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Technology affordances: the 'real story' in research with K-12 and undergraduate learners

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Abstract

Computer technologies for learning environments have been introduced with great expectations for improved learning outcomes. However, the great improvements have not materialised; some of these extant studies are examined. Of all the explanations for these disappointing results, the least examined are the affordances of the computer tools. This paper provides a rationale for studying affordances and presents two studies in K-12 and undergraduate settings showing how powerful affordances are in affecting outcomes. Finally, the paper presents guidelines on how to gradually move students from a game affordance of a computer to a learning mode.

Introduction

Educational technologies are frequently introduced to learning environments with great fanfare and expectations for learning outcomes. Unfortunately, recent meta-analyses of research about technology-enhanced learning environments showed minimal, or even negative, effect sizes (Azevedo & Bernard, 1995; Fletcher, Claire & Gravatt, 1995; Lee, 1999; Lou, Abrami & D'Apollonia, 2001). The causes frequently cited for these minimal effects include the tasks, learner variables, and design issues. Affordances of computer technologies for the learner are rarely mentioned as a possible cause for the mixed results.

Students in K-12 and undergraduate settings spend a majority of their computer time playing games and communicating with peers, therefore, their affordances for the computer are affected by these experiences. Affordances describe the interaction supported by the tool for each individual and is affected by their prior experiences. The students expect to be entertained by the computer and use it to communicate with peers and rarely consider it a learning environment. In the early days of television-based classes, Salomon and Leigh (1984) reported on a phenomenon he termed AIME (Amount of Invested Mental Effort). Similar to what we are experiencing with the computer-literate generation now, the TV viewers expected to be entertained and rarely engaged their minds in effortful thinking while viewing the programmes. This and the one-way communication of the medium resulted in many TV-based courses failing as good learning environments. Computer affordances for learners in K-12 and undergraduate settings may play a similar role in research outcomes if viewed as an entertainment medium that requires less engagement of the brain.

There are four major reasons why it is important to figure out the role of affordances in educational technologies. First, if young learners' expectations of computers are that they will be entertaining and game-like, should we always endeavor to meet those affordances and construct only games to promote their learning? Second, should we identify transitions to move learners from the game affordances to a learning affordance? Third, is it possible to change affordances of a computer tool for learners? Finally, as the numbers of web-based distance learning environments increase and are actually being used by K-12 and older students, do we really know what is going on in learners' minds as they interact with the computer? Additionally, do these students multitask based on their computer affordances and miss important learning or are they evolving into a different type of learner?

This paper describes two projects where technology affordances played a large part in the outcomes. Each study described includes the methods, results, and discussion. We begin with a description of computer technologies in learning environments, affordance theory, and then describe the research studies. The conclusion identifies strategies that can minimise the effects of the problems and methods that can move students to a learning affordance instead of propagating the game affordances of computers.

Computer technologies in learning environments

Computer technologies in the classroom include interventions like computer tutors, interactive learning environments, discovery learning environments, simulations, web-based distance learning environments, and communication tools. Table 1 shows a sample of such studies and presents the domain of study, education level of learners, outcome variables studied, and results. Participants range from high school students learning biology to undergraduate engineering students. Research results from these studies show limited effects on learning. One explanation for the mixed results in these studies is the computer tool affordance for the user.

Affordances

Affordances are the interactions between users and tool. The tool prompts, guides, or constrains the users depending on their previous experiences (Salomon, 1990). In order to accept the affordance of the tool, the user must have prior experiences with similar tools (Carter, Westbrook & Thompkins, 1999), domain knowledge (Kozma & Russell, 1997), and must be at an age where they are able to understand or relate to the

Table 1: *Sample research studies in computer-aided learning environments*

Authors	*Domain, participants, and treatment*	*Outcomes studied*	*Results*
Adams and Shrum (1990)	Biology—research High School Computer tool for collecting, displaying, recording, and graphing data	1. Graph construction 2. Graph interpretation	Conventional condition outperformed tool condition in construction. No difference in interpretation
Berge (1990)	Science process skills Grades 7 and 8 Climate database interaction	1. Hypothesis development 2. Research design 3. Testing	Low ability students improved significantly All improved
Bonk and Reynolds (1992)	English, Reading, and Writing Grades 5–8 Computer prompting	1. Organisation of writing	No significant effect
Cañizares and Faur (1997)	Engineering undergraduates MATLAP, MAPLE-V, EES, SOLVER-Q	1. Applied project 2. Observations of laboratory interactions	No significant effect
Carter *et al* (1999)	Physics—circuit design Grade 9 (qualitative)	1. Constructing meaning 2. Tool knowledge 3. Contribution of prior experiences	Students were constrained by the tool and lack of prior knowledge
Coleman *et al* (1998)	Engineering Undergraduates Computerised courseware	1. Test performance	Computerised condition performed worse than traditional instruction

