Making Learning Visible

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ABSTRACT— Almost two million children in more than 40 countries around the world have received a One Laptop per Child (OLPC) XO netbook computer. These netbooks represent the commitment of politicians, community leaders, and educators to implement disruptive, large-scale education reform initiatives that will advance their countries into the 21st century and prepare their children for interconnected, global, creative, and knowledge economies. Expectations for the success of these initiatives are high, and local stakeholders as well as numerous international organizations look to these experiments with cautious optimism. These programs hold the promise to expand the learning and creative potentials of broad populations. As such, arguably, one of the greatest challenges facing these initiatives is designing and implementing mechanisms that help make the outcomes visible, understandable, and actionable by all audiences. In this article, we discuss initiatives being developed by OLPC at different levels of scale: at the meta level to understand impact across nations and learn about the emerging developments in the different programs; at the mezzo level to allow stakeholders to understand the development of the program in their countries and their schools; and at the micro level to help teachers and students understand emerging learning by children over a given period of time. We present some examples of student work to illustrate how some children are making creative contributions to OLPC.

Inspired in the collaboration and work by Project Zero and Reggio Children, this article was given the name "Making Learning Visible." Beyond the title, the work presented in this article recognizes the child both as an individual and a group learner; recognizes the acts as well as the products of learning; and above all, values the children's reflections and approaches to make their learning visible.

BACKGROUND

The principles and philosophy of One Laptop per Child (OLPC) are rooted in Seymour Papert's constructionist learning theory. Constructionism is built on Jean Piaget's constructivist theory. Piaget proposed that learning is an active process, where learners are continuously building mental models and theories about their surrounding world. Papert argued that this learning is more effective when people physically construct in their world (Papert, 1980). Constructionism promotes the potential held by technology in the education field, and how it can penetrate learning environments.

For us, the phrase "computer as pencil" evokes the kind of uses we imagine children of the future making of computers. Pencils are used for scribbling as well as writing, doodling, and drawing, for illicit notes as well as for official assignments. We have shared a vision in which the computer would be used as casually and as personally for an even greater diversity of purposes. But neither the school computer terminal of 1970 nor the Radio Shack home computer of 1980 have the power and flexibility to provide even an approximation of this vision. In order to do so, a computer must offer far better graphics and a far more flexible language than computers of the 1970s can provide, and do so at a price schools and individuals can afford (Papert, 1980, p. 210).

Papert explained that children learn with particular effectiveness when they are engaged in constructing personally meaningful artifacts such as computer programs, animations, or robots (Papert, 1980). He also stated that the computer is seen as more than just a tool; it is a potential carrier of new ways of thinking about teaching, learning, and education. Interventions afforded by constructionism take into consideration the local knowledge and culture, particular interests, and different learning styles, and therefore have the potential of leading to appropriate actions in education.

Technological Fluency

A netbook computer can provide children with tools for designing, sharing, and debugging their projects. The idea is not to teach children technical skills—they can develop those skills as they use the technology—but to allow them to design and create fluently with it. Being fluent with technology means being able to express fluently as one would do with a natural language. To design and create things that are

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meaningful means much more than simply knowing how to use technological tools because it requires the learner to make decisions about which tool is best suited to create a project (Papert & Resnick, 1995). It is precisely this idea of fluency that potentially makes OLPC different from most ICT projects in education.

As children potentially reach this fluency, they are able to design, build, and debug their projects, and at the same time apply a variety of concepts from different disciplines (Mora, Barragán, & Urrea, 2012). During this process, children may develop other higher-order skills associated with design (problem solving, modularization, reflection, debugging, editing, etc.), computation (sequences, variables, conditions, events, etc.), and knowledge (learning, teaching, sharing, collaborating, etc.). OLPC's goal is to establish a culture of learning and independent thinking in the context of technological fluency. While we currently have no direct measure of how close we have come to accomplishing this goal, we have some encouraging indicators. In Uruguay, which has been running a nation-wide OLPC program for four years, we are seeing youths—12 and 13 years of age—engaging in software development in support of the program. Ten percent of the "apps" made available to OLPC users were written by these children. In a more recent study carried out in Peru by the IADB (Cristia, Ibarrarán, Cueto, Santiago, & Severín, 2012), the results revealed that children who are using XO netbooks, both at school and at home, are 5 months ahead from their counter parts in development of cognitive skills as measured by Raven's Progressive Matrices.

Creative Thinking

Creativity is both an innate talent and a skill. On the one hand, some people are born with creative dispositions. On the other hand, any individual may learn to increase his or her creative abilities. A diverse set of skills fuel creative behavior. Creative persons may be open to experience, have a tolerance for ambiguity, an attraction to complexity, the ability to resist premature closure, to accommodate opposites, the ability to sense gaps, a tendency to risk-taking, being self confident, intuitive and with a predisposition to learning (Barron & Harrington, 1981).

The creative process is characterized by two distinct modes of thinking: divergence and convergence, which are often used to represent different dimensions of creativity (Parnes, 1988; Puccio, Murdock, & Mance, 2007). Divergent thinking is an expansive mode of thinking. Convergent thinking is a contractive mode of thinking.

The Sugar learning platform, described in the next section, puts an emphasis on divergent thinking. Making that thinking visible to the learner is the goal of our efforts to explicitly introduce assessment tools into the platform and to equally promote cultures of expression and reflection.

OLPC Principles

Based on research and experience, OLPC seeks to promote the following five principles of deployment with the goal to maximize opportunities provided by the presence of the XO netbook (OLPC, 2007). OLPC also hopes that governments, NGOs, and other local partners, will not just follow these guidelines, but also undergo a process of rethinking learning and education in their country to determine the objectives and focus of their individual programs, taking into account local needs and local strengths.

Child Ownership

The XO netbook created by OLPC is extremely low cost and robust, and at the same time beautiful and friendly. OLPC advocates that each child would own his or her XO netbook, and become responsible for protecting, caring for, and sharing this important possession. Child ownership may lead to "extended learning"—that is, learning does not happen just in the classroom, but rather at many times during a child's development process. Child ownership increases the possibility that a child will have adequate informal time with the computer in which to explore and express his or her own ideas. An additional benefit is that the child will have increased opportunities to engage with parents, siblings, and other family members, where the child will often turn the table, taking on the role of teacher.

Young Children

The XO netbook was designed for children between ages six and twelve years of age, the years in which their core cognitive skills and their attitudes toward learning are developing. For children at this age, the computer can be both a toy to play with and a tool to learn with, blurring the lines in the child's mind between play and learning and reinforcing the rewards of "hard fun." As children grow, they should transition from the tools of expression to the tools of production. But first, the children need to learn about how to take intellectual risks, to be expressive with technology, to build confidence in their abilities as problem solvers. These are skills best developed early (Battro, 2010).

A child does not need to read and write in order to use Sugar, the netbook's learning environment. Literacy skills—and many other skills—are acquired from using the hundreds of available applications. A goal of Sugar is to foster a learning process that is unique to every child. It can be customized and adapted not only to the child's own learning process, but also to the child's physical and developmental needs. This individual learning process can be followed through the personal journal, in which each child records information about actions as well as objects that he or she created.

Saturation
OLPC is committed to providing new learning opportunities to all children in developing countries. A promising way to achieve this goal is to saturate a given population. The key is to select the best scale in each particular situation. It could be a country, a region, a municipality, or town, where each child owns a netbook. At scale, the community becomes responsible for the OLPC program and the children receive the support they need from various organizations, groups, or individuals within the community.

Connected
The XO netbook has been designed to work together with other XO netbooks through a local network of a few XOs or through the Internet. The children can collaborate by creating a document, programming a simulation, designing a piece of art, collecting data, sharing information, or even playing games over the net. Since the battery of the XO lasts many hours, children can also collaborate from their homes or other places in the community. Connectivity is important to the idea of "extended learning" as children would learn in formal and informal places, with teachers and peers, and other members of the family and community.

