Chapter 37

Squeak Etoys

Interactive and Collaborative Learning Environments

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ABSTRACT

Squeak Etoys is a free software program and media-rich authoring system with a user-friendly visual interface. The software is designed to help six to twelve year-old children learn through interaction and collaboration; it comes preinstalled on XO laptop computers distributed by the One Laptop Per Child Foundation. The goal of the One Laptop Per Child initiative is to create novel educational opportunities for the world's children by providing each child with a book-size, light and portable computer for personal use at school and at home. This chapter elaborates on the educational dimensions of the XO laptop and the Etoys environment developed to empower teachers and students with the capacity for creative learning, exploration, interaction, and collaboration. The authors focus on how the hardware and software capabilities of XO laptops can be utilized to allow children to interact, work together on projects, and engage in computer simulations and games while learning mathematics, physics, chemistry, and geometry.

INTRODUCTION

Squeak Etoys is a free and open source media-rich authoring system with a user-friendly visual interface which comes preinstalled on One Laptop Per Child XO computers. The One Laptop Per Child (OLPC) project[1] is a revolutionary blueprint for children's personal computer use created to bring an efficient and functional educational technological tool to nearly every child between six and twelve years old, throughout the world. The OLPC initiative is especially important to students in developing countries due to the fact that "most of the nearly two billion children in the developing world are

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inadequately educated or receive no education at all. One in three does not complete the fifth grade.”[2]

Founded in 2005, One Laptop Per Child Foundation[3] is a non-profit organization which brings forward innovative ideas on the use of personal computers by children and promotes widespread realization and assimilation of computer technologies. The goal of the OLPC Foundation is to create novel educational opportunities for the world’s children by providing each child in developing countries with a book-size, light and portable computer for personal use at school and at home. As the outcome of the OLPC program, the XO laptop is a low-cost, low power, Internet ready, multifunctional laptop computer. It is equipped with built-in speakers and microphone, video and still camera, and comes with preinstalled open source Linux operating system and free software for various activities: such as, reading, writing, drawing, painting, recording, music editing, web browsing, and basic computer programming. In case of limited availability of electrical energy, an XO laptop can be charged with alternate power sources. The XO laptop is safe to carry in a backpack and has sturdy hardware design with a waterproof keyboard. XO can withstand heat, humidity, and accidents that are ordinary in everyday lives of children; moreover, the computer has five-year life expectancy. In addition to a built-in standard WiFi capability, every XO computer can function as a wireless router creating a decentralized, self-configuring mesh network of interconnected computers within range. It allows children to collaborate and share activities in the classroom, and interact and communicate with classmates from home. As OLPC is an ongoing project, the XO-2, an improved model with less power consumption, is planned for production in 2010.[4]

The OLPC project was initiated by Nicholas Negroponte, professor of the Massachusetts Institute of Technology; it quickly expanded to include a wide range of dedicated people from academia, industry, and the open source community. Due to their efforts according to *The New York Times*, nearly 600,000 XO laptops have been ordered since 2007 to be distributed to children in more then 30 developing countries (Lohr, 2008).

The idea of an affordable notebook computer specifically designed for children’s use was long thought to be an unlikely scenario. Four decades ago at the early days of computer technology most computing machines were the size of a room and almost no one would dream that they would ever be suitable for children to use. However, the adaptation of the Logo programming language[5] for children in Seymour Papert’s experimental work at MIT demonstrated the educational potential of the constructivist ideas and computers in children’s education (Brand, 1987; Negroponte, 1995).