Table 1: Continued

Authors	*Domain, participants, and treatment*	*Outcomes studied*	*Results*
DeJong *et al* (1999)	Physics—momentum First Year undergrads. Simulations with different levels	1. Definitional knowledge (Multiple choice) 2. Intuitive knowledge (What-if tests) 3. Structural knowledge (Concept maps)	All students improved in definitional, intuitive and structural knowledge (no differences in conditions)
Dixon (1997)	Mathematics Grade 8 Geometer Sketchpad™	1. Visualisation 2. Rotation of objects	Tool condition showed significant improvement
Lindström *et al* (1993)	Mechanics Undergraduates Simulations	1. Holistic scores on interviews 2. Intuitive and conceptual Understanding	Some improvement in intuitive understanding but not on holistic scores
Mayes (1995)	Mathematics—Algebra College students Tool—derived	1. Computation 2. Manipulation skills	Tool condition showed significant improvement
Salomon, Globerson and Guterman (1989)	English, Reading, and Writing Grade 7 Computer reading partner	1. Recall of important themes 2. Metacognitive strategy 3. Organisation of writing	Significant differences
Williamson and Abraham (1995)	Chemistry—nature of matter First year undergraduates Computer animation	1. Understanding of concepts 2. Attitudes 3. Effect of reasoning ability	No differences in conditions. There were differences in conditions when reasoning ability was used in analysis

affordances (when the tool is within the zone of proximal development of the learners) (Carter, Westbrook & Thompkins, 1999). Norman (1998) says, 'affordance is not a property, it is a relationship that holds between the object and the organism that is acting on the object. The same object might have different affordances for different individuals' (p. 123).

For the focus of this paper, the tool or object is the computer. Based on previous experiences with the computer, the user can see it as a tool for data entry, as a method of communication with others, as a place to play games, or as a facilitator for writing a paper. Most students in K-12 and undergraduate settings have grown up with the desktop computer that has graphical user interfaces and advanced gaming capabilities. When these students are faced with learning from a computer or interacting with a computer to perform a problem-solving task, what are their expectations for that interaction? How do their expectations affect the outcomes of their experience?

Research on affordance has shown that undergraduate students perceived the numeric isomorph of a simple Tic-Tac-Toe game to be easier than the isomorph with shapes and colors (Zhang, 1997). The game-like isomorph and the students' view of the role of computers were better matched yielding easier ratings. Using qualitative analysis of data transcribed from high school student interactions with computer representation (physics concepts like behavior of a mass on a spring and graphs generated by the computer), Kelly and Crawford (1996) showed positive roles of the computer. The high school instruction used a computer to foster the construction of meaning. The computer exhibited vital information and presented anomalies to the students' expectations. The computer became the students' ally in making a case. The students used the computer representations to 'make a claim', make predictions, and look for clarification. They responded to the computer as a member of the group. The students appeared to learn to value the computer as a useful tool for inquiry rather than just a source of entertaining games.

In contrast, Roth (1995) and Roth, Woszczyna and Smith (1996), studied 11th grade students interacting with a physics microworld, Interactive Physics™, and showed that some students needed guidance in making the correct choices, navigating, and interpreting the outcomes of the simulations. Most troubling was their synthesis that stated, 'The teacher could implement and execute ideas and experiments as he planned; the computer software complex—provide him affordances, just as a chisel or circular saw affords many possibilities to a carpenter. On the other hand, from a students' perspective, the computer software complex—was a tool unready to hand' (Roth, Woszczyna & Smith, 1996, p. 1012).

In summary, computer affordances play a large role in learning outcomes. The current cohort of K-12 and undergraduate students, who are frequently the subjects in research studies, have used computers from a very early age to play games and sometimes do simple word processing tasks. The designers of both computer tools and research studies have backgrounds where computers were mostly utilised for programming databases and application design; they view computers from a utility-oriented perspective. This difference in perspective can cause a significant difference in each group's approach to computers and their use. Specifically, K-12 students and undergraduates see computers as gaming machines with minimal applicability as problem-solving tools. The opposite is true of the designers and researchers in many of these studies.

Designers and researchers keep creating learning environments (using information on motivation, learner variables, multi media, etc) in the hope of creating rich learning environments for young learners. Unfortunately, these learners want to be entertained, play games, and 'chat' with their friends, and the last thing on their mind is learning with the computer.

Therefore, there is a need to further study computer affordances. There is a fine line between aspects of design in technology that motivate and engage learners and those that distract them from learning what is important in the instruction. We have to find ways to move students from a 'game' affordance of the computer to a 'learning' affordance if we plan on propagating the use of computers in classrooms for learning.

Next we describe two studies where the affordances of the computer tool played a large role in the outcomes of the studies. We follow up with methods to change the game affordance to a learning affordance.

Research study 1: a pilot of web-based intelligent tutoring system (fifth–seventh grade)[1]

We created the Intelligent Tutoring for the Structure Strategy (ITSS) to teach fifth and seventh grade students a reading strategy called the Structure Strategy (Wijekumar & Meyer, in press). The Structure Strategy has previously been taught by human tutors and teaches learners that expository texts have six basic structures: comparison, problem/solution, cause/effect, description, sequence, and listing (Meyer *et al,* 2002). Originally, human tutors would model the use of the strategy by showing learners the signalling words, helping them write main ideas for the text passages, and then use the main ideas to construct a full recall of the text.