Free and Open-Source Software
A child with an XO netbook can potentially not just get access to information, but become an active participant of a learning community. As the child grows, she or he interacts and learns new ideas; the Sugar software is able to adapt to support that development process. The global nature of OLPC requires that a large part of this adjustment process occur at the local level, even at the level of the child. Each child can take advantage of the learning process of her or his peers, supporting everyone's intellectual growth.

There is no limitation or dependency in being able to localize the software to the local language, fix it to correct bugs, or customize it to meet local needs. Nor is there any restriction in regard to redistribution; OLPC cannot and should not control how the tools would be repurposed in the future. OLPC's goals require a world of great software and content, both open and proprietary. Children need the opportunity to choose from it all. In the context of learning, knowledge can be free. Further, every child can have something to contribute; the goal is to establish a free and open framework that supports the human need to express and share.

THE SUGAR LEARNING PLATFORM

Originally created for the OLPC XO netbook, the Sugar software platform (Bender et al., 2008; Sugar, 2008) was designed to promote collaborative learning through activities that encourage critical thinking. Designed from the ground up especially for children, Sugar offers an alternative to traditional "office-desktop" software. The Sugar learning platform is grounded in almost 40 years of university research in the area of technology and learning (Dewey, 1966; Freire, 1972; Papert, 1993; Piaget, 1970; Vygotsky, 1978) and research specific to computers in the classroom (Bonifaz & Zucker, 2004; Cavallo, 2004; DiSessa, 2001; Edwards, Gandini, & Forman, 1993; Ellerman, 2004; Hooker, 2008; Hoyles, 1993; Johnston, 2003; Kafai & Resnick, 1996; Lave & Wenger, 1991; McGily, 1998; Noss & Pach, 1999; Oram, 2001; Scanlon & Issroff, 2005; Stager, 2003; Thomas, 2007; Tinker, Galvis, & Zucker, 2007; Tyack & Cuban, 1995; Voelcker, 2009; Zucker, 2005). Members of the partnership team have worked closely with intellectual leaders, such as Seymour Papert, Marvin Minsky, Alan Kay, and Lea Fagundes.

The Sugar learning platform makes readily available tools of expression—writing, drawing, programming, modeling, etc.—along with tools of reflection—the Sugar journal and portfolio. The intention of making such tools readily available is to increase the likelihood that computation will be used as a critical-thinking tool in the context of open-ended exploration and discovery, going beyond the use of the computer as a tool of instruction.

Sugar is packaged with most major GNU/Linux distributions; it can run on almost any computer, even the old, obsolete hardware—the type of computer too often found in schools. Sugar is the core component of OLPC's worldwide effort to provide every child with equal opportunity for a quality education. Sugar is used by more than two million children in more than 40 countries. The Sugar software is maintained by a community of volunteers working with the non-profit Sugar Labs foundation, a member project of the Software Freedom Conservancy (2012).

Sugar Features

Three experiences characterize the Sugar learning platform: (1) Sharing: Collaboration is a first-order experience. The interface always shows the presence of other learners who are available for collaboration. Sugar users can dialog, support, critique, and share ideas with each other. (2) Reflecting: A "journal" records each learner's activity. It is a built-in place for reflection and assessment of progress. (3) Discovering: Sugar tries to accommodate a wide variety of users with different levels of skill in terms of reading and language and different levels of experience with computing by providing activities with a "low floor" and, where possible, "no ceiling."

Sugar Collaboration
Sugar tries to take advantages of a child's propensity to learn naturally with others by making it easy for children to create and learn together. One of the influences that led to this insight

can be traced back to the work of one of Papert's students, Michele Evard, who wrote a dissertation based on observing students collaborating in the classroom. In her thesis *Twenty Heads Are Better than One: Communities of Children as Virtual Experts*, Evard (Evard, 1998) observed that much of the learning that happens in the classroom is peer-to-peer. Once one child makes a discovery, it is only moments later that every child is informed. Sugar leverages this affinity by making the presence of other learners always present in the interface. Learning in a community gives every child the opportunity to advance from simplicity to complexity with the support of others, because every child has his or her peers as scaffolding for advancement. This peer-to-peer learning can even happen when children are not physically co-located; the mesh network technology built into the XO enables collaboration and sharing even at a distance.

The mechanics of Sugar collaboration draws inspiration both from observing how people collaborate on the Web—chat, how they socially network, how they engage in gaming, share media, and collaborate in media creation—and in what happens in an informal learning setting—looking over shoulders. The Neighborhood brings these two worlds together, directly facilitating sharing and collaborating without requiring an Internet connection. Learners write documents, share books, and pictures, or make music together with one mouse click. A benefit to collaboration is that it encourages learners to engage in reflective practice, a concept introduced by Donald Schön (Schön, 1982). Learners can apply their own experiences to practice while they are mentored by a teacher, a parent, a community member, or a fellow student engaged in a persistent critical and creative dialog.

Many Sugar applications are enhanced by specific features that help children to collaborate: sharing information, insights and discoveries; solving problems together and co-creating. Write, for example, has a feature that allows peers to edit an essay or a story a child might compose. Browse allows children to share bookmarks for pages they find interesting with other students. Record allows them to share photos in real-time. Turtle Art lets them program Logo turtles within the same workspace, sharing their artwork and their code. Working together is a fundamental part of how children learn with Sugar.

Sugar Journal

Sugar supports the notion of "keeping" rather than "saving." The interface tries to keep things that offer value automatically in the Sugar journal. The primary function of the journal is as a time-based view of the activities of a learner. As with physical media, such as pen on paper, no explicit "saving" step is needed. The individual journal entries are treated much like pages in a laboratory notebook. There is a title, room for taking notes, and adding tags. The learner is encouraged to adopt a routine where by time is taken to write about what they are doing either while they are doing it or immediately afterward. This process of note taking become the basis upon which they can subsequently engage in reflection (see Figure 1).

Sugar Discovery

In a manner synergistic with informal learning settings, the Sugar learning platform embodies ideas from "Studio Thinking" (Hetland, Winner, Veenema, & Sheridan, 2007)

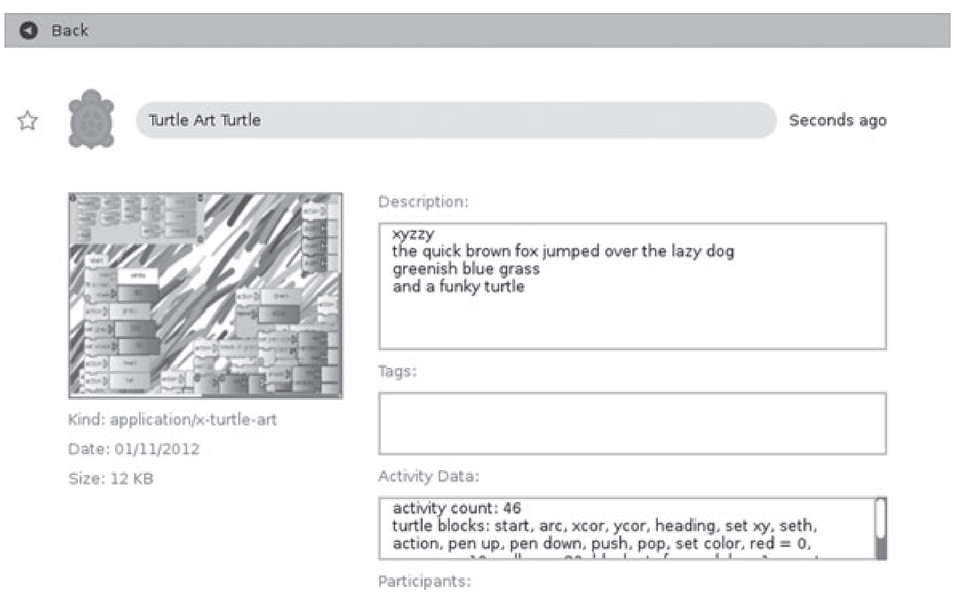

Fig. 1. Sugar users can take in-line notes while they are using an activity. These notes are recorded in a journal entry. Every journal entry includes a title, thumbnail screenshot, description, tags, activity-specific meta data, and list of collaborators.

directly into the user interface: demonstrations, projects, and critiques. Learners are given the platform to develop craft, engage and persist, envision, express, observe, reflect, stretch and explore, and understand. Sugar can be used as a critical-thinking tool in the context of *open-ended* exploration and discovery, going beyond the use of the computer as a tool of instruction.

