J. EDUCATIONAL COMPUTING RESEARCH, Vol. 29(3) 325-334, 2003

THE NEW SCIENCE OF LEARNING: ACTIVE LEARNING, METACOGNITION, AND TRANSFER OF KNOWLEDGE IN E-LEARNING APPLICATIONS*

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ABSTRACT

This article examines the key concepts of active learning, metacognition, and transfer of knowledge, as put forth by the National Research Council's approach to the new science of learning, in relation to ways that E-Learning applications might improve learning both inside and outside the classroom. Several initiatives are highlighted to illustrate innovative ways to improve E-Learning by linking these three concepts to four fundamental characteristics: 1) using engaging production features to motivate children to learn; 2) teaching children to construct their own learning paths with information; 3) encouraging collaborations that facilitate both cognitive and social aspects of learning; and 4) using story-telling and entertainment features to foster learning outside the classroom. Stealth education, in which children are actively engaged in a seamless entertaining learning application, is considered as a viable way for E-Learning to improve children's academic and social successes.

The new science of learning, as advocated by the National Research Council and the National Academy of Science, recognizes the importance of allowing children to take some control of their own learning experiences (Bransford, Brown &

*This work was supported by a grant (#012 6014) to the Children's Digital Media Center from the National Science Foundation.

Cocking, 1999). This new science of learning encourages the design of engaging curricula that apply to real-world situations, build local and global communities of practice, and most importantly, provide opportunities for children to learn both inside and *outside* the classroom.

This article focuses on the implementation of E-Learning, defined as the delivery of education through electronic media such as the Internet or CD-ROMs, at various points in development. We examine the ways by which E-Learning can foster the key concepts of the new science of learning, including **active learning**, where students take control of their own learning experiences, **metacognition**, in which students monitor their mastery of skills and their comprehension, implementing strategies to improve their learning, and **transfer of knowledge**, in which students apply knowledge that has been acquired to new learning situations (Bransford et al., 1999). We are particularly interested in ways that the lessons from entertainment media can be utilized to promote interest and active learning in educationally relevant materials and activities.

Our article proceeds as follows. First, we define the components of E-Learning. Then we explore prototypical research initiatives that illustrate the key concepts of active learning, metacognition, and transfer of knowledge that are germane to the new science of learning and that hold promise for E-Learning applications. These examples are: 1) using engaging production features to motivate children to learn (active learning); 2) facilitating children's constructions of their own learning paths with information (active learning and metacognition); 3) encouraging online collaborations that facilitate both cognitive and social aspects of learning (active learning and metacognition); and 4) using story-telling and entertaining features to foster learning outside the classroom (active learning, metacognition, and transfer of knowledge).

WHAT IS E-LEARNING?

E-Learning can be understood as the use of network technologies which foster an **anytime-anywhere** transfer of information. E-Learning environments contain no time/space constraints, are built with reusable components, are highly scalable, meaning the same program can be moved from 10 participants to 100 participants to even 100,000 participants with little incremental cost or effort (Rosenberg, 2001), and are cost-effective after the upfront costs of development are absorbed. These attributes highlight the value of implementing E-Learning applications in classroom settings.

The E-Learning approach is **learner-centered**, and its design entails a system that is interactive, self-paced, repetitious and customizable (Twigg, 2002). The educational advantages of this approach are manifold. For instance, children might become more engaged in their learning as they make active choices and navigate through the material, moving at their own speed as they work with personalized content.

By contrast, in traditional classroom settings, it can be challenging for teachers to activate the potential of all of their students, particularly if the classroom is overpopulated and has children of varying skill levels. In these situations, the teacher tends to teach to the middle, and the slower children can't keep up while the faster ones aren't sufficiently challenged. Self-paced materials give all children the opportunity to advance at their own speed, and the teacher can be more aware of each student's mastery of the classroom material. These materials can also be accessed outside of the classroom as homework.

E-Learning is increasingly utilized in the K–12 curriculum (NCES, 2002). This direction in learning is increasingly viable because of the penetration and use of new technologies in classroom, home, and library settings. A PEW Internet and Family Life survey, for instance, found that more than 78% of adolescents go online, either from their schools, homes, or libraries (PEW, 2001). Approximately 54% of adolescents and children had Internet access from home during the fall of 2001 (Commerce Department, 2002). Similarly, schools have made amazing advances in becoming wired. From 1994-2001, The National Center for Education Statistics found that Internet access in public schools had risen from 35% to 99% (NCES, 2002). Concurrently, the use of high-speed broadband connectivity has also risen, making it possible to download more interesting graphical material that is characteristic of entertainment media.

