation of the functionality of the technology; and the third level is the appropriation of the technology as a learning tool. The data used to support these findings is a combination of observations, and the analysis of files and video collected over the duration the study.

5.1 Appropriation of object

In this first level of appropriation, technology is treated in a very superficial way. It involves having and caring about the technological object without really thinking about the benefit, but knowing the importance of having it. Even though this level of appropriation does not really go beyond the one relating to having of a new object, it is crucial for success of the pilot experience.

Students expressed their commitment with the project and with the technology. After the computers were handed to the students, they received basic instructions on how to turn the computer on and off, and how to log in and out of the system, and also on how to take care of the computers and wireless cards. All the students expressed verbally their willingness to take care of these technologies, and also signed a commitment letter. These shows the students' initial intention to take care of the computers, but what happened with those computers throughout the experience shows their real commitment.

New activities were introduced to the students during the first weeks of the experience. Students worked on projects about the community, using all the available media. They created maps and projects about their communities using different technologies. As they were doing these activities the teacher insisted in allowing the students to take the computers homes. After the third week of work they were finally allowed to take the computers during the weekdays and weekends to finish a project they have been working on as part of the school work, or to develop projects or activities of their personal interests. They have continued to take the computers home, even during the vacation period. Some incidents with the computers have been reported, none of them involving student mishandling and use. These were rather related to the fact that the computers were not brand new, and thus some of them presented problems with previously assigned passwords and wear and tear.

The students showed ownership over the technology. As the program developed, the students observed and followed the recommendations from the principal researcher from MIT. She used the computer at all times to review activities, to document what the students were doing, and to write down new activities. Following the habit of the researcher, students started to bring their own carrying cases only two weeks after the program started. These cases were not made of neoprene, like the one the researcher had; they were made out of diverse fabrics with Spiderman, teddy bears, flowers, and car prints on them. The students had asked their mothers to make carrying cases for their computers, similar to the one the researcher had, even though they never specifically asked to see hers. By the second month, the teacher reported that all the students had a case for their computer. It was evident how quickly the students made the computer their own and started to take good care of it.

This level of commitment and appropriation of the technology has been extremely important for the success of the pilot experience. On the one hand, if the students would not have felt ownership over the technology, they probably would not have taken such good care of it, which would have resulted in problems for the pilot experience. On the other hand, it would have been difficult to take the project any further if the students would not have seen the technology as a valuable object to own and protect.

5.2 Appropriation of the functionality

This level of appropriation involves getting familiar with the computer's functionality. Students explored the technology and found ways to make it personal. They appropriated the technology even further because they made it their own. As the pilot experience continued, students also became aware of the different features of the computer; starting from simple things such as setting the background picture, changing the appearance of windows, and creating different screen savers; to more complex tasks such as accessing and organizing their files, and sharing folders to exchange files using the wireless network. The students learned all of these things as they were working on different activities and as they came across problems, which became opportunities to further appropriate the technology. Evidence of this level of appropriation will be presented in the context of the projects and the activities developed during the pilot experience.

Students explored and found out about simple properties and features of their computers. Observations of the classroom made at different times during the pilot experience revealed that new knowledge spread quickly among the students. Every time a student found a new feature or way to change something in the computer, the rest of the students quickly became aware of it and asked how it could be done. By the end of the day, all of the students had incorporated the new feature.

More complicated features were also learned by the students. The particular cases of two of the students are analyzed and presented in detail. The first is the story of Pablo, a third grade student who had a hard time learning to save his projects. Students were taught on how to create their own folder and how to save their projects on that folder. Most of them were successful at doing this, but Pablo. During the first two weeks students worked on activities related to their communities. They started by using paper and pencil to make a map of the communities; different approaches to design and illustration of the maps were discussed. After that, they created more sophisticated maps of the community using Microworlds; during a week the students had to investigate and write about different aspects of the community and to incorporate that information on their projects. Every morning students opened their projects to continue the work, but Pablo could not find his project, so he had to start all over again. After a while he became good at repeating part of what he had done the previous days, but he was never able to create the same project. Exploration of the files stored on Pablo's computer showed that after the first two weeks he had stored a lot less files on his folder than the rest of the students in the class, who had an average of 5 files per folder. He had two Microworlds projects, one of them was called "transportation and communication media", which the students did as one of the activities for the community; and another one was called "Viernes", Spanish word for Friday, which was his community project. He had probably started multiple versions of this project over the week, but he finally learned to save it with a name on his own folder. Similar incidents have been documented during the pilot experience, but they have decreased significantly as the students learned from their mistakes and received recommendations on how to solve them.