A dialect of high-level programming language LISP, Logo was developed in 1967 by a group of computer scientists including Papert. With its facility for symbolic manipulation Logo was specifically designed for children’s educational use. Initially, it was applied for teaching mathematics in schools. In 1970 Papert initiated the MIT Logo Group to investigate the impact of computers on children’s learning by making programming a part of their education. Stressing the importance of children’s early introduction to the emerging world of computers and computing, Papert (1980) noted in his seminal book *Mindstorms: Children, Computers, and Powerful Ideas*,

> *The computer is the Proteus of machines. Its essence is its universality, its power to simulate. Because it can take on a thousand forms and can serve a thousand functions, it can appeal to a thousand tastes. This book is the result of my own attempts over the past decade to turn computers into instruments flexible enough so that many children can each create for themselves something like what the gears were for me. (p. viii)*

The ideas of Papert were shared by Alan Kay, “the father of personal computers” (Negroponte, 1995, p. 134) who created Smalltalk, a forerunner of open source object-oriented programming language and development environment Squeak.[6] After learning about Papert's experimental work with children in the area of computer programming, Kay (1972; Kay & Goldberg, 2003) created a model of a personal computing device for children, which resembled what we today call a laptop or tablet computer. The DynaBook not only became the prototype of a contemporary notebook, but can also be seen as a precursor of the XO laptop and idea of mobile learning. From the beginning, Kay planned to use DynaBook to make Papert's vision true: using computers for fostering children's creativitive learning in a computer-enhanced educational environment:

We feel that a child is a "verb" rather than a "noun", an actor rather than an object; ... he is trying to acquire a model of his surrounding environment in order to deal with it; his theories are "practical" notions of how to get from idea A to idea B rather then "consistent" branches of formal logic, etc. We would like to hook into his current modes of thought in order to influence him rather then just trying to replace his model with one of our own. (1972, p. 1).

In the same line of thinking, Negroponte (1995) noted, in *Being Digital*, that instead of talking about "learning-disabled children," we need to start thinking about "teaching-disabled environments" (p. 198). He claimed that, "modern computer simulation techniques allow the creation of microworlds in which children can playfully explore very sophisticated principles" (p. 197) and where "learning by doing became the rule rather then the exception" (p. 199). Additionally, Negroponte (1995) emphasized that students in developing countries were as much computer and programming savvy as their counterparts from affluent American suburbs granted they had access to computers.

The combined thinking and efforts of computer technology visionaries and educators, such as Negroponte, Papert, and Kay, as well as recent technological breakthroughs and scientific advances, have lead to the OLPC program. XO laptops have some truly unique characteristics, among them: (a) very low energy consumption; XO consumes ten times less energy then a regular notebook; (b) rotating display with a tablet option and a high-resolution screen with two display modes: a regular full-color, and a black-and-white suitable for the outdoors; (c) mesh networking capability; (d) open source and free software; and (e) an emphasis on activity-sharing and collaboration. In this chapter, we elaborate on the educational dimensions of the XO laptop and the Squeak Etoys system as a means to empower both instructors and students with the capacity for creative learning, exploration, interaction, and collaboration based on the principles of constructivist learning.

BACKGROUND

Squeak software[7] is an open source implementation of the Smalltalk programming language (Kay, 2005). The Squeak programming environment with its direct manipulation interface provides a simple framework for the development and debugging of educational applications by running a portable cross-platform code. It offers a flexible tool for various educational programming projects. Among the practical characteristics of Squeak, one can find its modern user interface, the object-oriented, open source and expandable Smalltalk core, Unicode support, and Etoys (Guzdial, 2000; Guzdial & Rose, 2002. The Etoys program was originally designed by Kay in 1997 and developed collaboratively by a programming team (Barr, 2008).

Inspired by Logo programming language and implemented in Squeak, Etoys[8] provides a sophisticated media-rich authoring environment where children can construct on-screen interactive simulations using simple kits that teach object-oriented computer programming. The Squeak environment has a scripted object capability that runs on many platforms and supports numerous kinds of objects created by end-users. It includes features such as text, sound, images, 2D and 3D graphics, videos, simulations, presentations, and web integration capabilities (Kay, 2005). Since Etoys fully integrates the XO laptop capacity of screen sharing, many forms of real-time collaboration, mentoring, and instruction can be planned and implemented. The aforementioned characteristics make Etoys a good choice for collaborative education and learning (Allen-Conn, Kay, & Rose, 2003).