Our new system was designed using Flash to create an animated book-like web page with a talking head I.T., who spoke to the student in the role of a tutor. Figure 1 shows a sample of one of the pages designed. The system is interactive with I.T. modelling how to use the strategy, then giving students the chance to click on signalling words, write main ideas, write full recalls, choose from multiple choice answers, and provide immediate feedback to the learners.

The research presented here is a combination of pilot test data collected in spring 2004 and focus group conversations with students currently using the system.

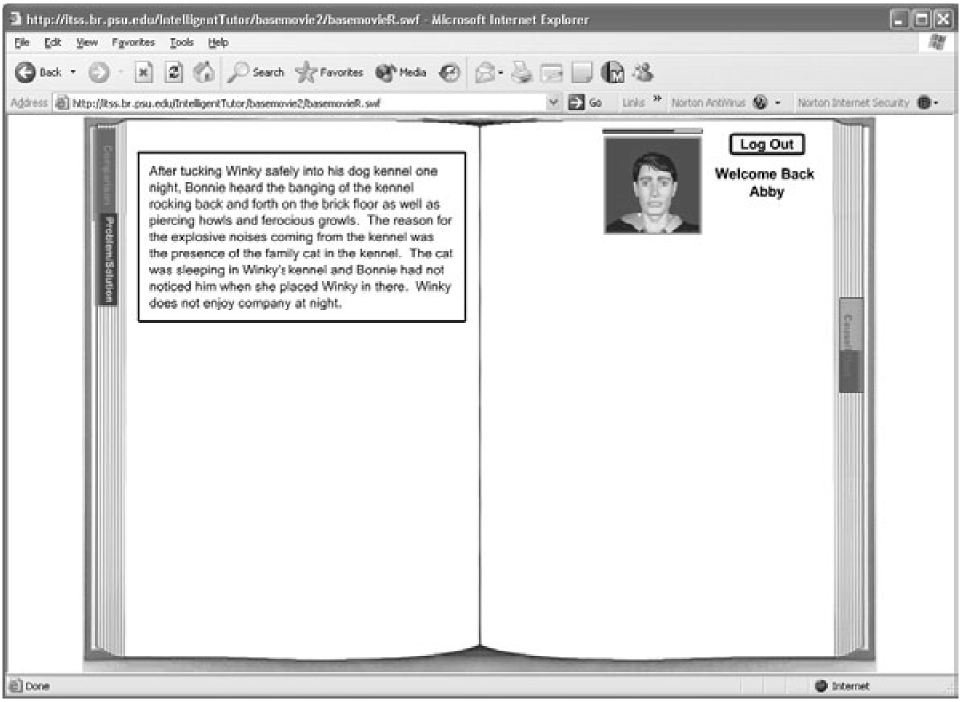

Figure 1: Sample screen from the Intelligent Tutoring for the Structure Strategy system

Research questions

- What computer tools are frequently used by fifth and seventh grade students?
- How is an intelligent tutoring system for a reading strategy viewed by fifth and seventh grade students?
- What affordance do computer tools support for students in Grades 5 and 7?

Participants

During the pilot test, 18 participants in Grades 4 through 8 were interviewed and observed. Twelve participants were males and 6 were females; 15 were white, 2 were African American, and 1 was Asian American. The participants were recruited through three school and university listservs. All participants owned computers at home and also used the computer in their school classrooms. All participants attended schools that have a minimum of one computer to four students ratio.

The focus group consisted of 28 students in fifth and seventh grades currently using the system in a long-term research study. There were 15 females and 13 males in this group. These participants were recruited through the school district and are a subset of over 200 students currently using the ITSS program in the school day.

Method

Participants completed an informed consent form and also surveys on their computer usage, self-efficacy, and demographics. After a short break and an introduction about the intelligent tutoring system, the participants individually worked through three lessons in the tutoring system.

After completing their interaction with the intelligent tutor and midway through the use of the ITSS in the schools, participants were interviewed about their experience. The conversation was open-ended, and participants talked about their prior experiences with computers as well as what they enjoy or dislike about computers. They also critiqued their interactions with the intelligent tutor.

Results

Students in both the pilot and focus group reported that I.T. was believable and looked interesting. They suggested that they would like to talk to I.T. about topics other than the reading strategy as well.

However, the students said that listening to I.T. for long periods of time or having to interact on a regular basis with I.T. can be boring because they would actually rather be playing games on the computer. One student reported how another computer learning tool was introduced in their school, and most students turned the learning environment into a game of trying to give as many incorrect responses as possible to the system. As these discussions continued, it was clear that the computer affordances for these students was that of a 'gaming' tool.

