CATS: A Tool for Identifying the Cognitive Affordances of Learning Technologies

Nada Dabbagh
Professor & Director
Division of Learning Technologies
College of Education and Human Development
George Mason University
4400 University Drive, MS 5D6
Fairfax, VA 22030

Susan Dass
PhD Candidate, George Mason University
7111 Woodglen Court
Fairfax Station, VA 22039

Abstract

This paper describes the development of CATS or Cognitive Affordances of Technologies Scale, a tool that can aid faculty, instructional designers, and e-learning specialists in identifying and leveraging the cognitive affordances of a learning technology. CATS includes seven multi-disciplinary research supported categories of cognitive affordances that can be harnessed to enrich student learning experiences in technology supported learning environments: experiential learning, discourse or dialogic learning, supportive learning, learn by doing, critical thinking, conceptual change, and self-regulated learning. Each category contains a list of cognitive criteria and each criterion is operationally defined and cited. Results of using CATS to analyze a technology supported learning environment are described. Implications for using CATS as a design and evaluation tool are discussed.

Introduction

The purpose of this research was to develop and evaluate a tool called CATS or Cognitive Affordances of Technologies Scale that can aid instructional designers, e-learning specialists, and faculty in identifying and leveraging the teaching and learning affordances (instructional attributes) of a learning technology. Specifically, CATS can be used as a tool to support and promote the design of courses that enrich student learning by harnessing the pedagogical and cognitive affordances of a learning technology. We describe the methodology used to develop CATS and present the results of its application in a technology supported learning environment (TSLE). The TSLE was an upper level undergraduate Economics course that used the immersive virtual world Second Life and simulation software as learning technologies to augment classroom instruction. Educational implications and future research goals are also discussed.

Theoretical Framework

Several researchers and practitioners in higher education have argued that course design and delivery technologies such as Learning Management Systems (LMS) have consistently emphasized faculty dissemination and administrative tools over student learning tools and technological convenience over pedagogical effectiveness (e.g., Harasim, 1999; Marra & Jonassen, 2001; McLoughlin & Lee, 2010; Valjataga, Pata, & Tammets, 2011; van Harmelen, 2007). Additionally, researchers have found that most faculty use technology for administrative rather than instructional tasks because they don't feel prepared or are not getting the technical or pedagogical support needed to develop effective instructional designs using technology (Dabbagh & Reo, 2011; Harrison, 2011). Compounding the problem is the fact that learning technologies are advancing at a rapid pace and understanding their cognitive and pedagogical affordances or instructional attributes is becoming increasingly challenging and complex (Milne, 2007). Furthermore, faculty, instructional designers, and e-learning specialists and administrators...
are continuously under pressure from their respective institutions and organizations to deliver more courses and programs online and to integrate innovative learning technologies and digital resources into the teaching and learning process in order to address student and market demand (Dabbagh & Reo, 2011). Given these technological and pedagogical challenges the question we engaged was, how do we facilitate and accelerate the process of understanding the **affordances** of learning technologies in order to help faculty (and other stakeholders) design quality courses that enricht student learning experiences?

The concept of affordances was first introduced by James J. Gibson in his 1977 article *The Theory of Affordances*. An **affordance** is a quality of an object, or an environment, that allows an individual to perform an action (http://en.wikipedia.org/wiki/Affordance). Greeno, Collins, & Resnick (1993) describe the inherent relationship between affordances and abilities as follows: “a situation can afford an activity for an agent who has appropriate abilities, and an agent can have an ability for an activity in a situation that has appropriate affordances (p. 114)”. This mutually exclusive relationship emphasizes perception and action rather than memory and retrieval and is considered an ecological approach to psychology or perceptual psychology (Hutchins, 2010; Greeno, 1994). According to Gibson, action and perception are linked through real-world objects that afford certain forms of action possibilities (affordances) for particular individuals or organisms (Albrechtsen, Andersen, Bodker, & Pejtersen, 2001). Simply put, affordances are the interactions between users and tools. Gibson’s theory of affordances has direct implications on learning technologies because it emphasizes the non-neutrality of the learning space and prompts designers to consider the expectations and potentials that each learning medium brings forth to the teaching and learning process (Dabbagh, 2004). Affordance-based design has been used in a variety of disciplines however our focus in this research is on the cognitive affordances of a learning technology. A cognitive affordance is a design feature that helps, aids, supports, facilitates, or enables thinking and/or knowing about something (Hartson, 2003). Cognitive affordances are considered one of the most significant user-centered design features of learning technologies and have been shown to impact students’ learning (Graver, 1991; Wijekumar, Meyer, Wagoner, & Ferguson, 2006).