Although the use of E-learning is more prevalent in schools today, efforts to get children to engage in E-learning outside the formal classroom setting continue to lag behind. Children will use online resources to do their homework (PEW, 2001), but their preferred choice of media use remains in the entertainment realm (Roberts, Foehr, Rideout, & Brodie, 1999). Indeed, children and adolescents freely invest their leisure time with entertainment media, spending an average of six to eight hours a day with them (Roberts et al., 1999). Rather than children dividing their time outside of school between entertainment media and homework, perhaps there is a way to connect the activities through stealth education where we teach children without them being aware of it. More specifically, while the new science of learning emphasizes deliberate and effortful self-regulation and planning when engaging in metacognitive activities (Bransford et al., 1999), strategies are constructed and used to solve problems even when posed in video games (Greenfield, 1993), just as they are utilized to tackle school work. The difference is that game play is structured in a seamless and entertaining way, making metacognitive activities more engaging and enjoyable to children, a process that we argue is central to our goal of achieving stealth education in informal out-of-school educational activities.

MOTIVATION AND ACTIVE LEARNING: THE USE OF ENGAGING PRODUCTION FEATURES

Children participate and interact with media when the messages are personalized, intuitive, challenging, and fun (Malone, 1981). Part of the solution for getting children to spend more time actively engaged in learning outside formal classrooms may be to combine appealing content with entertaining production features. Given the inherent properties of E-Learning as a "learner-centered" design, one that is customizable to the individual and offers self-pacing, repetition, and interactivity, the added focus on entertainment features may well improve children's motivation, attention, and learning.

The video game industry illustrates this point. A recent report by the Interactive Digital Software Association (IDSA, 2002) finds that at least one person in every household surveyed plays PC or console-based games, such as Nintendo or Playstation, and 31% of frequent gamers play online. The top three reasons for video game play are: 1) they are fun; 2) they are challenging; and 3) family or friends can play with them (IDSA, 2002). Games are fun, in part, because production features such as rapid action, rapid pacing, sound effects, and music engage the audience (Malone, 1981). These same features have been used in television content to involve the audience (Calvert, 1999). Can engaging features enhance education and learning?

In an early effort to utilize interesting production features such as action for learning in the computer world, Calvert, Watson, Brinkley and Bordeaux (1989) created a program called **Parkworld**, a simulated park. Objects such as a dog, cat, fish, tree, train, and car could appear in Parkworld, and were presented in the context of a story. Objects either moved or did not move, and the object's actions were combined in various studies with either sound effects or language that provided a label for the object. Children who participated in these studies varied in age from preschool through second grade.

Overall, the studies demonstrated that moving objects were more likely to be preferentially selected and recalled than were stationary objects (Calvert, 1991; Calvert, et al., 1989; Calvert, Watson, Brinkley & Penny, 1990). Action was particularly helpful for the youngest children as well as for second graders who were poor readers. We believe that action assisted children's memory because it supplied an additional visual mode of representation that supplemented the verbal names of objects, a practice which may be especially useful for young children who tend to think in iconic, visual forms.

Pauses introduced just before the targeted objects also elicited an early rehearsal strategy from children: naming objects (Calvert, 1991). Rehearsal strategies, which are a part of metacognitive activites, are rarely performed spontaneously by young children, but were prompted spontaneously in this seamless entertaining story context. The results suggest that the judicious use of production features can elicit children's interest, active engagement, and strategy production, thereby facilitating their memory of verbal content.

Building on these same production principles, Moore and Calvert (2000) created a CD-ROM to teach nouns to preschool-aged children who had autism. By using action, sound effects, and other engaging features, children's interest, attention, and learning of verbal material increased over a control group who received only a traditional therapeutic learning approach. This engaging computer program was an ideal way to deliver content to children with autism because these children are often uncomfortable with human interaction, enjoy repetition, and like constancy in their experiences.