Results about computer affordances

Interviews with the focus group students yielded some other interesting findings about their computer affordances. All students reported using the computer to play games either on the Internet or using CD-ROMs. A notable statement was made by one of the fifth grade participants. He said:

> When I finish my work in class, my teacher usually lets me 'play' on the computer till my classmates finish their work.

This statement was echoed by all the fifth graders in some form.

Similarly, all the fifth graders said they spend at least 10 to 15 hours a week playing Nintendo, Playstation-type video games, or games on their computers. All children reported playing Internet based-games like racing, puzzles, and sports. Male students from all grades reported a high interest in war and racing games. Female students reported a high interest in chatting with their friends using Instant Messaging and games like Sims. None of the female students played racing or war games on their computers.

When asked whether they use the computer for anything other than games, they said they sometimes email their friends and check homework that their teacher posts on the World Wide Web (WWW). The time they spent on the school-related tasks were about 10 to 30 minutes a week compared with the 10 to 15 hours spent on games.

One student reported that as soon as she gets home, the first thing she does is log on to the computer and start talking to her friends. When asked about her homework, she said she talks and does homework at the same time. Four students in the group said that they post an away message and then do their homework.

We asked the students what they expected the tutoring system to behave like before they started, and they all said they thought it was going to be a game. They also said that a game would be more fun. When asked whether they can think of the system as a teacher instead of a game, they said they probably can do it, but would rather play a game. These ideas are captured elegantly in a statement by a seventh grader from the focus group currently using the system:

> When I sit down at a computer, I think of all the fun things I could be doing like games and talking to my friends, so I try to finish any other work as fast as possible so I can return to my games and talking.

At the conclusion of the short pilot test and focus group, the students were asked how they enjoyed using the system, and they all reported that they had learned something new. They also were surprised to hear about how texts were organised and felt they would use them in their reading and writing. However, they all said that they would rather play games on the computer than learn. They also stated that they sometimes do 'work' on the computer, but that is usually for short periods of time.

Discussion

There are three areas of interest in these results. First, the computer affordance for our sample population was clearly that of a gaming and communication tool. As reported earlier, these participants all had computers in their homes. When we interviewed students in the school that did not own computers at home, they appeared much more receptive to learning from the computer.

Second, Harp and Mayer (1998) have referred to 'seductive details' in learning environments that distract from the learning experience. Research has shown that when learners are faced with peripherally related or unimportant information about course content, they are distracted and perform poorly. Students with low prior knowledge and limited metacognitive skills are more distracted than their counterparts who have prior knowledge and the metacognitive skills to tell the difference between the important and unimportant details of their learning activity.

This brings us to a dilemma: games may be interesting and somewhat educational, but at what point are they more destructive to the learning environment than useful? Not all learning materials should be or can be formatted into a game to gain the attention of learners. Our topic of reading comprehension is complex and requires the learners to engage their minds in the process. So it is important to help students move from their 'gaming' affordance of a computer to a learning affordance to aid in their acceptance of the system.

Third, what techniques can be useful to help the students see the computer as more than a gaming tool? Two techniques were created to gradually move students to a learning affordance of a computer for our continuing research programme.

1. Students are given an introduction by the teachers that the intelligent tutor was going to be like a teacher and that they should expect the system to behave like a classroom experience. They were also told that they would get rewards when they reach critical milestones in their tasks. We also introduced additional incentives and motivational components (special fireworks-like display when they completed all lessons for one structure) to encourage the students to actively participate in using the system.
2. Metacognitive modeling by the intelligent tutor was also incorporated to focus on using the computer as a learning environment. The modeling included good practices in reading comprehension and using the Structure Strategy.
3. A third technique of adding a game at milestones during the ITSS program is being considered for future enhancements to our program.

Finally, these three techniques are only the beginning of a long-term strategy and discussion on how we approach the mismatch in K-12 learner affordances of computers and instruction. These concerns are not limited to K-12 learners but are evident in undergraduate and graduate students as well. The next study shows how undergraduate and graduate students enrolled in web-based distance learning classes managed their computer use and how they were affected by their computer affordances.

Research study 2: chat rooms in online learning environments

Two reasons prompted us to conduct this research study. First, we wanted to investigate the efficacy for learning of conversations in two types of online chat rooms. We compared agenda-driven chat room discussions versus social chat room discussions for depth of discussion, cohesion of conversations, and compared test scores of students immediately after. Second, distance learning environments have been growing at exponential rates. However, all research justification for continuing to propagate them comes from the 'no significant difference' studies showing that they are no worse or no better than traditional face-to-face learning environments (adapted from Lockee, Burton & Cross, 1999). But the real questions are not being considered and include:

1. whether we are doing some long-term damage to students' approach to learning;
2. whether students are actually engaging less in learning;
3. whether the whole learning process has changed; and
4. whether we need to train students to adapt to the new cognitive demands of the learning environments.