The Etoys authoring environment integrates various ways of scripting. From the beginning, students can easily outline their sketches and learn how to write scripts to bring them to life. Programming in Etoys is visual, object-oriented, and is based on the drag & drop function. The desired functions -- copy, pick color, move, resize, rotate, and debug -- are only a few among the available options that can be applied to a range of objects (Kay, 2003, 2007). Its built-in particle system is scripted using the same conventions as employed for larger objects (Kay, 2005). This allows for an exploration of dynamic processes and creating simple computer simulations. Thus, Etoys is more than an unsophisticated visual programming environment, for it constitutes a potent programming-learning tool. Finally, Etoys "is multilingual, runs on more than 20 platforms bit-identically, and has been successfully used in USA, Europe, South America, Japan, Korea, India, Nepal, and elsewhere" (Kay, n.d.).

ETOYS: A COLLABORATIVE ENVIRONMENT OF THE OLPC XO

Interactive Potential of Collaborative Learning Environments

In the recent decade, educational technology has expanded into the area of development of computer-based interactive multimedia learning environments (Jonassen, 2004). At the same time, the field of education has been receptive to the constructivist philosophy of learning (Beck & Kosnik, 2006; Duffy & Jonassen, 1992; Hannafin, 1992; Rieber, 1996) as researchers and educational practitioners seek innovative ways to exploit the hidden potential of computer-based learning environments (Holstein & Gubrium, 2008).

The ideas of the augmented use of computers in education, shared computer-based learning environments, and the integration of object-oriented programming languages into the learning process are theoretically grounded in constructionism. The theory of *constructionism*, which is believed to be the driving force behind the OLPC program, was explicated by Papert (1980, 1986). Papert argued that children should have an opportunity to use computers both for learning and for enhancing their creativity. Constructionism is a philosophy of education which maintains that children learn by doing, exploring and discovering instead of being given prepackaged information (Papert, 1986). The theory suggests that learners are likely to generate new ideas when they are actively engaged in the making of some type of external artifact which they can reflect upon and share with others (Harel & Papert, 1991; Papert, 1993). One of the central ideas in Papert's theoretical framework is that children learn more effectively in a collaborative process by receiving feedback from peers (1986). Thus, constructionism explicates the creation of knowledge in the context of building personally meaningful artifacts (Kafai & Resnick, 1996).

Educational Simulations, Games, and Activity Sharing

It has been established in the theory of instruction that educational simulations and games can be combined to create an engaging learning environment (Rieber, 1996). Children's play activities are purposeful actions to which they dedicate great effort and commitment. Despite the encouraging findings of research of educational play and its role in the motivation of learning (Lytle, 2003), the dividing line between formal instruction and activities based on play remains mainly intact. Rieber (1996) wrote that the word "play" continues to raise misconceptions. While formalized instruction is well thought-of, educational play is not. One misunderstanding is that play is extraneous to learning, which is unfortunate because play can serve as an essential intermediary between subject matter and a student's motivation to learn. As Rieber emphasized, "given the range of open-ended explorable environments that can be constructed with computers, time has come to revisit the almost alarmingly simple, yet powerful construct of play and to legitimize play's role in the field of instructional technology" (p. 44).

The XO computer-based activity sharing falls into two basic categories. The first category deals with the tools that are offered through Sugar, the XO laptop graphical user interface. The second deals with the built-in mesh networking capabilities of the XO laptop. The Sugar platform allows children to tap into the XO sharing and collaboration features, while the mesh network enables the XO computers form a self-configuring wireless node network where every laptop acts as an access point and a router.

The activity-sharing functionality of XO computers takes advantage of the XMPP[9] technology as well as the Telepathy interface.[10] Much of the protocol uses Jabber[11] communication primitives, extending them when necessary. The Telepathy interface abstracts the details of the underlying protocol for the activities. When sharing of an activity is initiated, every user is assigned a name and a color icon. Information between users is transferred though a tube or a data channel using Telepathy primitives for the sending and receiving of data. The information can be sent either to one student or to a group of students. Tubes can carry reliable byte streams or unreliable datagrams by analogy to TCP or UDP. When a channel is open to a group, different semantics may be deemed more appropriate since a shared stream is not coherent. It is up to the connection manager to decide how tubes are implemented.

