Learning SMET in digital playscapes: Research on reflection, knowledge acquisition and knowledge transfer in technology-enhanced, playful learning environments

Context

Today's children are growing up immersed in media. Recent studies such as the Kaiser Family Foundation's 1999 Report on Kids Media & The New Millennium (Roberts *et al*, 1999) and the Markle Foundation's 2000 Report on Children and Interactive Media (Wartella *et al*., 2000) indicate that young people now spend as much time using media as they do in school, with family or friends. Research has also shown that playing computer games is the most common way that all children ages 2-18 use computers (Huston *et al*, 1999; Roberts *et al*, 1999)). Simply by virtue of the amount of time and attention that young people spend in digital playscapes, one may argue that their *external landscapes of learning* are dramatically shifting.

Researchers such as Prensky (2001) and members of the Next Generation Forum (1999) contend that *internal landscapes of learning* (including cognitive structures and abilities for a creative lifelong learning) are also shifting. For instance, Prensky suggests that today's children process more information more rapidly than previous generations and that linear instruction may actually be detrimental to young minds wired for non-linear and parallel processing. He maintains that for most young people today, visual intelligence skills supercede those of verbal intelligence. Consequently, images have become the primary means of experience and expression; text is secondary. Finally, he suggests that social connectedness is experienced much differently in digital generations.

The Next Generation Forum, focused on The Creative Society, supplements these arguments by suggesting that digital tools can empower children, by giving them a new voice, pushing learning beyond existing limits, deepening their understanding of science and society, bridging the gap between generations and opening new paths for social relationships. Technology can help children "push their boundaries".

Unique characteristics of digital playspaces such as character identification, active engagement, sensorimotor practice, control over decisions and outcomes, adaptive and powerful interfaces, response elicited by feedback, controlled microworlds by the user, as well as availability of fantastic tools (Salomon, 1990 and 1998; Galvis, 2001) may help us understand reasons behind the attraction and the potential educational gains of these technological devices.

Researchers (Downes,1994; Murray, 1999) have suggested that interactive play on computers has the potential to substantially improve computer literacy skills and to influence attitudes towards technology. Griffiths and Hunt (1995) report that fun is stated as the main reason for playing for both sexes and that computer playing for most children is fairly absorbing and harmless activity. For a small minority of children it may be problematic (Griffiths, 1997). Research also shows that aggressive behavior may result from playing video and computer games, especially among young children, but that it may also promote cognitive and educational progress, and social interaction among young people (Durkin, 1995; Emes, 1997).

Despite these trends, very little research is available about what young people learn through their engagement with digital playscapes, if and how they transfer knowledge and skills from these environments to their analog lives, and how transfer may be facilitated through the design of play environments as well as their contexts of use. Similarly, parents and teachers are generally not aware of the learning potential of technology-enhanced play and cannot assess the quality of various digital playscapes.

A Proposed Solution

General Description. This project seeks to enhance lifelong learning environments (formal and non-formal) by designing ways to promote knowledge transfer within computer-based playscapes in ways that prepares users for future learning of SMET and by developing a community of informed designers and consumers to advocate for quality digital playscapes that promote reflection and knowledge transfer.

Beneficiaries. Most immediately, teachers, parents, researchers, and developers will benefit from improved ways of understanding and evaluating the learning potential of various digital playscapes. Children and lifelong learners will also benefit from richer digital playscapes that result from design principles and prototypes generated from the project.

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Relationship to NSF's educational and research goals. This effort fits into Quadrants II and III of the ROLE concentration areas: It will help to uncover conceptual learning strategies in today's digital learners that can enhance lifelong SMET learning; it will provide deeper insights into the pedagogical implications of pervasive and playful, digital media environments; and it will make available design prototypes that cross formal, non-formal and technological learning contexts to support reflection and knowledge transfer through computer-based play.

Theoretical foundations. Given the potential benefits of educational playspaces, and the widespread popularity of computer games, what has prevented us from simply grafting game design principles onto learning environments? The answer may be that there are some fundamental incompatibilities between the nature of gaming and nature of learning. Popular games and play environments, by themselves, may not result in the right kinds of learning; similarly, traditional learning spaces may not result fun and motivating for many learners.