In support of open-ended exploration, Sugar is designed to be easy to approach, while not putting an upper bound on personal growth or expression. Many Sugar activities are designed such that the learner can peel away layers to go deeper, with few restrictions. (For example, the Sugar music suite, TamTam, enables the user to progress from playing a single instrument to playing in an orchestra, to composing music, to designing instruments. The Turtle Art activity enables the user to progress from simple logo programming to programmatic control of literally every aspect of the computer.) This emphasis on progression is intended to encourage the direct appropriation of ideas in whatever realm the learner is exploring: music, browsing, reading, writing, programming, or graphics.

STRATEGIES TO MAKE LEARNING VISIBLE

Since the goal of OLPC is to have learning as well as socio-economic impact on the children and the communities in which the XO netbooks have been deployed, an evaluation of the program must look more broadly than those data that are captured by standardized tests. Therefore, we present a series of recommendations for innovation in evaluation at different levels. The recommendations come as a result of presentations by the different participants and invited guest speakers, and the reflections, and discussion about implications in the OLPC programs and work. Also discussed were some software innovations that facilitate the use of portfolio evaluations within the context of OLPC deployments.

Strategies and mechanism should be design at different levels: micro (at the level of individual students, teachers, and parents); mezzo (at the level of a classroom or school); and macro (national and global indicators). These mechanisms, presented in the following sections, are orthogonal to the typical standardize-testing regimes; the two approaches—one serving administrators, the other serving learners—can coexist.

The Micro Level

At the micro level, we propose the further development of digital portfolios to support reflection that can help students (as well as teachers and parents) be aware of their own learning, and do so by documenting their work and thinking over time. The idea of increased utilization of portfolios is based on the work of Professor Evangeline Harris Stefanakis, from the School of Education at Boston University. Stefanakis shared her work on digital portfolios and multiple intelligences as part of a "comprehensive system that combines formal, informal, and classroom assessment, including portfolios, to inform the state, the district, the school, and the teacher." As she points out (Stefanakis, 2002), without a way to make visible what students do and what teachers teach, it is impossible to make changes to improve those dynamics.

The Mezzo Level

At a mezzo level, we propose to design tools that would help understand the impact and evolution of the program in a larger context—at the level of the classroom or the school. The goal is to design tools that navigate and visualize data backed up in a server, both in synchronous and asynchronous way. These data would help teachers, administrators, and stakeholders understand the impact of the program and make adjustments to it.

Typical of OLPC deployments is the use of a School Server. The School Server provides additional infrastructure extending the capabilities of the XO netbooks. While the Sugar-enabled XO netbooks are self-sufficient for many learning activities, other activities and services depend on the School Server providing connectivity, shared resources, and services. Services, tools and activities running on the School Server allow asynchronous interaction, can use larger storage capacity, and take advantage of the processing power.

The Macro Level

As an alternative from experimental evaluations, a strategy is proposed for understanding OLPC at a much larger scale. This strategy involves the design and implementation of a repository of objects or artifacts designed by children from different OLPC programs in different countries, all over the world. There are a number of similar repositories with artifacts from an individual already in existence, for example, the Scratch website.

The Scratch website (Scratch, 2012) is a portal for a community of 800,000 users from all over the world who have created and shared two million Scratch projects during more than 4 years. This collection of Scratch projects makes possible the analysis and understanding of the impact of the Scratch program at a large scale, and the learning that emerges, not only at the individual, but also at the collective level. The number of users/projects and the emphasis on design, sharing, and collaboration (remixing) has made possible the understanding of the impact of the program at a large scale, and analysis of individual as well as collective learning that emerges in the community (see Figure 2). It allows for understanding of the people who join the community (who we are), the

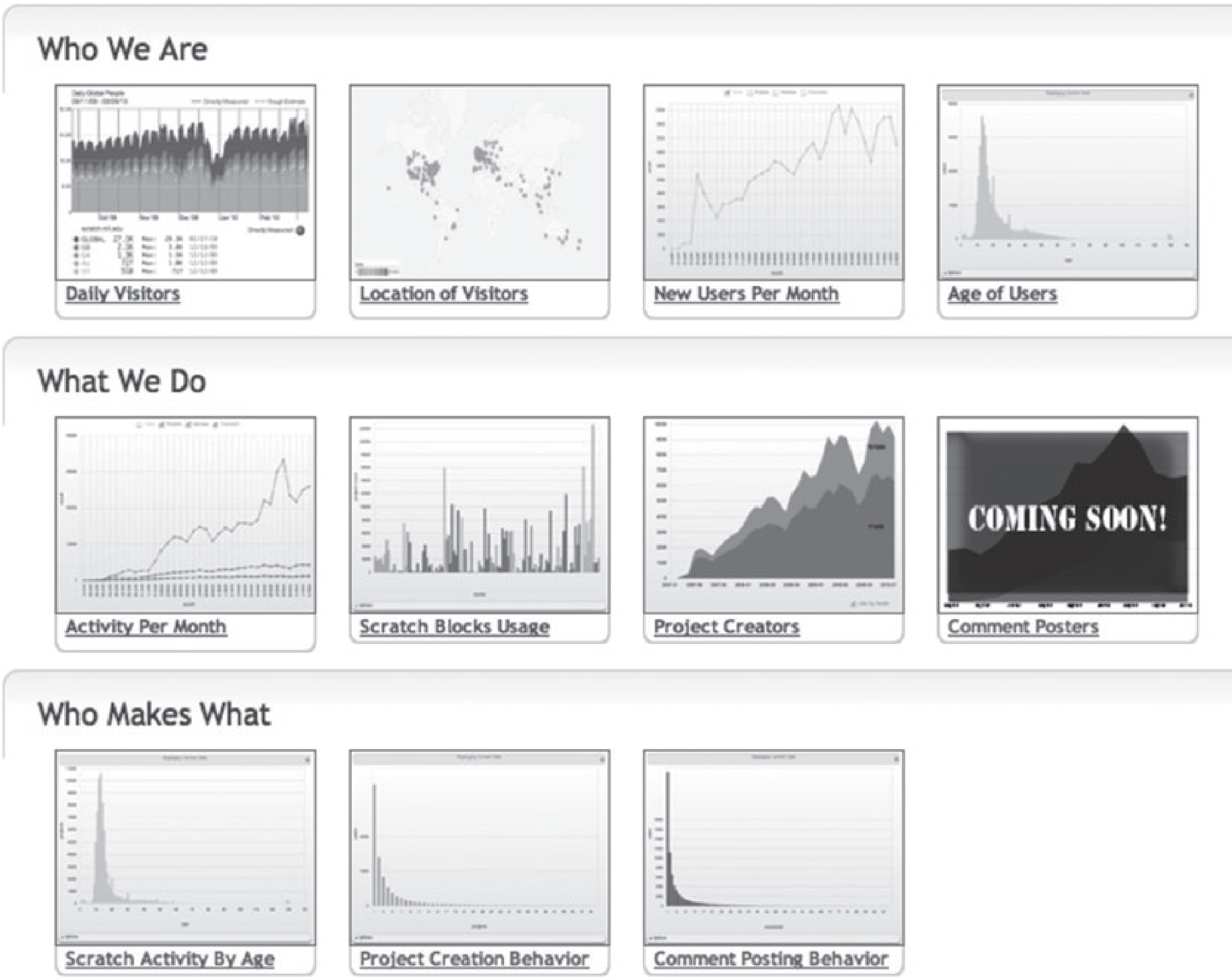

Fig. 2. Statistics in the Scratch community.

projects they create and share (what we do), and the type of interactions and contributions they make (who makes what).