For example, Allaire, Laferrier, & Gervais (2007) examined pre-service teachers’ perceptions or recognitions of the social and digital affordances of a networked learning environment designed to support and promote collaborative reflection and knowledge building activities. Social affordances were defined as human-to-human interactions mediated by technology such as an electronic forum and digital affordances were defined as human-machine interactions such as hard scaffolds (static learning supports that are embedded or built-in the software). The results revealed that social affordances were acknowledged or recognized by participants more quickly than digital affordances and that social affordances prompted more deliberative and critical levels of discourse than did digital affordances. Wijekumar et al. (2006) used two computer technologies to examine fifth and seventh grade students’ perceptions of their cognitive affordances; the first was an animated and game-like intelligent tutoring system designed using Flash to teach students a reading strategy and the second learning technology involved two types of chat rooms, agenda-driven and social chat. The results revealed that participants perceived computer technologies as communication tools, gaming tools, and as resources for completing homework. In other words, students in this sample population did not perceive computer technologies as learning tools. These results suggest that more research is needed to support affordance-based design that evokes meaningful and engaged learning. Hence, the focus of our research was to leverage the theory of affordances to develop a tool for identifying and purposively applying the cognitive affordances of learning technologies in course designs.

**Development of CATS**

CATS was developed in a doctoral course that examined the interaction between cognition and technology using multiple disciplinary perspectives including, cognitive science, psychology, neuroscience, education, design theory, instructional design, technology design, anthropology, sociology, information science, philosophy, semiotics, linguistics and other applicable fields.

We used a highly inductive mode of inquiry while remaining focused on the core of the issue which is how to facilitate the understanding of cognitive affordances of learning technologies in order to support the design of quality courses that enrich student learning experiences. This qualitative inquiry process began by identifying organizing frameworks for cognition gleaned from the course readings (see Bransford et al., 2000; Glaser & Chi, 1988; Greeno et al., 1996; Laourillard et al., 2000; O’Donnell et al., 2006; Rumelhart, 1980; Thagard, 1996; Sawyer, 2006) which included behaviorist/empiricist; cognitive/rationalist; and situative/pragmatist. Next we identified 99 cognitive criteria using these conceptual frameworks and organized these criteria using emergent themes through successive approximations and iterations. Initially, these themes included designing learning environments, constructing assessment, motivation, metacognition, self-regulated learning, and collaborative learning.
We then examined the cognitive affordances of the research-driven TSLEs provided in the course readings. Specifically, we examined the learning interactions enabled by these TSLEs and whether these interactions aligned with the themes and cognitive criteria we generated. This process yielded additional themes and cognitive criteria. We then revised and refined the themes and cognitive criteria resulting in the first draft of CATS which stands for Cognitive Affordances of Technologies Scale. A second draft of CATS followed after (a) revisiting the course readings for additional cognitive criteria, and (b) finding additional scholarly articles (e.g., Hartson, 2003; Jonassen & Land, 2000; Kim & Reeves, 2007; Graver, 1991) that address cognitive affordances of learning technologies. The current draft of CATS consists of seven categories and 41 cognitive criteria (see http://cehdclass.gmu.edu/ndabbagh/Resources/IDKB/CATS.html). The seven categories are: experiential learning, discourse or dialogic learning, supportive learning, learn by doing, critical thinking, conceptual change, and self-regulated learning. Each category contains a list of cognitive criteria and each criterion is defined and cited as well as examples of learning technologies that can be used to support the criterion. For example, the category ‘conceptual change’ involves instructor supported activities that purposely evoke a change in a student’s understanding of concepts and principles in the context of their existing knowledge; it is not a matter of simple skill acquisition or fact memorization (diSessa, 2006). The five cognitive criteria under the conceptual change category are: elicit prior knowledge, beliefs, and perceptions; bridge current idea to normative or new ideas; use pivotal cases; use anchoring experiences; and promote transfer. Each criterion is defined. For example, use of anchoring experiences provides a common experience from which a group can discuss and construct new knowledge (Krajcik & Blumenfeld, 2006). We used a wiki (https://edit802fall10.pbworks.com/w/page/28545057/EDIT-802) to document the iterative process of developing CATS. We also developed the following guidelines for using CATS as an analysis and design tool:

1. Begin by listing the design features of the learning technology you are using or thinking of using (e.g., an LMS);
2. Use CATS to observe a TSLE that uses this learning technology and analyze its cognitive affordances based on the following scale:
   - **Used and observed**: TSLE supports the cognitive affordance; it is used by the instructor and observable to the reviewer.
   - **Used but not observed**: TSLE supports the cognitive affordance; it is used by the instructor but it is not observable to the reviewer.
   - **Not used but available**: TSLE supports the cognitive affordance but the instructor did not use it.
   - **Not available**: TSLE does not support the cognitive affordance.
3. Identify the design feature(s) that engendered the affordance within the specific TSLE.

**CATS Applied to a TSLE**

Using these guidelines, CATS was applied to a TSLE to determine its viability in facilitating understanding of the cognitive affordances of learning technologies. The following subsections describe the selected TSLE for analysis, the learning technologies employed, the TSLE observation process, and the results.

**TSLE Description**

Economics of the Metaverse is an undergraduate, upper level, elective course requiring microeconomics and macroeconomics as prerequisite courses. The overarching course objective is to allow students to experience different intermediate level microeconomic concepts through role-playing so the student can ultimately discuss the concepts from a firsthand perspective. The course is intended to illustrate the applied and behavioral aspects of each concept using two learning technologies: simulation software and 3D avatar-based virtual worlds. The simulation software allows players (students) to participate in a variety of economic markets and games. For example, one game simulates a type of auction that allows players to try different strategies and experience bidding behavior whether one-on-one or one amongst a group. TerraEconomicus, a private Second Life island, provides a closed space for the students to access lecture slides, take quizzes, and socialize. Additionally, three private islands each support an economic experiment that allows the students as a group to experience the target concept. Besides these private islands, the course takes advantage of the public Second Life virtual world by directing students to specific locations to observe behaviors and actions associated with a specific economic concept.

The course covers six economic concepts. The first five concepts are reviewed using lecture slides, a virtual world field trip, and a group discussion of the activities and assigned readings. Depending on the concept, different simulations and virtual world experiments were used to illustrate the concepts. In total, four simulations were
accomplished for each of four concepts and four virtual world experiments were conducted for three concepts. The sixth (last) concept only used a virtual world experiment and two class discussions.

The class meets twice weekly in a computer lab for 1.25 hours each session but in hybrid format. Although class sessions intended for lecture slides and field trips are designated in the course schedule, real-world physical class attendance is not required for these sessions. However, the room is still available with instructor present should the student prefer to use the computer lab to access the virtual world at that time. The remaining class sessions intended for the simulations, virtual world experiments, and class discussions require real-world attendance. Although the simulations and virtual world experiments are online, real-world attendance is required to ensure minimum technical difficulties.

Students are randomly assigned to small groups (3 or 4 students) to visit the in-world lecture slides and go on joint field trips. Groups are re-assigned during the course. Individual written assignments include a 500-word paper per economic concept and a 10-page final paper. Group written assignments include providing questions for class discussion and a report for each field trip.

Technology Description

Two technologies were used in the course, albeit one having two instantiations to target two different purposes: the simulation software, the publicly accessible virtual world Second Life, and TerraEconomicus, a private virtual world using Second Life as the platform. The following describes each technology.

Technology: Simulation Software. Multiple economic simulation games are available online as part of what is called the VeconLab (Holt, 2005) although the course uses its own version in order to retain data entries and results. The software supports customization by the number of participants such as for randomly selecting one-on-one bidding or allowing multiple players in a single game session. As shown in Figure 1, the software uses a simple, two-dimensional interface, in this case for a one-on-one auction game. Each game requires two or more players to submit 'bids' or 'claims' across a number of rounds that in turn impacts their ultimate payoff (win). The software records all data entries and winning results.