What is the 'right' kind of learning? In brief, we recognize this kind of learning as having several characteristics:

1) Learning should be a process whereby knowledge is created through the transformation of relevant experience (Dewey, 1938; Lewing, 1951; Piaget, 1971; Kolb, 1984). This perspective argues the importance of active extension and grounding of ideas and experiences in the external world and through internal reflection about the attributes of these experiences and ideas (Kolb, 1984). Play and games have the potential to provide relevant experience; the challenge is to transform playful activities and environments into permanent vital knowledge, that is, able to contribute to future learning.

2) Learning should be long-lasting. The best way to accomplish this is to make sure that students develop well-integrated networks of ideas rather than isolated concepts (Norman, 1980; Novak, 1990). A web of associated ideas and skills will last longer than piecemeal fragments of knowledge.

3) Learning should transfer to new situations. Learners' conceptual, strategic, and process knowledge should be demonstrably useful in new problem situations. There is little benefit to giving students so-called inert knowledge that is useful only for passing school tests. Each learning situation should instead contribute to a strong foundation of problem-solving skills. Transfer of skills may be measured by immediate application to new problem sets (Thorndike, 1901; Wertheimer, 1959; Gick & Holyak, 1980). However, we agree with Bransford and Schwartz (2001) that a more promising measure of transfer is its provision for future learning, or PFL, in which case the focus shifts to assessments of people's abilities to learn in knowledge-rich environments (Bereiter & Scardamalia, 1993; Greeno *et al*, 1993; Lee, 1998; Singley & Anderson, 1998)

4) Learning should set the stage for future (lifelong) learning. Each learning experience is an opportunity not only to add to current knowledge, but also to 'learn how to learn'. The first step in this is to make learning an enjoyable experience, at least some of the time. Enjoyable learning experiences are ones that balance high challenge levels with learners' skill levels (Csikszentmihalyi, 1991) and provide constant, informative feedback. Students additionally need to learn to develop self-confidence in themselves as learners, them must learn to self-regulate to their own motivational and learning styles (Garcia & Pintrich, 1984); and finally they need to recognize learning itself as a worthwhile pursuit (Ames & Archer, 1988).

5) Learning should be focused on recognized curriculum objectives, which include both process (abilities, attitudes) and content (knowledge, skill) dimensions. Early childhood psychologists have documented the potential that play and game have for child learning and development (Piaget, 1945; Vygotsky, 1966; Reyes Navia, 1996). At the same time, digital playscapes that integrate reflection and transference have been shown to increase creativity, collaboration and problem solving in at-risk Colombian children (Galvis *et al*, 2000). There is evidence in nation wide research efforts studying the relationship between educational technology and student achievement in mathematics (ETS, 1998) that, for four graders, using computers for learning games was positively related to academic achievement and the social environment of the school; the same study does not provide further evidence of learning gains concerning digital playspaces in curricular settings. However, rubrics such as NAEP the National Assessment of Educational Progress (http://nces.ed.gov/nationsreportcard/about/) provide foci and measuring sticks for science and mathematics curriculum innovations.

The importance of reflection. In this proposal, we focus on fostering reflection on learning experiences as the key to using play and games to promote worthwhile learning, to transforming an engaging play experience into abstracted, transferable knowledge. Reflection involves scheduled, structured time to review and analyze an experience in order to gain deeper understanding of it (Close Up Foundation, 2000).

Research on transfer has long recognized the role of reflection, or abstraction. There are many well-documented instances of learners who, through experience, become facile with a certain body of knowledge, yet are unable to apply this knowledge in new settings. A game player will, with some practice, become an expert at balancing residential and commercial property in the game 'SimCity'. Without reflection and abstraction of this knowledge, however, s/he may not be able to apply this knowledge even to directly related situations, such evaluating arguments about zoning in the local newspaper. Reflection is also necessary for knowledge integration—the process by which ideas are integrated into larger webs of knowledge which are more robust and more usable (Linn and Hsi, 2000). Careful, sustained reflection is a necessary component in developing all kinds of expertise (Bereiter & Scardamlia, 1998)..