Turtle Art projects is a similar site that allows users to share their projects, but a general solution for sharing output from Sugar activities would greatly enhance the ability for the cross-pollination of best practices (see Figure 3). At the moment, the Turtle Art site does not keep demographic data of users, nor keep track of the interaction and collaboration among users, but it is certainly a place where users can share their work and retrieve ideas for their projects.

For the purpose of the article we will talk about the creation of electronic portfolios, as part of a strategy for assessment at the micro level which helps individual learners monitor their progress, and the capturing and analysis of journal meta-data, as part of a strategy at the mezzo level that helps teachers and administrators understand the impact and evolution of the program at the level of the classroom or the school.

MAKING LEARNING VISIBLE WITH THE SUGAR JOURNAL

Kolb (1984) describes a learning process that starts with concrete experience followed by personal reflection on that experience. For older students and adults, the cycle continues into abstract conceptualization and active experimentation. This work suggests that an effective best approach to learning involves doing and then stepping back to reflect on the doing: What did I learn? How can I use that? What questions do I have? By helping children to ask good questions about the things they have performed, as opposed to remembering the right answers, they begin to build the critical thinking skills that enable them to be independent problem solvers. Without reflection, learning is an open loop, and an open-loop system can neither identify and correct errors nor adapt to change.

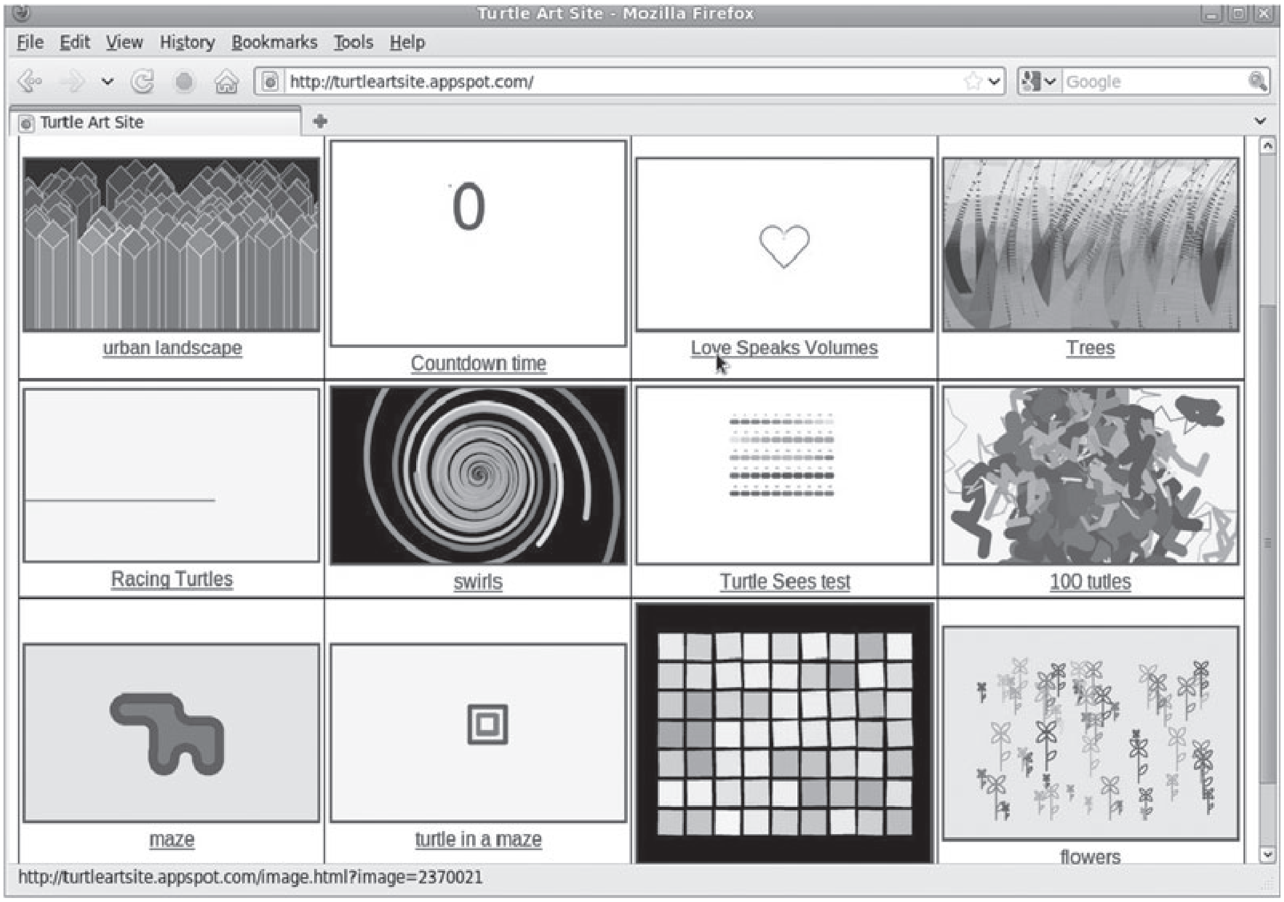

Fig. 3. Turtle Art site allows users to share their projects.

Sugar aims to facilitate reflective learning by ensuring that everything a child does is recorded in an electronic journal which includes screen capture of a child's work. During and after every activity, children are encouraged to share their observations, which are recorded in their journal. From this record of activities, children can view their journal as a multimedia narrative that shows what they have done, how they have done it and what their thoughts are on what they have created. Children essentially become curators of their own work. The child's process of telling about what they have learned as a "story" is a simple way to help reflection become a norm in their education (See "Portfolio" below).

In addition, the Sugar journal serves as a repository for meta data. This meta data can store a variety of metrics and milestones, which can subsequently be used to inform both the learner and teacher (See Sections "Adding Meta Data to The Journal" and "Rubrics for Capturing the Level of Fluency" below).

Portfolio

In practice, the Sugar journal is used as a diary of what each learner makes and does; every action taken is automatically recorded. It may also serve as a lab notebook, where learners can write notes, observations, and descriptions of their investigations. The Sugar portfolio (See Figure 4) acts as an assessment tool (Hebert, 2001) that utilizes the journal content. Learners can reflect on their work: what they have done; how they have done it; and how successful these efforts have been. The learner (1) selects important learning achievements, be they in reading, writing, arithmetic, arts, music, physical education, history, and social science, etc., answering questions such as "I chose this piece because . . ." (2) creates a multimedia narrative presentation from their selections (including audio voice-overs and video), reflective of the multiple ways in which we learn; and (3) shares their presentation with peers, teachers, and parents, both to celebrate what they have learned and to engage in a critical dialog about their work. Here Sugar innovates in three ways: (1) it builds upon a journal of all learning activities that is automatically collected; (2) it has programmability and is designed to be fun and accessible to even the youngest elementary school children, but interesting and engaging to middle-school children as well; and (3) it provides tools for both collaborating on the construction of the portfolio and its subsequent sharing with others.

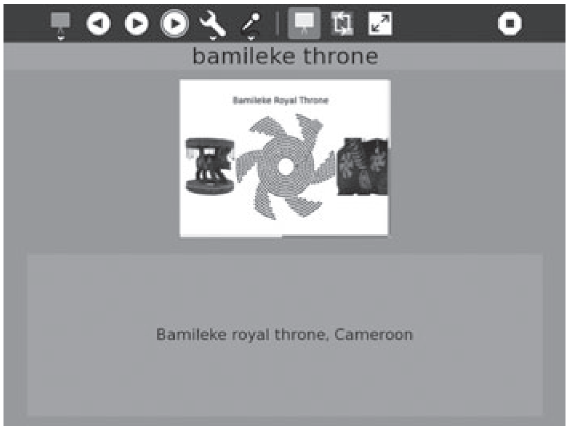

Fig. 4. The Sugar Portfolio activity draws upon Sugar journal entries to make a slide show of a learner's work. It extracts the title, screenshot, and description as the elements from which it composes each slide. The user can add audio voice-over notes for each slide.