Students actually learned to organize their projects by creating folders and classifying their information. Ninety percent of the projects created by the students during the pilot experiences included sound effects. Students imported existing sound files, and recorded themselves talking about their projects or producing sound effects. As they started organizing their files into different folders, they moved the Microworlds projects they had already created, but their projects did not work anymore. Students learned that they had forgotten to move the sound files along with the projects, but that they could either move the sound files to the same folder where the project were, or they could specify the location of every sound they had added to the projects. Analysis of data collected from the students' computers showed that there was an average of 5 folders per student's folder. Students had made different decisions about data classification: some students created a folder per project; others created a folder for projects and another folder for sound files; others used a combination of both. Careful examinations of data recorded on Pablo's computer at different times during the pilot experience revealed that he became more sophisticated at organizing his information. By the end of the first semester Pablo had created 8 folders: "Microworlds", "Music", "Word", "Projects" and 5 other folders with specific names of projects he had created. There was room for improvement, but evidently, he was exploring with different strategies.

The story of Maria, a first grade student, also presents an instance of how the students appropriated the functionality of the computers. The school did not have enough laptop computers for all of the students, Maria and two other 1st grade students used two desktop computers the school already had. Those computers are connected on a network and share the same storage system that the Omar Dengo Foundation set up. Maria's mother came to the school one morning to talk to the teacher. She was concerned because Maria did not want to go back to the school because she felt she was not allowed to work on the computer. After listening to Maria and her mother, Maria was asked to find her folder and open her projects. It was not an easy task. Maria had to go at least through four levels of folders to access her files, but she had no problem doing so. She had ten projects on her folder and she was asked to open couple of them and explain how she had designed and created them, which she did in a very fluent way. It was concluded that Maria not only had been doing a lot of work with the computer, but she had also developed a good sense of how information was organized in her computer, and how she had to navigate to store and find it. Maria explained further her problem by saying, "I don not want to share the computer with other students in the class. I want to have my own computer." Two decisions were made in order to solve the issue: a third desktop computer was set up for the 1st grade students, and collaboration and group work became part of the routine the school.

Students were not only interested in learning to use the wireless network, but they were also interested in understanding how it worked. Some of the activities developed during the pilot experience required the students to integrate their work on a single group project. For example, there was an activity about Costa Rica's geography and division of territory. Students organized themselves in groups of two or three to do projects about the different provinces. At the end of the activity the work of every group had to be integrated into one single project about Costa Rica. In order to integrate the content, students needed to exchange their project, so they decided to use the wireless network. Students learned how to modify the properties of their folders and personal files to make them accessible and visible to others in the network. For this particular project students learned to make their folders public and started to exchange information. Since the Internet connection was not activated at the time, this also became the way to exchange messages. During an observation by one of the Omar Dengo advisors, an experiment ran by students was documented. They wanted to find out how far from the school they could take their computers without being out of the network. They took their computers out of the school and kept checking the network. They found out that a computer could be as far as the church, which was probably 80 feet from the school, to still see – or be seen by – other computers. They finally had a discussion about how the wireless network was set up and whether or not they could have access to it from home.

5.3 Appropriation of new ways of learning

This is the deepest level of appropriation, which involves using the technology as a learning tool to develop projects that are relevant to local conditions, interests and problems; and integrate powerful ideas in math, science, and social science, as well as civic and human values. This level of appropriation involves integrating the computer into their ways of thinking and perceiving the world. Data collected over the course of the pilot experience show how students became better at using the technology to learn about other things.

Students became independent learners. At the beginning of the pilot experience the students expected a lot of directions and needed a lot of support and attention. For example, for the first activity about their community, students had three main tasks: create a map of their community using pencil and paper, create a map of the community using Microworlds, and create a 3D map of the community. As part of the tasks, students also investigated about related topics and wrote reports on those investigations. They spent almost two weeks working on those projects. At the end of the activity they had to talk about their projects and the decisions they made in order to design and build them. When they were asked to present their projects they had a hard time finding the right words. Most of them went through the different tasks they were given, instead of their own learning process. The principal researcher had to come up with specific questions, such us, "how did you come up with the idea for this project?" or "how they used the technology on specific situations?", to get them to think about the different aspects of the projects.

As they got used to the new learning style, they also started to take a more active role at the school. A second visit and observation happened two months after the pilot experiences had started. The principal researcher arrived to the school with one of the Microworlds experts from the Omar Dengo Foundation, who came to help and to observe the work. During the first meeting, students presented the projects they were doing on Costa Rican relief, and the work they were doing with the preschool kids that came about from the students' interest in teaching their younger siblings how to create projects using Microworlds. After being asked by the students, the teacher supported their idea and helped them design their own activity with the preschool children. They decided what they wanted to teach and how they wanted to teach it to them. During this meeting the teacher talked about how he had changed since the pilot experiences started. He said that "the biggest change for me since the pilot experience started has been

the way I plan my classes. I am listening to my students even more and allowing them to guide how activities are run and how they want to do their projects." He also said that with this new methodology of work, the students were becoming very good at integrating content from different disciplines into their projects. The teacher's testimony reflected the level of appropriation not only of the technology, but also appropriation of the methodology of work. Students and teacher were able to use the technology to create projects that were meaningful to them, and they were also able to integrate powerful ideas from different disciplines using the Costa Rican framework as reference.