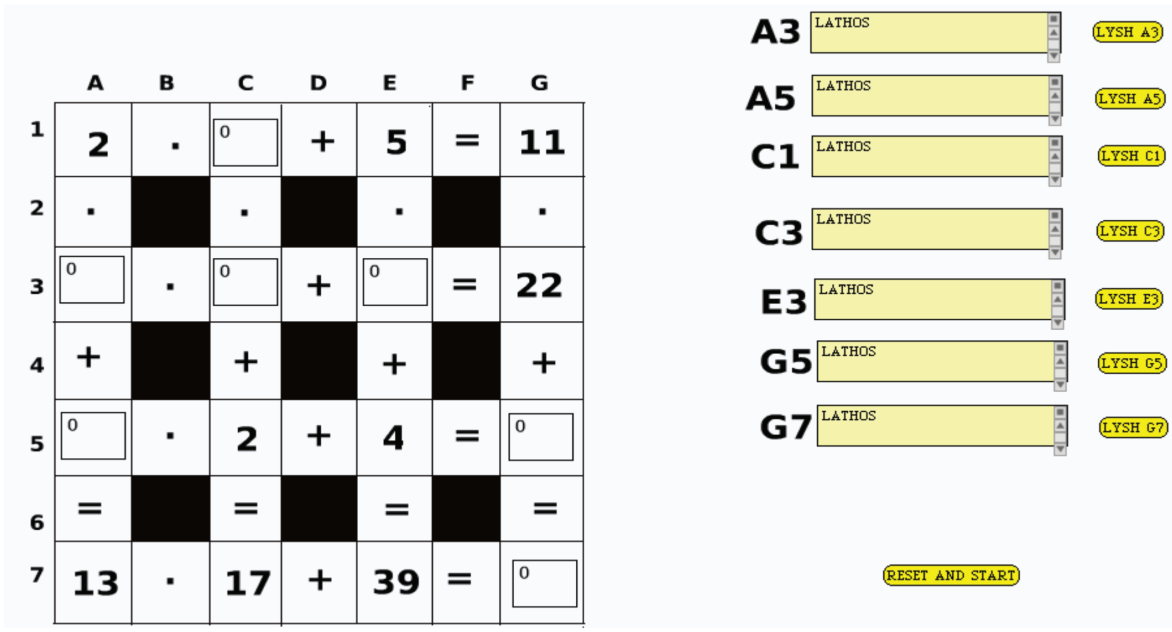
When a student desires to join an activity, the presence service of the Sugar graphical user interface informs the user of the following: the name, type and color of the activity; the Telepathy channel that carries the activity; the default activity chat channel; and, the tube negotiation channel. When a new user joins, the Sugar activity module communicates with the Telepathy backend to create a full list of participants. As a result, an application or a program created by a student can be shared and tested by anyone who is able to reach to the specific user through a mesh network. The connected users are able to interact and access the application or program, test it or play with it, change it, and make it more complex.

Thus, the development environment of Squeak Etoys coupled with XO built-in activity sharing features becomes a learning community of students and teachers who collaborate in an educational activity or play. Given the mesh networking capabilities of XO computers, Etoys can act not only as a medium for collaboration and communication between students, but also induce a learning environment in which groups of students construct their own activities based on provided examples and templates.

Etoys Educational Activities

The main goal of our Etoys content development team is to provide a format for creating collaborative environments for students and teachers. The most representative Etoys activities and interactive exercises that we have created include: a numerical crossword (mathematics), a visual representation of the correlation between pressure and temperature (physics), chemistry Tetris (chemistry), measuring the area of geometrical shapes (geometry), and solving a second-degree mathematical equation. With examples delineated

Figure 1. Numeric crossword



below we demonstrate that the creation of simple and effective educational simulations that can be shared by students is possible.

Activity 1: Mathematics

The first activity was created as a game for students to help them learn the basic numerical operations of integers; it can be extended by students to create multiple and varied crosswords on the skeleton program that we developed. The user is provided with the crossword shown in Figure 1, consisting of numbers, operations and empty spaces. The student must fill all of the empty spaces with the correct numbers to solve horizontal and vertical equations. By utilizing this crossword game, students can improve their math skills while teacher can test their weaknesses on specific operations. It is important to note that the application can be enhanced further to support such operations as subtraction and division of fractions and decimals.