The Sugar portfolio creates a "PowerPoint"-like slide show from Sugar journal entries that have been selected to be of interest by the learner. The Sugar environment makes it easier for children to mark their work—selecting a star in their journal that indicates it is favored and should be included in the portfolio. The Portfolio activity uses the entry title as well as the preview image and description.

When running the Portfolio activity, buttons are used to step one-by-one through the slide show. There is also an auto-play button to start/pause a slide show. Additional features include: recording audio notes for each slide (the audio notes are played back whenever the slide is viewed); customizing the order of the presentation through a thumbnail viewer; exporting and archiving the presentation to both HTML and PDF documents; and finally, sharing Portfolio with others to receive feedback. Inspired in the work by Allen and Blythe (2004), a protocol is being developed by the OLPC community to promote its use among students and their teachers, as well as a video export of the portfolio, automatically generated from the slides and audio notes. It is expected that these two new features will promote and extend the opportunities children will have to share and make visible their work with their teachers, parents, and peers.

By building upon the automatic accumulation of work in the Sugar journal, the portfolio process can readily be integrated into the classroom routine. It can be used as an assessment tool to help teachers, parents, and school administrators understand better the depth and breadth of what a child has learned (Stefanakis, 2002). At a "portfolio social," parents could be invited to view presentations and ask children about their learning. The classroom teacher can add additional assessment slides to the portfolio addressing themes such as work habits and personal growth. This can become part of an archive that travels with a child across grade levels. Through juxtaposition, the child and teacher can see what has changed over the course of the years, trends, and areas for improvement.

Adding Meta Data to the Journal

The journal has a fixed set of meta-data entries, that are displayed in the journal detail view for all entries, for example, *description*, *tags*, and *preview*, as well as activity-specific meta data. For example, when assessing student work, it is of interest to teachers to know what tools a student may have used and, perhaps how many iterations a student made in creating an artifact. These data may vary from activity to activity, hence an enhancement to the journal "expanded view" enables activities to specify which meta data fields would be useful to display.

The mechanism is twofold: (1) a special meta-data field, *public*, is used to list those meta-data fields that should be displayed; and (2) a new text field is added to the expanded view to display these data. As shown at the bottom of Figure 1, two fields are displayed: Iterations and Block Types. These fields were set by the Turtle Art program. Other activities may set other fields (or no fields, in which case, the new text field would not be shown.)

This feature will enable activities to post structured data to the journal that is visible to the student and teacher. They are also of utility for both self and formal assessment as per the Rubrics described below.

Making the Case for Creativity

While it is challenging to assess creativity, there are some well-established metrics. In the context of divergent thinking, one measure is the Torrance Test of Creative Thinking (Torrance, 1966). The TTCT measures four distinct divergent production skills: (1) fluency: the number of options generated; (2) flexibility: the breadth of categories of the generated options; (3) originality: the level to which options generated are novel; and (4) elaboration: the level of refinement.

The pedagogy team at Paraguay Educa (2012) is trying to model the creative process of children as they use Sugar as a creative tool. Paraguay Educa started its OLPC program based on the premises that traditional learning environments do not help children develop the skills they need for a knowledge society and that these environments do not allow children to develop their own potential as learners. Their main goal is to better prepare Paraguayan children for a technology-driven modern society. The program started in the city of Caacupé in 2009 with 4,000 children (first to sixth grades) from households of limited economic and social means receiving an XO netbook. In April 2011, the program was extended to another 5,000 children from the same geographic region and economic and social conditions.

According to informal observations by the pedagogy team at Paraguay Educa, during the first two years of the program the children who received XO netbooks began to demonstrate high levels of creativity (and other high-level skills), which are not often valued or tracked by their teachers in the classroom. Paraguay Educa's team decided to start their own initiative to document and assess creativity of children in the context of the educational program. The study compares and correlates levels of creative expression of children shown in the design and creation of artifacts built using Sugar activities with the test scores those children received in their formal education. New instruments were designed and validated for the study that involves 180 children from seven schools in the city of Caacupé currently enrolled in fourth grade.

In order to analyze the creative process of children, Sugar activities that allow them to design and create were selected: Labyrinth, Etoys, Write, Tuxpaint, Turtle Art, Scratch, Memorize, Paint, and Fototoons. These activities were assigned a value given the creative process they foster (see Table 1).

Rubrics for Capturing the Level of Fluency

Extending the work of the Paraguay Educa team, we have set out to design rubrics that capture the level of fluency with the technology as well as the creative use of the tools by children. The rubrics associated with the use of the tool would be captured automatically in the future as meta data of the activities; the rubrics associated with the creative process will be assigned manually by evaluators. The following criteria were defined in order to create the action rubrics: nature, source, and purpose.

Group Actions of the Same Nature

We also identify actions of the same nature and then group them, assigning a larger value to the type of action and a smaller value to the detail of the action (the discrete use of a particular tool). For example, several activities encourage children to program in order to design and create projects (art, games, simulations, etc.). The same learning happens regardless of which activities are used by children to create their projects. If a value of 20% is assigned to each of those activities (see Table 2), a student who uses at least one of the programming activities to create projects and one of the painting activities would never get a significant total value on the use of creative tools.

Table 1
Mapping Creative Skills to Sugar Activities

Skill	*Activity*				*Percentage assigned (%)*
Communication	Write			10%	10
Organization of ideas	Labyrinth			10%	10
Artistic expression	Paint	5%	Paint	3%	10
			Tuxpaint	2%	
Logical thinking, Computational thinking	Programming	30%	Scratch	10%	60
			Tortugarte	10%	
			Etoys	10%	
Memorization	Memorize			5%	5
Narrative	Fototoons			5%	5
Total					100

Table 2
Mapping Activities by Their Creative Use

Activity	*Total percentage expected (%)*	*Real use (%)*
Write	10	10
Labyrinth	10	0
Paint	5	5
Tuxpaint	5	0
Scratch	20	0
TurtleArt	20	20
Etoys	20	0
Memorize	5	5
Fototoons	5	5
Total	100	45

If all the activities are grouped, each according to its nature, the total percentage of use could be divided between the group and the individual activities. Using the new criteria, the same child would get a much different value in his use of creative tools (see Table 3).

Source of the Media

It is important to track the source of media included in the projects to do further analysis of style and practices among children. We anticipate that preference by region or by gender may be found in future analysis. More value would be given to media that is found on the Internet and that is created using other activities in the XO (Record, Paint, etc.), than to media that is found on a local clip-art library (e.g., Scratch media).

Table 3
Activity Categories

Activity				*Total percentage expected (%)*	*Real use (%)*
Write			10%	10	10
Labyrinth			10%	10	0
Paint	5%	Paint	3%	10	8
		Tuxpaint	2%		
Programming	30%	Scratch	10%	60	40
		Tortugarte	10%		
		Etoys	10%		
Memorize			5%		5
Fototoons			5%		5
Total				100	68

Table 4
Mapping by Media Source

Type of action	*General use*	*Discrete use*	*Total percentage assigned*
Inserts an image has a total value of 35%	Insert any image (18%) +	Inserts an image from the Internet (5%) Inserts an image from Record activity (5%) Inserts an image from Paint (5%) Inserts an image from Library (2%)	28%

In the example shown in Table 4, if two images are integrated into the project, one from the Internet and one from the Record activity, the total value assigned to this action is 28% (18 + 5 + 5).

Prioritize by Purpose
Special attention was given to any of the tools within the activity that associated with the main goal of the activity. For example, Paint is used to create pictures but it also has a text feature. The valuation of the painting tools is larger than the valuation of the peripheral functions. The same criteria apply to Write activity, used to create a document that may integrate text as well as images and tables. More value is given to the use of tools that allow the user to integrate and format text, than other things such integrate a picture or a table; and to Turtle Art activity, used to program your own art, simulations and games. The tools associated with the Turtle Blocks, Pen and Color, and Flow operators are more important that other tools (see Table 5).