Reflection is also a necessary for the motivational and affective components of lifelong learning. Self-regulating learners must reflect back on the learning process, to notice what has gone well, what has been difficult, and make predictions about what will help them learn effectively in the future. Reflection on what has been learned is necessary for learners to gain a sense of efficacy and a sense of enjoyment in learning, and come to adopt learning goals (Ames and Archer, 1988).

Tension between maintaining engagement and fostering reflection. Unfortunately, the goal of reflection is somewhat at odds with the usual methods of video game designers, who strive to keep players engaged and 'in the moment' continuously during a game experience. *The Jack Principles of Jellivision Interface and Design* (Gottlieb, 1997) a fascinating document, written by the company that produces the popular "You don't now Jack" interactive trivia game, lays out techniques for creating and maintaining a game experience through a constant, lively, and interactive fictional character who paces and narrates the game. A few of Jack Principles are: "Make sure the user knows what to do every moment", "Focus the user's attention on the task at hand", and "Pause, quit, or move on without the user if response doesn't come fast enough". The problem with these principles, and the unstated principles behind most popular computer games, is that they seem to leave no room for the deliberative reflection that is necessary for worthwhile learning. The Jack Principles highlight the incompatibility between the goals of meaningful learning and current game design principles. It would be a mistake to see this problem as being intractable. Rather, we view it as a design challenge of the highest order. How can we design the process of reflection into engaging play experiences? (Bos 2001 details this).

Means of fostering reflection. Educational researchers have a growing set of tools, technological and otherwise, with which to try to promote reflective thinking. There is some research on the use of metacognitive prompts, such as computer-generated questions or suggestions that appear at set intervals, or in set situations in a game. (Sandoval & Reiser, 1998; Jackson, Krajcik, and Soloway, 1999). Unfortunately, these prompts usually detract from the game enjoyment, and are also easily ignored by students. More effective prompts are ones that are deeply embedded into the game context, either forming part of the game storyline (e.g. a character asks the player for advice, a general must instruct his soldiers on effective strategy) or are in some other way an integral part of the game experience. Galvis (2001) examined critical design aspects in one popular game environment, The Incredible Machine: Contraptions (Sierra Online, 2000). He found that this software uses 'help' features to balance the learner's need for feedback with learning goals, does not provide right answers to problems until player has produced a correct answer on own, and uses prompting for better solutions even after player has proposed a solution. We see embedded reflection in the games as an under-studied but potentially very fruitful direction of study.

There are several emerging tool environments that can be used in conjunction with game environments to promote reflection. The Progress Portfolio is a tool that uses a combination of screen capture and annotation capabilities to help student investigators document their inquiry process. Without such tools, students in inquiry classrooms struggle with complex and ill-structured projects, where it is often difficult for them to monitor their own progress, and even harder for teachers to tell what they have done. (Loh, Reiser, Radinsky, Edelson, Gomex, and Marshall 1998). A very different tool, CSILE (now Knowledge Forum) tries to encourage class-sized groups of students to work in concert as co-investigators of problems by facilitating their online discussion of emerging findings. Cohen and Scardamalia (1998) gives an example of how CSILE could be used to provide a reflective super-structure to a complex simulation environment, Interactive Physics.

Design of effective prompts will also make use of current research on visual representational forms. As Roschelle (1991) has shown, giving students the right visual representation to work with can promote collaborative reflection, even without direct metacognitive prompting. We intend to review and adapt representational innovations as concept maps, system block diagrams or flow charts, visual programming, outliners, building diagrams, and frame games for our purposes.

There is also an unfilled gap in knowledge of how to use more social tactics to promote reflection in game environments. Roschelle, Chi (1994) and others have shown how powerful peer conversation can be in promoting reflective thinking. Tsikalas' (2001) observation of students playing the computer game "The Sims" (EA Games, 2000), this dialogue prompted reflection and learning beyond what solo learners might have experienced. We will seek to expand this with more prescriptive social prompting mechanisms surrounding commercial games.