Technology: Virtual World – Second Life. A virtual world is an online, persistent, 3D, interactive animated environments accessible by many users simultaneously (de Freitas, 2008; EDUCAUSE, 2006). Individuals, represented by avatars, control their in-world actions whether to move, communicate, collaborate, create, or socialize in-world (EDUCAUSE, 2006; Robbins & Butler, 2009). Many different kinds of virtual worlds exist, offering role-playing games, procedural training and simulation, and socialization. This economics course uses a social world, Second Life, which emphasizes communication and community building. Second Life requires login through an interface called a viewer. Second Life is a publicly accessible environment. In this course, students are directed to locations to observe economic behaviors.

Technology: Virtual World – TerraEconomicus. TerraEconomicus is comprised of four islands created specifically for this course and for economic experiments. Although flying is supported on the main island, the experiments do not support flying as all movement is done by walking or running. The following summarizes the main island containing the skybox lectures and two experimental islands. The TerraEconomicus Main Island provides a covered auditorium-style seating area and areas to socialize such as participate in a game. Houses are
used to contain information and provide teleport from the house to the associated skybox lecture. Each economic
calendar has a house. The purpose of other parts of this island is not known as well as the objects found underwater.
Figure 2 provides a view of one house (for orientation) and the covered auditorium-style seating area.

Figure 2 TerraEconomicus Main Island – House for Orientation and Covered Auditorium-Style Seating

Tiki Island is a separate area dedicated for experiments. For this island, the experiment premise is that each
student is assigned a house on one of two sub-islands. Each student’s house is capable of producing two of four
available colored seeds. Students can fertilize their two seeds differently to produce different amounts of each
colored seed. Students are given a value for seeds, for example, two red seeds and one blue seed, may be worth a
L$1.00 to them. However, they may be producing red seeds and green seeds. Hence, going to market to trade their
seeds with other students is how the student earns money. It is designed so that the opposite island has more
opportunity to produce a particularly valuable seed. Additionally, one student is awarded a key to the other island
which then also becomes tradable. If the experiment runs repeatedly, the results should indicate that only producing
one color seed and trade for the other color seed needed is economically advantageous, i.e., focus on niche markets.

Hurricane Island is also dedicated to a particular experiment. In this experiment, each of the eleven students
has a house on an island subject to damage causing hurricanes. Each student earns money at a rate commensurate
with the amount of damage their house has; the lower the damage, the higher the earning rate. Weather stations exist
that can provide 100% protection if manned properly, that is, manned with three or four students depending on the
weather station; less students mean less percentage protection. Students can also choose to remain in their house to
individually defend against a hurricane but at a reduced rate. Subsequent repair time reduces the time available to
earn money. The students make the choice of uniting to defend their houses, perhaps taking turns to man a weather
station, or individually defend their houses.

TSLE Observation Process
Six real-world class sessions were attended. These included observing the Second Life orientation class,
one software simulation on auctions, two different Second Life experiments, and two class discussions. During the
Second Life orientation class, the reviewer participated in-world for a brief period for a first person perspective.
Four virtual world sessions were accomplished independent of the class, including completing the Second Life
orientation class activities embedded in a skybox lecture, reviewing two additional skybox lectures on two different
economic concepts (but not the quiz), and conducting a field trip to an instructor-provided virtual world auction site.
Real-world class observation of the software simulation and the two virtual world experiments allowed the reviewer
to peer over the shoulder of each participant to see what each person was doing from their first-person perspective,
i.e. seeing what they were seeing. During all real-world class observations and independent virtual world sessions,
the observer maintained notes on all activities; this included directions and comments made by the instructor as well
as student comments and questions. Since this was a hybrid course that relied on real-world class time and two
different technologies (simulations, virtual worlds), each technology was evaluated separately to determine whether
different cognitive affordances were supported. It was anticipated that the classroom may also offer different cognitive affordances, hence the classroom was evaluated as a separate learning environment based on class discussion as well as the affordances associated with the written assignments.