Future Analysis
It is important to identify the specific use of a tool within an activity, even if there is no difference in the nature of the action (see Table 6). Tracking the details of the use of different tools would allow further analysis of style and preferences, or type of tools used globally across all OLPC/Sugar programs.

Table 5
Turtle Art Block Types

Turtle Art Activity	
Tool	*Percentage assigned (%)*
Turtle Blocks	15.0
Turtle's pen/—Color (5%)	10.0
Numeric operators	7.5
Coordinates	2.5
Flow operators	20.0
Variables	7.5
Procedures	7.5
Media	5.0
Extras	5.0
Sensors	5.0
Programming logic	15.0
Total	100.0

Table 6
Mapping by Action

Type of Action	*Discrete use*	*Percentage assigned (%)*
Numeric operators (7.5%)	Basic operations	2.5
	Logic	2.5
	Random	2.5

Examples From the Field
A few examples by the children will be used to illustrate the different strategies to make learning visible, using portfolios, meta data in the journal, and finally, using some of the proposed rubrics that capture the level of fluency with the technology as well as the creative use of the tools by children. These examples were created by children in Nigeria. These children are from the OLPC-SEED program in Nigeria, which was created by "an innovative multi-sector collaboration between two nongovernmental organizations (NGOs), a mining company, and three local schools."[1] 6,000 students from three different schools located in the south region of the country received their own XO netbooks to use both at school and at home. The goal is to "allow personal growth through the use of digital technologies. Students will use their computers to learn mathematics, science, and other fundamentals—both independently and collectively."

Portfolios by Children
The following portfolios pages feature Turtle Art projects designed by children, all different ages. The students' projects are quite sophisticated, and their reflections very different in nature. One of the children describes his project by writing on his journal "a landscape on Turtle Art" (see Figure 5).

Two other children add phrases that indicate their pride and joy as they learn and build their projects (See Figure 6). One of them writes in his journal, "Wow on this great day, I made a human being using the Turtle Art activity", and the other one writes, "Amazing designs that can be made with

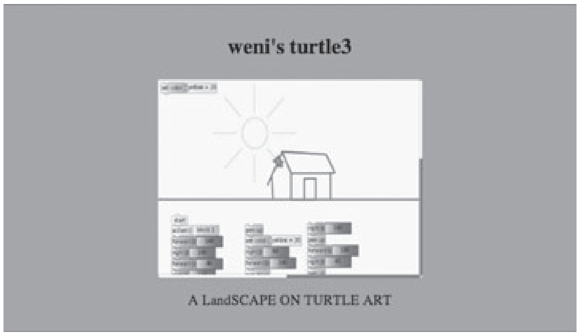

Fig. 5. Sample portfolio entry, a landscape.

Turtle Art," and continues by providing details of how he created it: "This can be achieved by a combination of two or more blocks with looping procedure."

In the final example, the child talks not only about his projects, but about his learning experience with Turtle Art. He writes, "This is teaching us the use of blocks to perform an action. We can form shapes, the movement, or sounds through the use of sensors." In this project, the child integrates a number of functionalities, not only the art design visible the portfolio (see Figure 7).

All of the previous examples illustrate the use of Portfolio by children in Nigeria. The Turtle Art examples were selected, among a variety of other projects created using other activities, given its rich meta data available in the Journal. Even from the small sample presented here, it is apparent the variety of skills the individual learners are demonstrating; and while it is not possible to measure progress by sampling a single point in time, these examples will be useful reference points for both the learners and their teachers when they later assess their progress.

Meta Data of Turtle Art Projects

In this section, we analyze the meta data of two of the projects that is made visible in the Journal. The first project is a "human being" created with Turtle Art (see Figure 8). In order to create

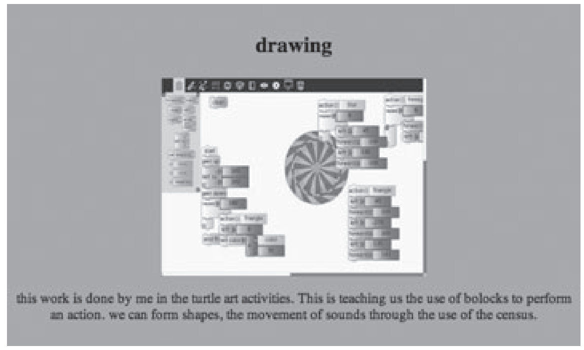

Fig. 7. Sample portfolio entry, art, and other designs.

this project, the child used the following blocks, which tell the story of his building approach:

"activity count: 6
turtle blocks: start, set xy, pen up, clean, set pen size, forward, right, back, left, pen down, arc"

The activity count indicated the number of times the Turtle Art project has been opened for review, and the rest of the information indicated the different commands used by the child to build his design, the human being.

The second example, an "art design," by a different child uses some of the same blocks, but also color, arithmetic operations and control blocks, which he had referred in his portfolio as "looping procedure" (See Figure 9). In order to create this design, the child used the following blocks, which tell the story of his building approach:

"activity count: 4
turtle blocks: start, clean, pen up, set xy, pen down, start fill, end fill, repeat, forward, right, set color, +, color"

Analysis of Technological Fluency and Its Relation to Creativity

Using the rubrics presented in the previous session ("Rubrics for Capturing the Level of Fluency"), the two Turtle Art

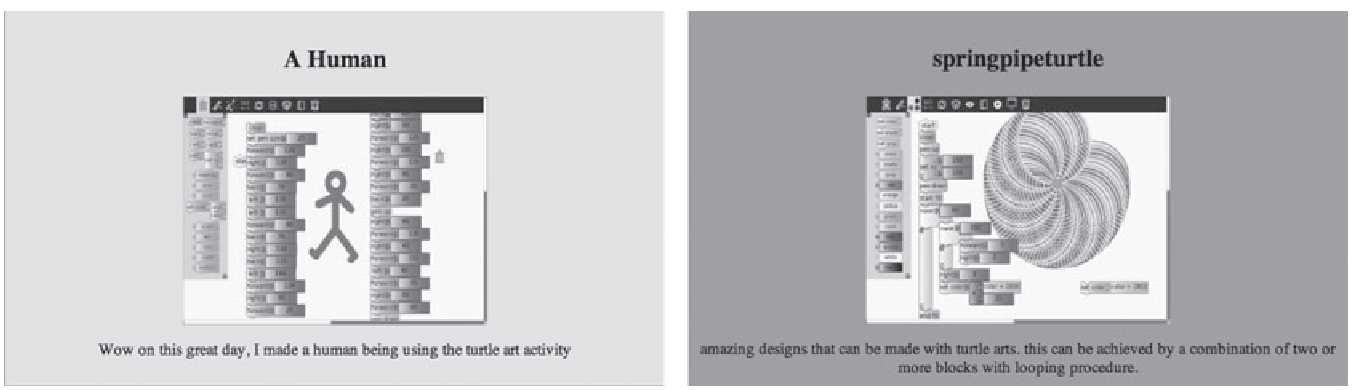

Fig. 6. Sample portfolio entries, a human being and an art design.