ACTIVE LEARNING & METACOGNITION: CHILDREN AS CONSTRUCTORS OF THEIR OWN LEARNING

Some E-Learning applications appear superficial and replicate rote memorization techniques, not altogether different from historic learning machines that broke lessons into small incremental steps, rewarding the correct response and punishing the incorrect one. Even though these approaches are not avant-garde applications, they often facilitate learning as they allow children to practice and master new information. Intelligent computers can now concentrate and tutor individual children toward specific areas of weakness (Beal & Arroyo, 2002). In addition, production techniques are often used to reinforce children's learning by using interesting visual images or sounds after a successful response.

In the new science of learning, however, the focus is on how to engage children in deep processing of information where links are created with existing knowledge bases as well as how one generates knowledge (process) rather than just displaying its products (Bransford et al., 1999). Metacognition and deliberate strategies can assume an increasingly important role, even when the application is to create an entertaining educational video game. Consider, for instance, what happens when children learn to create their own computer programs about fractions.

The **Game Design Project**, developed by Kafai (1996), was a six-month-long project that taught fractions by allowing third graders to create their own video games in the programming language Logo. Each day, children actively controlled their learning by creating plans, an important component of metacognition (Bransford et al., 1999), which they would then implement to create their own fraction video game.

The results documented gender differences in the construction of video games. Although both boys and girls built games that told stories, boys tended to construct action-adventure games based on the concept of Good versus Evil; by contrast, the games girls created never presented evil themes, instead focusing on teaching or developing skills that reflected their personal interests. Most girls built their games in real-world settings, while most boys built fantasy worlds.

Research that examines what children create when allowed to develop their own learning environments provides educators with a window into children's preferences and interests that are important to E-Learning applications. Moreover, creating these programs can engage children for long periods of time in constructive, educational activities that teach math skills at a concrete level as well as the scientific process of discovery at an abstract level. Kafai (1996) believes that this heightened motivation is a promising path for learning.

Indeed, it does appear that intrinsically interesting learning environments offer benefits for learning. For instance, Lepper and Malone (1987) found that when children were allowed to choose to play an action-oriented dart game about fractions, they chose to play more often, and hence learned more, than when they had the choice to play a drill and practice version of the same material. These differences in learning disappear if one controls for learning time. Nonetheless, they suggest that stealth education applications, which focus on building intrinsically-interesting and seamless educational experiences, are more likely to succeed in getting children to interact with entertaining educational software in out-of-school settings than are simple drill and practice applications.

ACTIVE LEARNING & METACOGNITION: COLLABORATIVE PROJECTS FOR COGNITIVE & SOCIAL GROWTH

In a verbal literacy project designed to empower children as they engage in active learning, Druin et al. (2003) is working with third graders to create a **digital library**. Although many universities or organizations are developing digital libraries, children between ages five to ten are virtually ignored and the interfaces available to elementary schools are not that usable. Therefore, she designed a project that enables children to collaborate with her adult research team to create interfaces and search features that are optimal for children.

Children make the final decisions about the books that do or do not go into the digital library. Such decisions require planning**,** a component of metacognition. In a time when educators are concerned about verbal literacy, such initiatives are a promising way to involve children in collaborative activities that get them interested in reading and evaluating books.

The **Junior Summit Project** was designed to allow children's voices, especially those that are rarely heard, to have an open forum to prosper in an online global community. To do so, Cassell (2002) brought together 3,000 children, aged 10-16, from 139 different countries in an online forum. Children became the moderators, as well as the facilitators, of the online forum. They translated for one another. They solved their own problems with a minimum level of adult intervention. In short, they took active control of their learning experiences, and in the process, learned to problem solve, a component of metacognition, negotiate and understand the communications of others, and gain valuable experience in reading other languages.

If success can be measured by sustained interest and active involvement, then this project was a smashing hit. After a culmination of the project at a six-day event at MIT, the children continued the forum on their own, refusing to allow the project to end.

ACTIVE LEARNING, METACOGNITION, AND TRANSFER OF KNOWLEDGE: META-NARRATIVE AND E-LEARNING

Integrating all three components of the new science of learning is challenging, but it can be done. Consider, for example, **KineticCity.com**, an after-school program for fourth and fifth graders that synthesizes active computer-guided learning and hands-on applications to foster science education. Using the action-adventure formula, in which good triumphs over evil in an action-oriented format, the learner becomes the hero who helps save planet “Vearth” from an evil hacker who has spread computer viruses to destroy the world (Malcolm, 2002).