Analysis of the TSLE Cognitive Affordances

The cognitive affordances of the TSLE were evaluated using CATS. Evaluation meant noting if each cognitive affordance was: (1) used and observed, for example, feedback was provided automatically in the simulation and the virtual world while the instructor also provided feedback; (2) used but not observed, for example, collaboration was used but not observed, in that, the virtual world group field trips were accomplished outside the class that required a group paper to report findings but the activity was not directly observed; (3) not used but available, for example, independent exploration of Second Life could have been promoted but was not; or (4) not available, for example, the 2D simulations did not support collaboration or reflection. The results of this evaluation for each learning environment (class (Cl), virtual worlds (VW), and simulation (Sim)) are provided in Table 1. The analysis of the TSLE results for cognitive affordances is discussed by the seven major CATS categories.

Experiential Learning

In experiential learning, students are provided an authentic problem to generate hypotheses, gather information, and provide solutions, action plans, recommendations, and interpretations of situations (Dabbagh & Bannan-Ritland, 2005). This course used experiential learning extensively. The virtual world experiments afforded opportunities to problem solve. The experiments were scenario-based challenging the students to maximize earnings for the given conditions which represented an authentic but simplified economic context. Both the simulation and virtual world experiments supported hypothesis generation in that students developed action plans in accordance with their hypothesis on how to improve earnings. The technologies provided repeated cycles for students to act and react to test their hypotheses and re-strategize as appropriate. Additionally, the simulation and virtual world experiments provided opportunities to role-play as an auction bidder, a small business owner, and a home owner. If one considers the student’s development of new strategies as the generation of new ideas, then both the simulation and experiments supported this affordance. Similarly, the simulation and virtual world experiments supported experimentation through the ability to test new strategies.

Table 1 - CATS Economics of a Metaverse Observation Results

<table>
<thead>
<tr>
<th>COGNITIVE AFFORDANCE</th>
<th>Used, Observed</th>
<th>Used, Not Observed</th>
<th>Not Used, but Available</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiential Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Solving</td>
<td>X</td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Hypothesis Generating</td>
<td>X X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Exploration</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Role Playing</td>
<td>X X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Generate New Ideas</td>
<td>X X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Experimentation</td>
<td>X X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Teacher-Guided Discovery</td>
<td></td>
<td></td>
<td>X X X</td>
<td></td>
</tr>
<tr>
<td>Inquiry-Based</td>
<td></td>
<td></td>
<td>X X X</td>
<td></td>
</tr>
<tr>
<td>Discourse/Dialogue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaboration</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Reflection</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Multiple Perspectives</td>
<td></td>
<td></td>
<td>X X X</td>
<td></td>
</tr>
<tr>
<td>Articulation</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Supportive (instructor or system)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coaching</td>
<td></td>
<td></td>
<td>X X X</td>
<td></td>
</tr>
<tr>
<td>Scaffold</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Modeling</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Explaining</td>
<td></td>
<td></td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td></td>
<td></td>
<td>X X X</td>
<td></td>
</tr>
</tbody>
</table>
Although students strategized and observed the effects of their actions in an authentic environment, they did not frame questions to be solved. Therefore, exploration was not considered available in the simulation and experiments. However, Second Life might afford the opportunity for exploration. Teacher guided discovery and inquiry-based learning was also not available in the simulation and the virtual world experiments as it is not appropriate for the purpose of those specific instructional activities. Second Life could afford the instructor providing insights and guidance if so desired as well as possibly creating an inquiry-based problem to be addressed but that would need to be investigated.

**Discourse / Dialogic Learning**

Dialogic learning emphasizes social interaction through discourse, dialogue, conversation, and social negotiation (Dabbagh & Bannan-Ritland, 2005). The simulation did not support discourse or dialogic learning. The virtual world experiments did not support collaboration, articulation, or reflection. Although the virtual world experiments relied on students working cooperatively using text chat, it was to maximize earnings, not to achieve shared understanding. Collaboration, articulation, and reflection was however supported in the field trips since students were required to visit instructor-provided Second Life sites as a group to observe an economic behavior and subsequently provide a group report in response to instructor-provided questions. Since these field trips are conducted in-world at a time selected by the student group, it was not observed and unknown if the students discussed the questions while in Second Life or used other means.