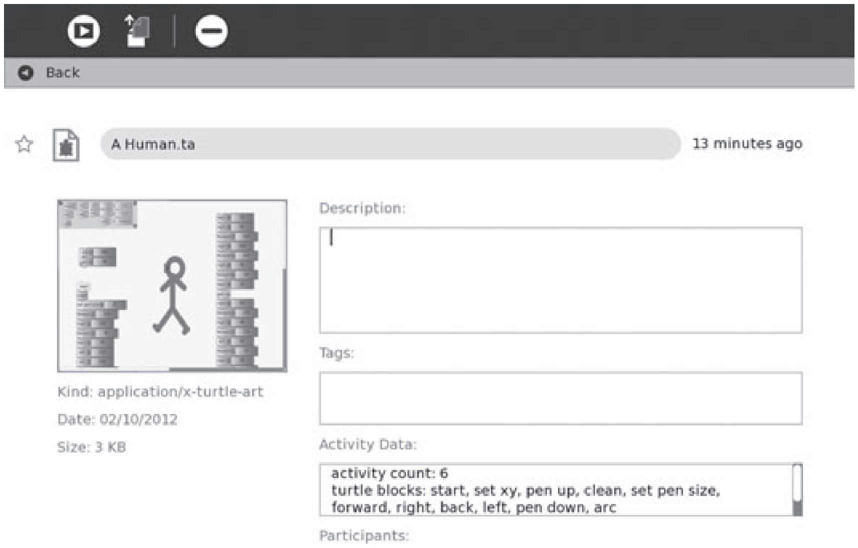

Fig. 8. Meta data captured in the Sugar journal, the "human being" project.

projects can be analyzed as follows (see Tables 7 and 8). In the "human being" project, the child uses the commands of the turtle, some of the pen commands, and "Start" block, included in the project by default. The final score of the project is 42.

In the "art design" project, the child uses, in addition to the turtle commands and color, control, and operations command, which show greater fluency with Turtle Art. The final score, when the same metric is applied, is 60.

The two metrics—portfolio and meta data—reveal different aspects of the learning. In the case of the "human being" project, the image captured in the portfolio gives an immediate sense of the level of sophistication the learner has achieved. As the child progresses, it will serve as a reference by which progress can be measured. The meta data and the application of the rubric reveal other characteristics: the learner revisited the project six times—an indication of persistence and passion about the task. The score, 42, suggests that the programming skill level is still quite low. In the case of the "art design" project, again, the image captured in the portfolio provides a reference. In regard to the meta data, the fact that such a complex design was achieved after only four sessions is a testament to the programming skills of the learning. The relatively high score from the application of the rubrics, 60, confirms this assessment.

While the portfolio provides a qualitative, visual reference to a learner's development and progress, the rubric can provide a

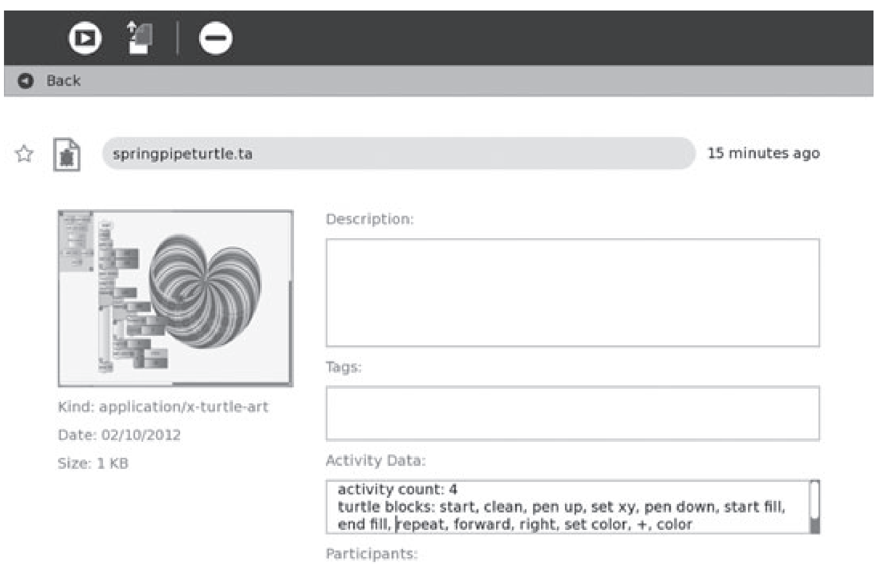

Fig. 9. Meta data captured in the Sugar journal, "art design" project.

Table 7
Rubrics Applied to the Meta Data Captured in the "Human Being" Project.

Total (%)	Category	Details	%	Value Category	Total % per Category	Value Detailed	Total % per Detail
15.0	Turtle commands (5%)	Forward, Back, left, right blocks	3.33	1	5	1	3.33
		Arc, Heading blocks	3.33			1	3.33
		Coordinates blocks	3.33			1	3.33
10.0	Pen commands (5%)	Pen up, Pen down, Pen size blocks	2.50	1	5	1	2.5
		Start fill, End fill blocks, Fill color shade blocks	2.50				
7.5	Numerical operators	Basic operations	2.50				
		Logic blocks	2.50				
		Random block	2.50				
2.5	Coordinates	Set xy	2.50			1	2.5
20.0	Contro blocks—(10%)	Repeat, Forever, Wait blocks	2.50				
		If, If else, While, Stop action, Until blocks	7.50				
7.5	Variables	Store in Box 1, Box 1, Store in Bosx2, Box2	2.50				
		Caja, guardar en valor	5.00				
7.5	Procedures	Start, Action1 (definition and use), Action2 (definition and use)	2.50			1	2.5
		Action blocks (definition and use)	5.00				
5.0	Media	Include media objects	5.00				
5.0	Extra blocks	Usa paletas de opciones	5.00				
5.0	Sensors	Sensor panel	5.00				
15.0	Intention	Programming	15.00			1	15
100.0	Total (20% +)		80.00		10		32.5
TOTAL				**42**			

more quantitative reference regarding specific skill acquisition. Together they give a more complete picture of the learner.

IMPLICATIONS AND FUTURE WORK

The challenge of assessment is summed up succinctly by the old saw, "We value what we measure rather than measure what we value." For example, it is all too easy to measure whether or not a child can do 100 simple multiplication problems in three minutes or less—a challenge one of the authors of this article failed time and again in 3rd grade—than to measure whether or not a child is able to apply multiplication to problem solving. The former skill has no value while the latter represents the principal reason we teach multiplication. Further, the message sent to the learner who fails to measure up to the superficial metric is one of discouragement that can lead to disengagement, exactly the opposite impact one would want from assessment.

The goal of the work presented in this article is to bring to the surface the things we value in education: the development of high-order skills and also their application to the creation of artifacts that have personal meaning to the learner. In evaluating these artifacts, we aspire to engage the learner in a reflective process, one in which they—and their teachers and parents—can assess progress and refocus their efforts towards further achievements.

Specifically, we have discussed two mechanisms: portfolio generation by the learner and activity-specific meta data capture and analysis. Looking forward, we need to develop strategies to have portfolio more routinely integrated both into the classroom and the dynamic of assessment of both learners and their teachers. We need to further the expand the list of activities for which we are capturing meta data specific to development of skills and creative expression, and we need to improve upon the mechanisms whereby the learner and teacher can monitor these data. We will continue to support the OLPC/Sugar community in the use of these mechanisms and continue to develop others, according to their needs. The ultimate goal is to promote and foster a new culture of assessment that promotes learning.

Acknowledgments—We would like to thank Bakhtiar Mikhak and the rest of the group who participated in the Innovation in

Table 8
Rubrics Applied to the Meta Data Captured in the "Art Design" Project.