We will also investigate the possible uses of reciprocal teaching strategies (Palincsar & Brown, 1984). Reciprocal teaching employs students as prompters for each other in an engaging and somewhat gamelike manner. Each student in a group takes on a role (summarizer, predictor, etc.) and consistently plays that role as the group works through a text. Many other studies of small group work have since documented how learners can formally or informally prompt reflection and learning in each other by demanding explanations and clarifications. For this research, we will intentionally develop role-playing strategies by which students may prompt each other for reflection in a game environment. We will attempt to develop roles that can be seamlessly embedded into a game context, ideally by fitting into the game storyline, but also prompt abstraction of important concepts or strategies.

Prior work. In this project, we intend to build upon and extend existing work of The Digital PlaySpace Collaborative and its members. This Collaborative is supported by The Center for Innovative Learning Technologies, an NSF-funded project intended to seed collaborations across academic, commercial, and direct service sectors that will improve the landscape for children's learning in this country. Members of the Digital PlaySpace Collaborative include researchers, practitioners, and designers from the United States and South America. Meeting since September 2000, the group has examined a variety of computer-based play environments and identified features in the play spaces themselves, as well as in children's appropriations of these spaces that promote learning. (See URL http://concepts.concord.org/playspace for examples of the group's work and accomplishments.) The Playspace group has been a surprisingly energetic and productive collaboration, that has achieved much and garnered much attention with very little money. We are optimistic that this project will continue to grow quickly and have influence beyond the group's participant list with infusion of more research funds.

Project Components

Research questions. In implementing this project, we will investigate several timely and important questions about learning that occurs in digital playscapes and how these environments may prepare users for lifelong SMET learning. Among our questions are:

- What characteristics of digital playscapes render them particularly amenable to SMET learning and knowledge transfer? (Possibilities include game content, type of problems presented, structure of feedback mechanisms) Answers to this question will help refine a playscape assessment rubric and will provide criteria for selecting digital playscapes to be examined in our research studies.
- What strategies and techniques can be used to elicit reflection in playful environments? In approaching this question, we will consider both computer-based and social strategies (such as reciprocal teaching). We will examine a range of reflective techniques including but not limited to text-based conceptual prompts, visual mapping, and role playing situations.
- How does one select appropriate reflection strategies and tools for particular play environments?
- What are the best ways to document and measure what people gain/learn from digital play?
- What are the best ways to document and assess the ways that learners transfer knowledge from digital playscapes in ways that prepare them for future SMET learning?
- What are the best ways to present research findings on digital play-based learning and reflection to consumers and designers of these environments? How do we build a community of researchers and practitioners who are active in better understanding and lobbying for more reflective digital playscapes?
- What do digital playscapes that promote reflection and SMET-related knowledge transfer look and feel like?

Products. In the project, we will deliver several products, including:

- A tested and ready-to-use rubric for evaluating the learning potential of digital playscapes.
- Research instruments for documenting and assessing learning, reflection and knowledge transfer in digital play environments.
- Digital reflection tools to be used in parallel or to be embedded in digital play.
- Strategies for promoting reflection in digital playscapes, derived from direct interaction with kids and learning facilitators and from experimenting with various kind of reflection tools.
- A strategy for engaging the community in translating research findings into design specifications. For example, a contest for designing playful learning environments, cooperative design workshops with the users.
- Prototypes of digital playspaces and games that make use of effective reflection strategies and tools. These prototypes will implement the designs generated by the participant community, very likely using open source and under the care of professional developers.

Research Plan

Our proposed research plan consists of three sequential, but overlapping phases: 1) Planning; 2) Implementation; and 3) Prototype Design and Testing.

Planning the project and collaborative process. In the first phase of work, we will identify test-bed sites (formal, non-formal, and technology/Internet-based learning sites) and assemble a network of study groups at these sites across the country. These groups will include researchers, middle school teachers, community facilitators, parents and students. Guided by a group of primary researcher, the groups will select playscapes for the study, identify reflection strategies and tools, and develop research instruments. The primary researchers will also develop a collaboration plan (to include meetings and data sharing strategies) and data reporting structures/formats.