Reflection was afforded through the group field trip reports and the 500-word papers per concept as some instructor-provided topics were reflective in nature. For example, one question available for the paper inquired about the institutional features that were present or absent during the Hurricane Island experiment that promoted / inhibited coordination on group weather defense. Real-world class discussions were also reflective in nature at
times, requiring students to articulate their personal perspective. Multiple perspectives were also provided in the readings. Since a web browser can be opened in Second Life, other means to directly add reflection to the technology is possible such as accessing a blog or uploading documents. Multiple perspectives could also be afforded by providing multiple Second Life sites that exhibit different perspectives to an economic concept.

Supportive Learning (instructor or system initiated/driven)

These cognitive affordances are initiated by the expert, coach, mentor, instructor, or embedded performance support system, with the goal of modeling the desired performance, skills, or process, and observing and supporting learners during their execution of a learning task (Kitsantas & Dabbagh, 2010). The simulation only provided one supportive learning affordance, feedback. At the end of each simulation game, the student is informed of their earnings and also the highest earnings recorded. The student can mentally assess how well their strategy worked through comparison of results. This type of feedback does not address corrective action or suggest future strategies, indicating the feedback could be improved for deep learning. The virtual world experiments supported modeling and feedback. The experiments themselves were models of economic principles that allowed the students to experience those concepts. Similar to the simulation, feedback informed the student of their current earnings but without recommended improvement or alternative strategies. The TerraEconomicus skybox lectures provided explaining and the use of visuals through text and graphics. The graphics represented mathematical equations and relationships governing different economic concepts. During one class discussion, the instructor provided a graphic display of student results from the Tiki Island experiment to illustrate the results of their negotiating for the buying and selling of their product (seeds) as compared to the theoretically predicted relationship. This same graphical comparative approach was used to illustrate the effects of personal valuation of goods relative to the community’s utility value. The instructor also used scaffolding by providing verbal hints to help the students articulate their thoughts and bridge to normative explanations. Task breakdown was not considered applied although the course syllabus breakout into six economic concepts might be considered as such.

Learn by Doing

In learn by doing, students apply the objective concepts and skills in a realistic activity which develops the student’s expert knowledge construction via experience (Cobb & McClain, 2006; Greeno et al., 1996; Koedinger & Corbett, 2006). The simulations, experiments, and field trips were relevant to the course but may or may not be personally relevant to the individual. With monetary generating web sites such as ebay and craigslist, and the notion of real-life negotiating for products such as automobiles, it would seem some activities would be considered personally relevant. However, for at least two students during the Hurricane Island experiment, the notion of public defense for home ownership did not seem personally relevant based on their observed behavior. One student chose to not earn money and expressing that the rewards did not warrant an effort to earn money. Another in that same experiment purposefully did not participate in the group defense fully recognizing this as aberrant behavior as indicated by comments made at the end of the experiment. That being said and assuming engaged participation indicates personal relevance then the activities were relevant to most students. It is unknown if attending an auction for horses (field trip) would be relevant to the students. In the end, it was decided that the simulations and virtual world activities were relevant as well as authentic, i.e., these types of economic decisions exist in the real-world.

With regards to the cognitive affordance of context situated, the simulation was not set in a meaningful context; it was a simple computer game to illustrate auction activity. The virtual world experiments and field trips were context situated albeit the experiments were provided in a simplified context to highlight specific economic concepts. Real-life may embody these economic concepts but not in such a simplified manner by reducing influential variables. For example, during Hurricane Island, some students spoke about wanting a means to trade and negotiate for time spent in the group defense weather station. Others were noted as being opportunistic by reaping the benefits of group defense but not personally contributing time. In real-life, economic policy as well as personal interaction may promote entire group participation. These types of accountability balances and checks were not supported in the experiment. No activities provided an opportunity to explicitly externalize personal knowledge by building artifacts.

Critical Thinking

Critical thinking involves processing of collected information including behaviors reasoning, deciding, analyzing, synthesizing, critiquing, and arguing (Paul, 1995). Decision making and analysis were observed in the simulations and virtual world experiments as evidenced by the choices students made based on the information provided to them. The technologies themselves did not support synthesis, critique, or constructing an argument. However, the class discussion did provide the forum to analyze their behaviors within the context of the readings.
and to synthesize into a more coherent representation of the economic concept. Additionally, the assigned papers provided another opportunity to develop critical thinking skills through analysis, synthesis, critique, and argumentation in written form.