Total (%)	*Category*	*Details*	*%*	*Value Category*	*Total % per Category*	*Value Detailed*	*Total % per Detail*
15.0	Turtle commands (5%)	Forward, Back, left, right blocks	3.33	1	5	1	3.33
		Arc, Heading blocks	3.33			1	3.33
		Coordinates blocks	3.33			1	3.33
10.0	Pen commands (5%)	Pen up, Pen down, Pen size blocks	2.50	1	5	1	2.5
		Start fill, End fill blocks, Fill color shade blocks	2.50			1	2.5
7.5	Numerical operators	Basic operations	2.50			1	2.5
		Logic blocks	2.50				
		Random block	2.50				
2.5	Coordinates	Set xy	2.50			1	2.5
20.0	Contro blocks—(10%)	Repeat, Forever, Wait blocks	2.50	1	10	1	2.5
		If, If else, While, Stop action, Until blocks	7.50				
7.5	Variables	Store in Box1. Box1. Store in Bosx2, Box2	2.50				
		Caja, guardar en valor	5.00				
7.5	Procedures	Start, Action1 (definition and use), Action2 (definition and use)	2.50			1	2.5
		Action blocks (definition and use)	5.00				
5.0	Media	Include media objects	5.00				
5.0	Extra blocks	Usa paletas de opciones	5.00				
5.0	Sensors	Sensor panel	5.00				
15.0	Intention	Programming	15.00			1	15
100.0	Total (20%+)		80.00		20		40.0
		TOTAL			60		

Evaluation meeting in April 2011. In particular, the members of the OLPC programs from the different countries who share their experience and work on evaluation (Pacita Peña from Paraguay, Félix Garrido from Nicaragua, Andres Peri from Uruguay, Sandra Barragán from Colombia, and Heddy Becerra from Perú). We also want to thank the group of experts who accepted our invitation to share their research and work, including Evangeline Stefanakis, who has advised us on our approach to portfolio assessment.

Special thanks to the members of Paraguay Educa, who have led some of this innovative work in assessment. They decided to document and assess children's creativity in the context of their educational program, and motivated us to implement some of the mechanism presented in this article. Finally, we want to thank all the members of learning teams from countries who participate in the weekly chart. They inspire us with their work, push us to create and share new ideas and strategies, and contribute in different ways with all the work with do in learning.

NOTE

1 More information about the program can be found at: http://www.planetseed.com/olpc

REFERENCES

Allen, D., & Blythe, T. (2004). *The facilitator's book of questions: Tools for looking together at student and teacher work*. New York, NY: Teachers College Press.

Barron, F., & Harrington, D. M. (1981). Creativity, intelligence, and personality. *Annual Review of Psychology*, *32*, 439–476.

Battro, A. M. (2010). The teaching brain. *Mind, Brain, and Education*, *4*, 28–33.

Bender, W., Hyde, A., Cramer, D., Farning, D., Grinbergs, J., Boyle, T., Gentle, A., Swisher, J., Woodworth, S., Collett, M., & Ploskonka, Y. (2008). *The sugar manual*. (http://en.flossmanuals.net/Sugar).

Bonifaz, A., & Zucker, A. (2004). *Lessons learned from providing laptops to all students*. Newton, MA: Education Development Center.

Cavallo, D. (2004). Models for growth—towards fundamental change in learning environments. *BT Technology Journal*, *22*(4), 96–112.

Cristia, P., Ibarrarán, P., Cueto, S., Santiago, A., Severín, E. (2012). Technology and child development: Evidence from the One Laptop per Child Program, IZA DP No. 6401.

Dewey, J. (1966). *Democracy and Education*. New York, NY: Collier Macmillan.

DiSessa, A. (2001). *Changing minds: Computers, learning, and literacy*. Cambridge, MA: MIT Press.

Edwards, C., Gandini, L., & Forman, G. (Eds.) (1993). *The hundred languages of children: The Reggio Emilia approach to early childhood education*. New York, NY: Ablex.

Ellerman, D. (2004). Autonomy in education and development. *Journal of International Co-operation in Education*, *7*(1), 3–14.

Evard, M. (1998). *Twenty heads are better than one: Communities of children as virtual experts (PhD thesis)*. Massachusetts Institute of Technology, Cambridge, MA.

Freire, P. (1972). *Pedagogy of the oppressed*. New York, NY: Continuum.

Hebert, E. A. (2001). *The power of portfolios: What children can teach us about learning and assessment*. San Francisco, CA: Jossey-Bass.

Hetland, L., Winner, E., Veenema, S., & Sheridan, K. M. (2007). *Studio thinking: The real benefits of visual arts education*. New York, NY: Teachers College Press.

Hooker, M. (2008). *1:1 technologies/computing in the developing world: Challenging the digital divide*. Global e-Schools and Communities Initiative.

Hoyles, C. (1993). Microworlds/schoolworlds: The transformation of an innovation. In C. C. Keitel & K. Ruthven (Eds.), *Learning from computers: Mathematics education and technology* (pp. 10–17). Berlin, Germany: Springer-Verlag.

Johnston, B. (2003). *Never mind the laptops – Kids, computers and the transformation of learning*. Iuniverse.

Kafai, Y., & Resnick, M. (Eds.). (1996). *Constructionism in practice: Designing, thinking and learning in a digital world*. Hillsdale, NJ: Erlbaum.

Kolb, D. A. (1984). *Experiential learning*. Englewood Cliffs, NJ.: Prentice-Hall.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

McGily, K. (1998). *Classroom lessons, integrating cognitive theory and classroom practice*. Cambridge, MA: MIT Press.

Mora, A., Barragán, S., & Urrea, C. (2012). The one to one model, One Laptop per Child, on the strengthening of education and culture. In T. Amiel & B. Wilson (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2012* (pp. 1534–1543). Chesapeake, VA: Association for the Advancement of Computing in Education.

Noss, R., & Pach, N. (1999). The challenge of new technologies: Doing old things in a new way, or doing new things?. In P. Mortimore (Ed.), *Understanding pedagogy and its impact on learning*. London, UK: Paul Chapman.

One Laptop per Child (OLPC). (2007). *One Laptop per Child Core Principles*. http://wiki.laptop.org/go/Core_principles

Oram, A. (2001). *Peer-peer: Harnessing the power of disruptive technologies*. Sebastopol, CA: O'Reilly & Associates.

Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas*. New York, NY: Basic Books.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York, NY: Basic Books.

Papert, S., & Resnick, M. (1995). *Technological fluency and the representation of knowledge*. Cambridge, MA: Proposal to the National Science Foundation.

Paraguay Educa. (2012). *Paraguay Educa home page*. http://www.paraguayeduca.org/

Parnes, S. J. (1988). *Visionizing*. East Aurora, NY: D.O.K. Publishers.

Piaget, J. (1970). *Genetic epistemology*. New York, NY: Columbia University Press.

Project Zero & Reggio Children. (2001). *Making learning visible: Children as individual and group learners*. Reggio Emilia, Italy: Reggio Children.

Puccio, G. J., Murdock, M. C., & Mance, M. (2007). *Creative leadership: Skills that drive change*. Thousand Oaks, CA: Sage.

Scanlon, E., & Issroff, K. (2005). Activity theory and higher education: Evaluating learning technologies. *Journal of Computer Assisted Learning*, *21*, 430–439.

Schön, D. A. (1982). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

Scratch. (2012). *Scratch home: Imagine program create*. http://scratch.mit.edu/

Software Freedom Confederacy (SFC). (2012). Software freedom conservancy website (http://conservancoftwarefreedom.org).

Stager, G. S. (2003). Tops in school — A wonderfully cautionary tale (See http://www.stager.org/articles/laptopbookchapter.html).

Stefanakis, E. (2002). *Multiple intelligences and portfolios: A window into the learner's mind*. Westport, CT: Greenwood Press.

Sugar. (2008). *The Sugar Labs project website* (http://sugarlabs.org).

Thomas, M. (2007). Laptops in literacy: Learning in the wireless classroom. *British Educational Communications and Technology Agency*, *38*, 1145–1146.

Tinker, R., Galvis, A., & Zucker, A. (2007). *1:1 Computing in support of science and mathematical education: Recommendations for large scale implementations*. Concord, MA: The Concord Consortium.

Torrance, E. P. (1966). *Torrance tests of creative thinking: Norms-technical manual*. Bensenville, IL: Scholastic Testing Services.

Tyack, D., & Cuban, L. (1995). *Tinkering towards utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

Voelcker, M. (2009). Challenges on applying technology to transform learning. In A. Tatnall & A. Jones (Eds.), *Education and technology for a better world: Ninth IFIP world conference on computers in education*. New York, NY: Springer.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Zucker, A. (2005). *One-to-one computing evaluation consortium: Policy brief* . Concord, MA: The Concord Consortium.