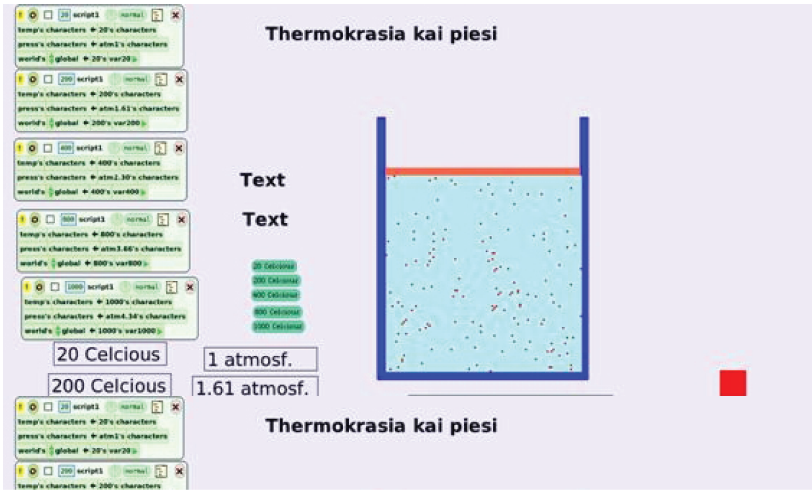
Activity 2: Physics

The second example, demonstrated in Figure 2, illustrates the correlation between temperature and pressure that can be observed on the molecular level in an enclosed space. Physics is a subject that frequently requires laboratory experiments so if a particular school setting cannot offer such an opportunity, experiments can be replaced with computer simulations. XO laptop and Etoys thus provide the environment of a virtual laboratory. This example shows the movement of molecules within an enclosed space following pressure or temperature changes. Such virtual experiments can form the foundation of virtual school laboratories of the future.

Activity 3: Chemistry

The third activity that we created is chemistry Tetris (see Figure 3). While chemical elements appear on the screen, students must decide if

Figure 2. Pressure and temperature simulation



each element is a liquid, or gas and direct them accordingly. In this example, students are able to learn the basics of chemistry playing a Tetris-like game. This educational game can be enhanced further, as the teacher is able to assess the level of student learning while children self-evaluate their knowledge during the game.

Activity 4: Geometry

The fourth example of Etoys implementation was aimed at helping students learn how to measure the area of basic geometrical figures such as triangles, squares, or circles. After observing a demonstration by the teacher of how one can measure the area of a basic geometrical shape, the students then proceed with their own experimenting and practicing. Because XO computers and Etoys can form a collaborative environment through mesh networking, the teacher can assign specific tasks to the children and check their knowledge and understanding of geometry, and more specifically, on how to measure the area of the basic shapes.

Activity 5: Mathematics

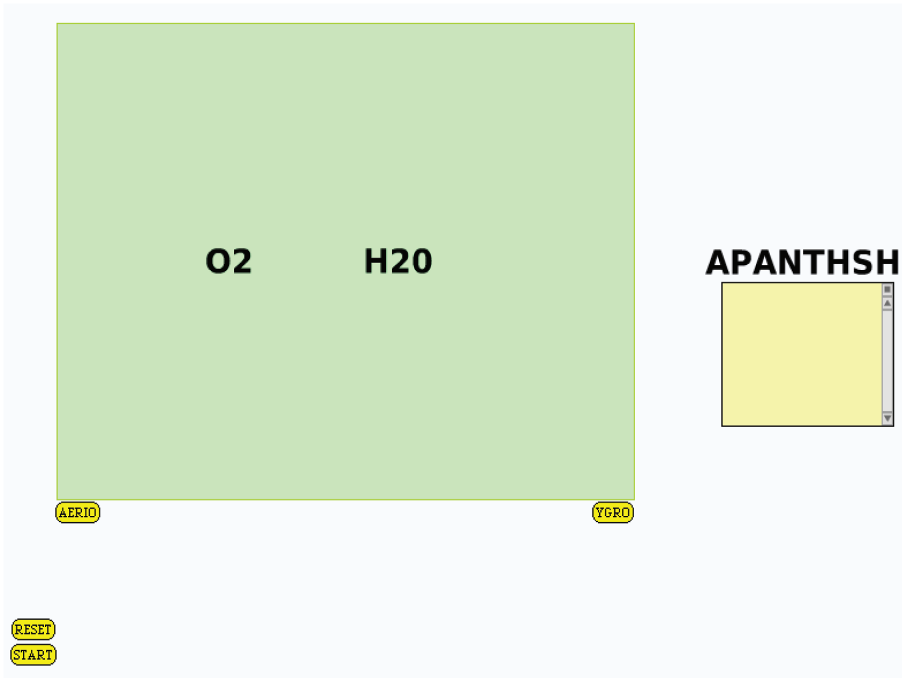
The fifth activity involved the solution of a mathematical expression of second degree by converting temperature measurements from Celsius to Fahrenheit temperature scale. This example proposes two basic approaches: (a) the teacher is recommended to show through a presentation how a mathematical problem is solved; and (b) the students can learn how to apply the conversion tool while trying to find a correct answer.