Conceptual Change

Conceptual change involves teacher supported activities that purposely invoke a change in a student’s understanding of concepts and principles in the context of their existing concepts; it is not a matter of simple skill acquisition or fact memorization (diSessa, 2006). The instructor conducted a pre-course survey of student technological familiarity but it is unknown if student prior knowledge of the target economic concepts were solicited. The course requires a microeconomics and macroeconomics course as prerequisites but it is not validated as noted by the instructor. Additionally, eliciting for prior knowledge via survey may only reveal a student’s perception of their knowledge. Eliciting prior knowledge through student externalization is more indicative of their understanding (Bransford et al., 2000). It is unknown if the first class included explicit exhibition of prior knowledge. The class structure and format of the simulation and virtual world experiments appears to preclude customization to student’s current knowledge (although the domain expert may best assess if customization is possible). The skybox lectures contained pivotal cases to support an economic concept through text and graphic representation. The course used multiple anchoring experiences from the simulation, virtual world experiments, and field trips that were made reference to during class discussion. Transfer was not afforded by the technologies, that is, there was no opportunity to re-apply what was learned to new contexts or situations. The concept on auctions could be supported if actual bidding were conducted during the field trip, that is, re-apply what they learned from the auction simulation. Through class discussion, the instructor promoted bridging the students’ articulated ideas to normative ideas, translating novice representations to expert terminology and at times using examples to transfer concept application across different domains such as buying an automobile as another example of price negotiation.

Self-Regulated Learning

Self-regulated learning is goal oriented actions that an individual uses to acquire knowledge and skills without relying on others; the learner orchestrates one’s own learning by planning, monitoring and correcting errors (Kitsantas & Dabbagh, 2010). The simulation and virtual world experiments only supported motivation, intrinsic and extrinsic, as affordances for self-regulated learning. Both technologies provided extrinsic motivation in the form of awarding monetary earnings per student. The earnings are paid to the student in Second Life Linden dollars. Second Life has a real economy with purchasable virtual items. Linden dollars can also be exchanged for US dollars; L$270 is worth approximately US$1 as per the instructor. Awarding student earnings was done purposely as motivation for students to actively participate in the simulations and experiments as opposed to passive participation. However, as one student noted, their current earnings was worth about US$0.30. While low in real-life purchasing power, it may be of more value in Linden dollars. So what might have the appearance of extrinsic motivation is actually dependent on a student’s personal valuation of the earnings. With regards to intrinsic motivation, the simulation and experiments may provide a challenge or curiosity that increases a student’s motivation through curiosity to investigate different strategies and determine their impact. Interestingly, the instructor verbally noted that students should be intrinsically motivated to actively participate in the simulation and experiments as they are a means to learning about economic principles. Lastly, the instructor supported time management by verbally stating upcoming assignment due dates during class time and also stated emails were sent class-wide with the same information.

TSLE Cognitive Affordances – Conclusions and Recommendations

Economics of a Metaverse provided multiple opportunities for cognition. In accordance with CATS, 29 of 41 cognitive affordances were observed within the learning environment (albeit two not directly observed). Three of the seven categories were completely addressed by all cognitive criteria indicators. Three categories had at least 61% of the indicators addressed. One category, self-regulated learning, was the least addressed with only three out of eight indicators addressed. Some of the 12 missed (unaccounted) opportunities for cognitive affordances may be a reflection of course content and learning objectives. For example, as the course content was not procedural or task oriented, the need for coaching may be limited. Additionally, if one’s epistemological belief holds that building artifacts is strongly related to deep learning, then the category of discourse / dialogic could be improved.

It is important to note the cognitive contribution of each technology and the classroom to the overall cognitive affordances of the learning environment should the course be updated. The simulation contributed the least amount of cognitive affordance, with discourse / dialogic being completely void; indicating the need for these types
of simulations to not be left stand-alone activities without additional supporting cognitive affordances. The classroom (discussion and papers) and virtual world (experiments, field trips, and skybox lectures) provided nearly the same amount of cognitive affordances but were strong in different categories. The virtual worlds provided ample cognitive opportunities through experiential learning, supportive, and learn by doing. Where the classroom environment was void of experiential learning and learn by doing, it was however rich in supportive and discourse/dialogic opportunities. One could argue that the virtual world activities were classroom activities, but for the purposes of understanding the contribution of the individual technology components to the overall learning environment they were separated.