Underneath the story is a science curriculum designed for elementary school children, thereby achieving a goal of stealth education (Malcolm, 2002). The production techniques used in the video game portion of the program rival the content and animation of arcade and home console game titles, which is important in capturing the attention of young children who are used to fast-paced, graphic-intensive video games. Combining entertainment segments with educational concepts is a nice blend for motivating children to learn. Furthermore, children can access KineticCity.com from home, and may continue their learning activities anytime-anywhere.

According to the new science of learning, metacognition involves self-regulation in which children plan and then examine success and correct errors in relation to their intentional learning activities (Bransford et al., 1999). By breaking up each scientific module into several activities, children can actively control and monitor their completion of each task in KineticCity and figure out the skills that are left to master.

KineticCity.com also embraces the *Pokeman* format, where children get merit badges as they defeat dozens of these viral monsters. Collecting awards by completing learning goals are excellent motivational features. The positive reinforcement techniques support children’s interests outside of the classroom, such as collecting trading cards, and can facilitate learning through classic reinforcement principles.

By modularizing science information into various activities that culminate with quizzes and hands-on experiments and projects, transfer of knowledge can also be facilitated. More specifically, because all activities focus around a central story, or meta-narrative, children can take previously understood material and apply it to new learning situations. For instance, after a child learns a scientific concept, he or she continues with a hands-on activity or a new lesson that builds on the preceding material. Because all lessons are part of the same central story, children may feel more invested in the theme as it carries the learning experience. Although children knew more basic scientific concepts after using KineticCity.com for two months (Malcolm, 2002), the deeper learning that we expect from this program has not yet been examined.

The acquisition of scientific knowledge is often a collaborative activity where groups of people pool their knowledge and talent to solve problems. This view of science contrasts with the more traditional academic approach in which individual children work on their own to display what they know. KineticCity.com embraces collaborative group learning through its program. After-school programs create local clubs of learners, who are given the opportunity to work with and communicate with other clubs, encouraging a global community of practice. On their Web site, children can see a rotating globe with a real-time feature of existing clubs as well as individual players in various parts of the world. These team-building exercises and venues for global communication promote the social side of learning. By collaborating, children are learning more than just science concepts; they are learning how to interact and share knowledge and resources with one another, both locally and globally.

DISCUSSION

The E-Learning projects we described highlight innovations in creating learning environments for children that are interesting to them. Each provides exemplars of the new science of learning: they empower children to take active control of their own learning (Cassell, 2002; Druin et al., 2003; Kafai, 1996; Malcolm, 2002); they allow children to plan and to monitor their own learning process (Kafai, 1996; Malcolm, 2002); they encourage an environment where learning can be applied to new situations (Malcolm, 2002); and they foster collaborative learning activities (Cassell, 2002; Druin et al., 2003; Malcolm, 2002). They also provide examples of stealth education: children are learning, often without even knowing that they are being taught.

The inherent principles of E-Learning as a scalable, transferable medium allow children to explore learning both inside the classroom, as they create fraction games (Kafai, 1996), and outside of the classroom where they work together on science projects (Malcolm, 2002), create digital libraries (Druin et al., 2003), and translate each other's e-mails (Cassell, 2002). Because most children who are online use the Internet for school research (PEW, 2001), E-Learning provides opportunities for creative assignments that foster learning with the technologies that pervade our children's daily lives and free time.

Fusing entertaining production techniques and story-telling techniques with educational content might be another mechanism for keeping children motivated to learn. Interesting stories and adventures presented via action are engaging, inspiring active learning and memory of targeted verbal (Calvert, 1999; Moore & Calvert, 2000) as well as scientific content (Malcolm, 2002). Attention and motivation should be benchmarks in the creation of intrinsically interesting learning environments for children (Malone, 1981). We want children to be just as interested in learning when they are out of school as when they are in school. Stealth education, which brings entertaining features to the forefront of the learning situation in a seamless, game-like way, provides an important avenue for making this happen.

Social dimensions of learning can also be fostered in online communities. Children learn lessons of value from one another, including tolerance and sharing resources (Cassell, 2002). Being a citizen of an online community transcends time and spatial constraints, potentially bringing us closer as we tackle complex problems together.

What will the future bring to E-Learning? Will we use this promising technology to teach to the test, which surely will improve academic test scores? Or will we teach our children *how* to know, what to do when they don't know the answer to a question, and what questions are worth even asking? The latter issues of process are a key to the new science of learning and to scientific discovery, and in our opinion, the key direction for the future of E-Learning.

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