Research implementation. In the second phase of the project, primary researchers and site-based study groups will develop a plan for collecting baseline data, process data, and learning transfer data at each site using instruments and tools developed in the prior phase of work. Baseline data consists of information the skills and knowledge users acquire through engagement in digital play. Process data consists of observations and reports about user choices, strategies, and comments while playing in computer environments that have been enhanced with devices (tools and strategies) to elicit reflection. Transfer data consists of users' performance on multimedia-based tests designed to measure preparation for future SMET learning.

Detailed research plans will vary slightly by site, as each study group will select the playscapes, reflection and research tools they feel most appropriate for their particular learning context. Primary researchers will ensure consistency across sites and will manage data analysis and reporting processes.

Design, development and testing of prototypes. Based on tools and strategies developed in the first phase of the project and on research findings from the second phase, we will solicit design specifications for digital playscapes that promote reflection and SMET knowledge transfer. We will do this by sponsoring a series of competitions and cooperative design workshops among community, university-, and commercially-based development teams.

Following the selection of exemplary design specs, we will work with developers from Concord Consortium and other participant organizations to build prototypes of these playscapes. The prototypes will be tested in our site-based study groups.

Organizational aspects

This project will institutionalize the idea of a network of cooperating researches that has started with the CILT-Playspace seed project. Principal investigator, Alvaro H. Galvis, from The Concord Consortium, Concord, MA, will be in strong cooperation with co-principal investigators, Nathan Bos from CILT - Center for Innovative Learning Technologies, Kallen Tsikalas from Computers for Youth in New York, and with Kevin Ruess from George Mason University, Fairfax, VA. In each one of four poles of action (Boston, Ann Harbor, New York and Washington) there will be a study team—comprised of researchers, middle school teachers, parents, children, and community facilitators, under the direct leadership of the PI or CO-PI.

At the global level of the project we will invite outstanding researchers in related fields, some of which we have already contacted, to serve as advisory committee members: Fred Goodman (U. Michigan, Ann Harbor, MI), John Zuman (Intercultural Center for Research in Education , Boston, MA), Wally Feurzeig (BBN, Boston, MA), Roy Pea (Stanford University, Palo Alto, CA), Paul Hortwitz and Robert Tinker (The Concord Consortium, Concord, MA).

We will also be in touch with people developing significant efforts in the field of learning by playing, such the academic groups behind Zoombinis (TERC, Boston, MA), Phoenix Quest (University of British Columbia, Vancouver, CA), The Return of The Incredible Machine (Sierra Online), Ciudad Fantastica (Uniandes-Lidie, Bogota, Colombia). Other groups sharing similar experience and products will be also invited to contribute. In addition we expect to be in touch with commercial organizations trading these products, in order to explore synergies with them.

Our plan is to devote the first year to planning the project and collaborative process and, by the end of that year, to start research implementation. Implementation will be mainly done during the second year. The third year will be devoted to develop and test prototypes.

We plan to organize a permanent seminar about the project, through the net, in which we will share and discuss ideas with the network of participants. In addition we will organize at least one face-to-face seminar per year, open to other researchers and groups interested in our focus of study, as a means of getting feedback and exploring alliances. At least four papers per year will emerge from this project, to be presented on referee-based events or reviews.

Estimated cost of the proposed project is approximately $525,000 per year, $1.6 million for three years. This includes support for Alvaro Galvis, PI, at 50% for three years, and three co-PI's -- Nathan Boss, University of Michigan, at 33%, Kevin Reuss, George Mason University, at 33%, and Kallen Tsikalas, Computers for Youth, at 33%. Staff as well as part-time research assistants will be needed to assist with the research design, program implementation and data analysis. Three part-time developers / graduate students will be required to analyze software and develop new programs. Honoraria for the participating schools and community groups would be provided, as will payment for advisory committee members. Approximate staff and consultant salary (and benefit, where appropriate) costs will be $900,000 for three years. Other costs include the expense of the software licenses, travel for teacher training, program implementation and data collection, occupancy, phone, postage, office supplies, computer services and other indirect project costs.

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