FUTURE TRENDS

As early as 1970 Papert proposed "using computers as engines that children would teach and thus learn by teaching" (Negroponte, 1995, p. 199). One Laptop Per Child project can create a starting point for a truly global educational community of teachers and students creatively applying computer technology. One should realize that the teacher's role would not be nullified in the future, but rather enhanced with modern educational technology and innovative instructional ideas. The XO laptop hardware and software capabilities to create a community of learners and motivate students can generate innovative changes within school curricula and ultimately influence the way children are taught in the future.

The future of the idea to incorporate programming into a school curriculum is tied with the

Figure 3. Chemistry Tetris



acknowledgment of the collaborative nature of learning, and the need for combined efforts of students and teachers in adopting and embracing the new computer technologies. Our content development team intends to continue to pursue the opportunities provided by computer-based learning environments in the context of national curriculum in Greece. It is important to note that by no means do we consider our work complete. Our efforts are targeted to share the results with the community of educators and software developers and stimulate others to expand on our work. The Etoys educational activities that we developed can form the basis for a subsequent exploration of the educational possibilities of the Etoys environment. Overall, the Etoys platform has a potential to promote and enhance collaboration and communication in schools worldwide.

CONCLUSION

The belief in collaboration as a fundamental principle of successful learning underscores the commitment of our content development team to augment the use of computer-based learning environments such as Squeak Etoys. The multiple functionality offered by Squeak and the versatility of the Etoys environment encourage collaboration and interaction in the learning process. Etoys educational simulations and games can become effective learning tools for all potential users. The Etoys authoring system with its visual scripting capability can be used for creating collaborative learning environments in schools worldwide, and developing countries in the first place. The learning potential achieved through teaching object-oriented programming to young children can become an essential component of children's education. Collaboration in this process is not limited to teachers and students but includes educational researchers, software and content developers, as well as the open source community.

In this chapter, we have explicated how Etoys can be utilized by schools as a medium for learning, communication, and collaboration. We have emphasized how the hardware and software of the XO laptop can be employed to allow children to interact through activity sharing, work together on projects, and engage in computer simulations and games to learn mathematics, physics, chemistry, and geometry. The educational activities that our team has developed can be used as a format and a template for collaborative learning achieved through the common efforts of students, teachers and all users of XO computers.

The OLPC XO computer provides students and teachers with new ways to collaborate, create, present, and distribute their learning projects. Since activity sharing is one of the most important capabilities offered through XO laptops, it should be fully utilized as a means for learning. Overall, XO laptops present an effective way for children to learn through interaction and exploration, and share new ideas, images, and materials with friends around the world. XO laptop computers can be viewed both as a window and a tool: a window into the world of knowledge, and a tool for social change through education. As the Internet is becoming a ubiquitous medium of communication, the One Laptop Per Child initiative brings the momentum needed to create a worldwide educational community to collaborate on the enhancement of computer technology and harnessing its creative potential for the betterment of society through education.

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