Are students who have grown up using computers to play games and communicate more likely to view web-based learning environments as extensions of these affordances and engage their minds less in problem solving and other higher-order tasks? 'Computer-based tasks often involve high cognitive load that might be susceptible to interference from interruptions' (p. 21, Baecker, Grudin, Buxton & Greenberg, 1995 in Speier *et al*, 1999). Are students keeping multiple windows open and having multiple conversations while engaging in a web-based discussion or chat room? How much time and concentration does it take to synthesise and really contribute to the discussion?

The second study sprang from these concerns. The research questions were:

1. What affordances do computers have for undergraduate and graduate students?
2. What techniques (cognitive and metacognitive) are used by successful students in managing their online learning experiences?
3. What roles do chat room discussions play in online learning environments?

Participants

A total of 77 undergraduate and graduate students enrolled in three different online classes participated in this study. The classes were in undergraduate nutrition education (two sections, with 21 and 22 students in each), undergraduate information technology (19 students), and graduate safety science (15 students); 41 participants were men and 36 participants were women. All the classes were designed by the same instructional designer and were orientated towards problem-based learning. Each 15-week course had approximately 10–12 learning modules. Each module was organised around a problem that the student had to solve using the resources and scaffolds provided by the instructor.

In each class, we introduced both agenda-driven- and social chat rooms (Wijekumar, 2001). In 15-week semesters, we conducted five agenda-driven chat rooms and five social chat rooms. The agenda-driven chat rooms had questions posted by the instructor, and students were asked to prepare their thoughts for the chat room. The instructors then followed a round-robin pattern to ask questions from the learners and provide feedback.

An example of a discussion question from the Safety Science class agenda-driven chat was, 'what methods can be used to reduce workplace violence?' Students were given 3 days to research the question and be ready for a focused discussion in the chat room. In the social chat, there were no agendas posted and discussion was frequently about social topics and sometimes about course requirements (details about projects that were due, etc).

Method

In order to compare discussion and learning outcomes, three independently trained raters coded all of the postings from chat rooms and examined the test scores of the students. The coded chat room discussions showed statistically significant differences in the contents of the agenda-driven chat rooms compared with those of the social chat rooms. Students in the agenda-driven chat rooms had deeper thoughts about the topics and more cohesive discussions about the content.

Next, we compared how much students remembered about topics that were discussed in the agenda-driven chat room versus the social chat room. Test scores were not significantly different for within-subjects comparisons of test performance. Even though the students in the agenda-driven chat rooms had significantly higher quality discussion (depth and cohesion) than the social chat students, we found that the recall of the discussion was a problem. The same group of students did not recall much from any type of chat conversations.

To delve deeper into why this phenomenon emerged, we interviewed four undergraduate students who performed well on the recall and four undergraduates who did not. The eight students were selected based on their performance in the tests and prior experiences with computers. Four students who remembered over 90% of the chat discussion were chosen. Two of the students reported they had over 10 years of experience using computers and use them daily. Of the four students who performed poorly in the recall of the chat discussion in the test (remembered less than 50% of content), three said they had used computers for over 10 years.

Students were interviewed about their activities in the online class. Specific interview questions included:

1. How many windows do you have open on your desktop when you are working in your online class?
2. What windows are usually active?
3. When you are conversing in a chat room, what other windows do you have open?
4. How much of the chat discussion do you read and how easy is it to synthesise the information?
5. What do you think you gain from the chat discussion?

Students were also asked specific questions about recent chat discussions to determine whether they actually remember information from the discussions.

We interviewed these eight students immediately after the agenda-driven chat room concluded and they had completed a test on that discussion. The discussion was about nutritional supplements, their effects on users, the effects of advertising on the usage of the supplements, and general questions about the class.

Results

All five participants with extensive computer experience used computers to play games and communicate with colleagues. Each had from 6 to 10 windows open on their desktop while doing any task. They included a web browser, two or three instant messaging windows, notepad/wordpad, and sometimes a game. They all stated that they multitask and switch their attention between all windows. When conversing in a chat room, they still continued to talk to other friends.

All students felt that the social chat rooms that were impromptu with student-initiated questions fell into two categories. The first type of discussion was social and did not have much to do with the course content but made them feel at ease with the instructor and colleagues. The second type of discussion was about grades and questions about specific tasks with which they were struggling.

All students felt that the agenda-driven chat room was focused towards learning. They explained that it felt like a classroom environment.

There was a clear pattern in three of the multitasking users' recalls. All were disjointed and missed many details of the conversations. Examples of the disjointed recalls and the well synthesised recalls are described next.

The two students who were novices at computer usage recalled twice as much information from the chat discussion as their multitasking counterparts. They also tended to organise their recall in themes that were similar to the instructor's content organisation.