Changes were made in order to accommodate the needs and interests of the teacher and the students. Over the semester they continued to work on activities. Sometimes the MIT researcher was there to facilitate the work, other times she was coaching them and helping them over the Internet. Specific activities were proposed and changed according to the feedback from the teacher and from the students. The teacher also customized those activities according to his needs and interests. Over the course of the semester the whole process became a continuous interaction between the teacher, the Omar Dengo Foundation and the MIT team. The following are some of the changes that were introduced over the course of the pilot experience: instead of receiving the same task, students were given several options, so they could decide what they were interested in doing; students were given the freedom to decide who they wanted to work with, but occasionally suggestions were made about other ways to work together in groups; and students' interests and suggestions were taken into account.

By the end of the first semester it was evident that the students had started to integrate the computer into their ways of thinking and perceiving the world around them. An open house was organized at the end of the year with students and parents, members of the community, the Omar Dengo Foundation, and the Department of Education. In preparation for the open house the students reviewed the projects they did over the semester and selected ten of them for the open house; they also decided which project they wanted to present. As they prepared for the open house, the teacher and the MIT researcher started to ask questions to encourage them to reflect on their design and building process. Students also came up with their questions. They were as engaged preparing for the open house as they were designing and building the projects. Interviews with the parents during and after the open house revealed that they were not only pleased with what their children had learned and accomplished, but they were also "extremely proud of how motivated and committed they were", one the parents said. They were even happier as they heard the members of the Ministry and the Omar Dengo Foundation congratulated the children and the teacher for the "remarkable work they had done, the students' level of understanding of the concepts incorporated in the different projects, and the technological fluency."

6. CONCLUSION

Preliminary results of the study showed that the students acquired high level of fluency with the technology. Students' appropriation of technology allowed them not only to feel ownership over the technology, but also to feel empowered to design and create projects. Full access to technology had positive implications on the pilot experience.

Students learned about the technology and its features while using it to learn about other things. Opposite to many initiatives that bring laptop computers into the classroom by teaching some kind of technology class previous to any work in the classroom ([15],[16],[18]), students explored the technology and acquired the knowledge and skills they needed, as they needed them. For instance in the Copernicus Project, a multi-district effort designed to incorporate laptop computers into the instructional and learning process of the public school, "technology is not considered an additional subject, but a tool to be used in all subject areas" ([17]). Results of the observations showed that most teachers taught students about computer skills at the same time they taught about the academic content, with the exception of one of the participating high schools, where technology was taught in a separate course. However, students spent most of their time using Word to write reports, Excel to entry data and design graphs, and PowerPoint to make presentations, but they were not using technology to make deeper connections with powerful ideas.

Students used technology to design and create projects, both on the screen and in the physical world. Besides productivity tools and Internet, students used construction toolkits to develop projects that were relevant to the local conditions and interests; and that incorporated powerful ideas in math, science, and social science, as well as civic and human values. Furthermore, students demonstrated a deep level of understanding of the concepts incorporated in each of their creations. Given the technologies used, it is not surprising that studies published about a number of laptop experiences ([14],[15],[16],[17],[18]) reported improvement in writing as the most salient achievement.

Finally, as the students appropriated the technology, they also integrated the technology into their ways of thinking, and perceiving the world; they used it to make connections with their lives and interests. For example, the study by Angrist & Lavy [13] showed no effect between computers and achievement. It is not surprising that technology had no impact on student achievement given the limited access students had to the computer. However, an important point that cannot be ignored is the fact that in this study only computer-based activities were evaluated from the point of view of the teacher (i.e. how they use the technology to teach), as though only computer-aided instruction was sufficient without paying attention to the activities the students engaged in or how students use and appropriate the computer. The study by Ruseell et al [14] resulted on higher use of technology, higher level of motivation and engagement in classrooms with full access to laptops. Even though this second study shows the importance of full access to technology, there were no connections with students' lives or interests, and no connections with powerful ideas in the way it was proposed and facilitated during the study described in this paper.

Although the preliminary results presented here do not focus directly on the effect of technology appropriation on student learning, they show significant evidence of student readiness to use the technology to learn about other things, therefore improving their achievement. Students gained a level of fluency with the technology that puts them in a better position to learn in action what might be impossible or at least greatly more difficult to learn in an academic way. Fluency might be needed in order for appropriation to take place on a deep level and in order for it to have important effects, but appropriation should be the central issue for thinking about the role of the computer in education.

Before the presence of technologically saturated environments, appropriation could become the crucial in facilitating a significant change in education.

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