Instructor: What supplement did you research?
Student A: Ginkgo Biloba
Instructor: Interesting, why did you pick this one?
Student A: I saw some advertisement saying that it improved memory so I picked it.
Instructor: What did you find?
Student A: I went to www.blueprintforhealth.com Gingko has been most commonly used to improve blood flow, treat memory loss, dizziness, and ringing in the ears. It can cause nausea and headaches, and is not suggested for use by those who suffer from allergies or hemophilia.
Student A: www.webmd.com Ginkgo may decrease the chances of conception by interfering with normal hormones. Gingko has also been used to increase lung inflamation, but may result in excessive bleeding to those who are taking blood thinners.
Student A: www.intelihealth.com Gingko has not been reviewed by the FDA. Because of this, their is a lack of information concerning the effects of taking Ginkgo Biloba in conjuction with other drugs.
Student B: I think my mother takes that supplement.
Instructor: Does it help?
Student A: www.fda.gov Gingko Biloba has been said to be a memory enhancer because it has been tested on people with alzheimer's disease and showed positive results. But, it has not been tested on people who do not suffer from this disease. Therefore, there is no evidence which suggests that Gingko also promotes good memory for the average person.
Instructor: Student A, do you think this is a useful supplement?
Student A: I was completely unaware that Gingko Biloba has negative effects on people with hemophilia and similar diseases. And it was shocking to me that it may also have negative affects on allergy suffers.
Instructor: Have you changed your opinion about it?

Student A: Before doing this research, I was under the assumption that Gingko was an entirely good thing. But, after see the number of affects it can have on people, I feel that the number of negative effects of taking this supplement outweigh the positive ones.

As shown in the sample discussion above , the novices outlined that there were four themes in the discussion. The first was how Gingko was portrayed in the advertisement as helping memory. Second, that the research showed that it worked with Alzheimer's patients but not proven in healthy humans. Third, that the possible negative effects of abnormal bleeding and allergies would be cause for concern. And finally, he also suggested that another student said his mother used the supplement.

Similarly, two of the computer-literate students who turned off the chimes on their Instant Messaging (IM) programmes and posted away messages when participating in the chat room remembered most of the discussion and organised their recall effectively.

On the other hand, three students with high computer skills and multiple windows open during their chat room summarised the discussion as 'Gingko can be ok for most people but can be dangerous'. Even when the interviewer prompted them for more information, they did not recall any of the specific details from the discussion.

These multitasking students were asked whether they were affected by their multiple conversations at the same time as their class chat rooms. They all reported that they did not feel interrupted or distracted in having 6 to 10 windows open and carrying on multiple conversations at the same time.

The one computer novice who performed poorly on the recall said that he had difficulty in reading all the postings and making sense of the discussion. He felt that the conversations on the agenda-driven chat room were more organised but still did not flow smoothly. This particular student was the first to request the logs of the chat rooms to be posted to the course web site. This allowed him to sort through the discussion and gather his thoughts on the topic without time constraints.

The discussion above continued with another student asking questions about whether this information would be on the next exam, and other students chiming in on peripherally related information like 'the FDA really should look at these types of claims more carefully' followed by another student saying 'the FDA cannot be reviewing everything, that is why there is a backlog for them'. This type of interaction in a short time frame requires students to process lots of information. The student suggested that the chat discussion put all the participants in one level of importance. He also said that in a traditional classroom, the teacher is usually in the role of the moderator and his/her presence was set apart from the presence and contributions of the students. However, in the chat room, all participants posted to the same text window, and even though the teacher's name was clearly visible, all postings competed for his attention with equal weight.

Result on computer affordances
The outcome of the tests, interviews with the students (high and low recall), and survey data collected at the beginning of the class all suggested that these students viewed computers as communication tools (to instant message friends, email colleagues), as gaming tools, and as resources for completing homework. One graduate student noted, 'I think I am different because I do not talk to everyone all the time on IM. When I am in the library or lab reading on the Internet, I see almost everyone else there talking to friends.'

Most of the undergraduate students reported using IM to talk to friends during the time they entered the course chat room, and some even reported continuing to play games.

Similar to our first study participants, this group of undergraduate and graduate online learners also saw the computer as a communication and gaming tool. Their affordance of the computer prompted them to multitask even at the expense of their learning.

Discussion
This study shows that undergraduate and graduate students enrolled in these online classes did use the chat room for learning. However, the students who had used computers for a long time tended to have multiple windows open on their desktop and then believed they were not affected by the multitasking. The results of their recall showed that their synthesis of the chat room was actually disjointed and quite incomplete.

Salomon and Almog (1998) report on a phenomenon called the 'Butterfly Defect' that can be caused by fractured knowledge building in hypermedia environments. The recall of the chat room discussion by the multitasking students can be an example of this concept.

The students who were novices and those that turned off their multiple windows synthesised the chat discussion quite differently. They organised their summaries very effectively and remembered twice as much information as their counterparts did.

Based on these findings, we introduced two elements to the online classes we developed. First, students were advised on how they should manage their learning in these online environments. They were given a written handbook that told them to limit the numbers of windows on their desktop, allocate time and concentrate on one task at a time, and try to summarise their understanding of the chat conversations to check their knowledge.

Second, the instructor posted the chat logs after they were edited to organise the discussion. This helped students go back and check their understanding and organisation. This method also helped the novice student who had difficulty reading the fast-paced chat discussion and synthesising all the communications in the short time frame.

General discussion

Computer technologies are here to stay, and are being used by young and old. However, the computer's affordance for these two groups is different. The studies reported here show that our participants in K-12, undergraduate, and graduate settings are more likely to play games, talk to friends, and multitask in the computer environment.

This research has started the process of answering the questions reported earlier.

1. Are we doing some long-term damage to students' approach towards learning? Students' orientation towards learning is different when computers are present because students in these studies say they multitask and attend to playing games and communicating while learning. Thus, the primary, learning task is interrupted and competes for memory with the secondary tasks like games and communication. In fact, the learning task may become secondary to the task of communicating with friends. Task switching increases the complexity of the learning situation and taxes cognitive resources, such as working memory, ultimately leading to poorer performance on learning tasks in the laboratory (eg Baddeley, 1996; Callicott *et al*, 1999). The second study in an authentic academic learning situation suggests that students remember less from their learning when they multitask. Some focus group students from the first study also said, 'Why do we have to remember anything anymore? We can always look it up'. This is another phenomenon that needs to be investigated. Pea (1985) has suggested that computer tools can be used to promote higher-order tasks while delegating the low-order, simple number crunching tasks to the computer. This statement from the focus group students makes us wonder whether Pea's hypothesis holds true for these learners.
2. Are students actually engaging less in learning? There is some reduction in the time spent on task versus other activities. However, Golub (2004) suggests that before computers allowed students to counteract boredom by playing games, reading emails, and instant messaging, others were distracted by crossword puzzles, doodling, and making up games, and their time spent on tasks was not any higher. However, the new tools on the desktop like instant messaging demand more attention and can be initiated by external sources and limit the engagement of the learner (Grinter & Palen, 2002).
3. Has the whole learning process changed? The studies reported here suggest that the computer affordances for the students are that of a gaming or communication environment. The learning process has changed. However, the long-term strategy may be to take advantage of the communication tools and games to help the students learn.
4. Should we train students to adapt to the new cognitive demands of the learning environments? The options are to train the students to adapt to the new cognitive demands or adapt to the learning environments to capture the affordances. Either option is limited by the current technologies. A combination of both approaches is probably a good compromise. Learners (specially those with poor metacognitive skills) should be educated about where and when they can use the technologies effectively and how they can most effectively and efficiently switch their focus from

the gaming mode to a learning mode. Technologies can be designed to engage the students through games but then gradually move them to a learning affordance. Technologies can also adapt to learners' motivation and stress levels to improve learning.

5. Finally, are students who have grown up using computers to play games and communicate more likely to view web-based learning environments as extensions of these affordances and engage their minds less in problem solving and other higher-order tasks? Is there a way to take these students' familiarity and preference for instant messaging and tweak it towards evaluation, analysis, and application to enhance learning? Further research will need to focus on answering these questions.

Conclusion

When constructing learning environments for K-12 and older student, designers, researchers, and teachers must look to balancing gaming and learning, engagement and distraction, and concentration and interruptions. The change from the gaming affordance to the learning affordance can play a critical role in learning outcomes and must be addressed immediately. Addressing the affordance issue can make the difference between a future society that can innovate and produce versus people who cannot think without a 'game'.

Notes

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References

Adams, D. D. & Shrum, J. W. (1990). The effects of microcomputer-based laboratory exercises on the acquisition of line graph construction and interpretation skills by high school biology students. *Journal of Research in Science Teaching, 27*, 6, 777–787.

Azevedo, R. & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research, 13*, 2, 111–127.

Baddeley, A. (1996). The fractionation of working memory. *Proceedings of the National Academy of Sciences, 93*, 13468–13472.

Baecker, R. M., Grudin, J., Buxton, W. A. S. & Greenberg, S. (1995). *Readings in human-computer interaction: toward the year 2000*. San Francisco, CA: Morgan Kauffman Publishers.

Berge, Z. L. (1990). Effects of group size, gender, and ability grouping on learning science process skills using microcomputers. *Journal of Research in Science Teaching, 27*, 8, 747–759.

Bonk, C. J. & Reynolds, T. H. (1992). Early adolescent composing within a generative-evaluative computerized prompting framework. *Computers in Human Behavior, 8*, 39–62.

Callicott, J. H., Mattay, V. S., Bertollino, K. F., Coppola, R., Frank, J. A., Goldberg, T.E., *et al* (1999). Physiological characteristics of capacity constraints in working memory as revealed by functional MRI. *Cerebral Cortex, 9*, 220–226.

Cañizares, C. A. & Faur, Z. T. (1997). Advantages and disadvantages of using various computer tools in electrical engineering courses. *IEEE Transactions on Education, 40*, 3, August, 1997.

Carter, G., Westbrook, S. L. & Thompkins, C. D. (1999). Examining science tools as mediators of students' learning about circuits. *Journal of Research in Science Teaching, 36*, 1, 89–105.

Coleman, J. N., Kinniment, D. J., Burns, F. P., Butler, T. J. & Koelmans, A. M. (1998). Effectiveness of computer-aided learning as a direct replacement for lecturing in degree-level electronics. *IEEE Transactions on Education*, *41*, 3, August, 1998.

DeJong, T., Martin, E., Zmarro, J., Esquembre, F., Swaak, J. & van Joolingen, W. R. (1999). The integration of computer simulations and learning support: an example from the physics domain of collisions. *Journal of Research in Science Teaching*, *36*, 5, 597–615.

Dixon, J. K. (1997). Computer use and visualization in students' construction of reflection and rotation concepts. *School Science and Mathematics*, *97*, 7, 352–358.

Fletcher, F., Claire, M. & Gravatt, B. (1995). The efficacy of computer assisted instruction (CAI): a meta-analysis. *Journal of Educational Computing Research*, *12*, 3, 219–241.

Golub, E. (2004). *On audiences activities during presentations*. Norfolk, VA: Consortium for Computing Sciences in Colleges.

Grinter, R. E. & Palen, L. (2002). Instant messaging in teen life. *Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work*, November 2002. New Orleans, LA. New York: ACM Press, 21–30. Retrieved April 23, 2005, from http://www.isr.uci.edu/~jpd/classes/ics234cw04/grinter2.pdf#search='grinterinstant%20messaging%20in%20teen%20life'

Harp, S. F. & Mayer, R. E. (1998). How seductive details do their damage: a theory of cognitive interest in science learning. *Journal of Educational Psychology*, *90*, 3, 414–434.

Kelly, G. J. & Crawford, T. (1996). Students' interaction with computer representations: analysis of discourse in laboratory groups. *Journal of Research in Science Teaching*, *33*, 7, 693–707.

Kozma, R. B. & Russell, J. (1997). Multimedia and understanding: expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching*, *34*, 9, 949–968.

Lee, J. (1999). Effectiveness of computer-based instructional simulation: a meta analysis. *International Journal of Instructional Media*, *26*, 1, 71–85.

Lindström, B., Marton, F., Ottosson, T. & Laurillard, D. (1993). Computer simulation as a tool for developing intuitive and conceptual understanding in mechanics. *Computers in Human Behavior*, *9*, 263–281.

Lockee, B. B., Burton, J. K. & Cross, L. H. (1999). No comparison: distance education finds a new use for 'no significant difference'. *Educational Technology Research and Development*, *47*, 3, 33–42.

Lou, Y., Abrami, P. C. & D'Apollonia, S. (2001). Small group and individual learning with technology: a meta-analysis. *Review of Educational Research*, *71*, 3, 449–521.

Mayes, R. L. (1995). The application of a computer algebra system as a tool in college algebra. *School Science and Mathematics*, *95*, 2, 61–67.

Meyer, B. J. F., Middlemiss, W., Theodorou, E. S., Brezinski, K. L., McDougall, J. & Bartlett, B. J. (2002). Older adults tutoring fifth-grade children in the structure strategy via the Internet. *Journal of Educational Psychology*, *94*, 3, 486–519.

Norman, D. A. (1998). *The invisible computer*. Cambridge, MA: MIT Press.

Pea, R. D. (1985). Beyond amplification: using the computer to reorganize mental functioning. *Educational Psychologist*, *20*, 4, 167–182.

Roth, W. M. (1995). Affordances of computers in teacher-student interactions: the case of interactive physics. *Journal of Research in Science Teaching*, *32*, 4, 329–347.

Roth, W. M., Woszczyna, C. & Smith, G. (1996). Affordances and constraints of computers in science education. *Journal of Research in Science Teaching*, *33*, 9, 995–1017.

Salomon, G. & Leigh, T. (1984). Predispositions about learning from print and television. *Journal of Communication*, *34*, 2, 119–135.

Salomon, G., Globerson, T. & Guterman, E. (1989). The computer as a zone of proximal development: internalizing reading-related metacognitions from a reading partner. *Journal of Educational Psychology*, *81*, 4, 620–627.

Salomon, G. (1990). Cognitive effects with and of computer technology. *Communication Research*, *17*, 1, 26–44.

Salomon, G. & Almog, T. (1998). Educational psychology and technology: a matter of reciprocal relations. *Teachers College Record*, *100*, 1, 222–241.

Speier, C., Valacich, J. S. & Vessey, I. (1999). The effects of task interruption and information presentation on individual decision making: an information overload perspective. *Decision Sciences*, *30*, 2, 337–360.
Wijekumar, K. (2001). *Can chat rooms be more than social gathering places?* Paper presented at the American Educational Communications Technology Conference, Atlanta, GA.
Wijekumar, K. & Meyer, B. J. F. (in press). Design and pilot of a web-based intelligent tutoring system to improve reading comprehension in middle school students. *Journal of Computers in Schools*.
Williamson, V. M. & Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching*, *32*, 5, 521–534.
Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science*, *21*, 2, 179–217.