Some simple changes could be made to this course to improve its cognitive affordances in accordance with CATS. Additionally, given that students (1) expressed concerns over lack of time to forge business partnerships and develop individual responsibility for group defense; (2) indicated Linden dollars was not a strong motivator; and (3) showed discontent with the lack of individual accountability in participating in group public defense, the course could be improved to address these student-perceived shortcomings. The following summarizes these recommendations.

Discourse / Dialogic, Reflection: Although reflection is currently provided through group papers and possibly through individual papers, it could be more prominent as a requirement. For example, students could compare their selected strategies for improved earnings to that provided in the readings and why the results were similar or different. In this manner, the reflection affords the opportunity for the student to articulate their understanding of the concepts relative to their experience. Blogs had been tried previously but were found ineffective. It is unknown if there was poor participation or if the quality was subpar. It is also unknown if the blog structure and rubric posed barriers to successful implementation.

Learn by Doing, Build Artifacts: Building artifacts was not afforded in this course although the possibility exists with some programming within TerraEconomicus. For example, the auction simulation can be run multiple times allowing each student to use a different strategy each game. Students can record their strategy and corresponding earnings in sequence and subsequently posted to TerraEconomicus for public review. Others can view the different types of strategies, the order of the strategies, and the winning strategies; all serving to provide multiple perspectives, motivation to be the high earner, and a means to externalize their understanding.

Conceptual Change, Transfer: Classroom discussion was the only means of transfer. Although the concept on auctions might have supported transfer if actual bidding were conducted during the Second Life field trip, that is, re-apply the strategies they learned from the auction simulation. Alternatively, create a TerraEconomicus auction to accomplish the same opportunity for transfer but in a more controlled environment, that is, not participate in a public site where the items for auction are not controlled. Auction items might include a half-point on their final grade or 100% protection card for during a hurricane.

Self-Regulated Learning, Extrinsic Motivation: In addition to Linden dollar earnings, it may also increase participation to track and publicly record the highest earnings per course offering. One could create a ‘wall of fame’ within TerraEconomicus that includes the earnings, a photo of the avatar, and the avatar name.

Self-Regulated Learning, Multiple Indicators: The class syllabus and a more explicit calendar could be posted in TerraEconomicus for persistent public viewing. The calendar can include class date, activities for that session, in-world/real-world location, and assignments due that session. Since participation is in part measured through class attendance, this information could be publicly posted using avatar names for anonymity (albeit anonymity may be questionable in a small class environment).

CATS as a Design and Evaluation Tool

In the Economics hybrid course, the 2D online simulations were found to support the least number of cognitive affordances based on CATS with the discourse/dialogic category being markedly absent suggesting that other learning technologies are needed to evoke additional cognitive affordances. The classroom and virtual world experiences provided nearly the same degree of cognitive affordances but in different categories of CATS. Specifically, Second Life provided ample experiential learning and learn by doing while the classroom experience was rich in supporting discourse/dialogic learning.

CATS allows the instructor or instructional designer to examine the cognitive affordances of a TSLE by observing and analyzing the extent to which each cognitive affordance is being engendered or invoked. The goal is to improve the cognitive design of a TSLE in order to support purposeful and meaningful learner actions and learning interactions. By better understanding the cognitive affordances of a learning technology, instructors and instructional designers can produce more effective student centered instructional designs.
This exploratory research revealed that CATS has the potential to become a highly effective tool for understanding the cognitive affordances of a learning technology and assisting faculty in purposively and intentionally taking advantage of these affordances to develop effective, engaging, and enriching TSLE. This has implications to all faculty, instructional designers, and e-learning developers and administrators involved in using learning technologies to support the design and delivery of instruction. Specifically, this research revealed that CATS can be used to:

1. Evaluate/analyze the cognitive affordances of a technology supported learning environment
2. Purposively increase the cognitive affordances of a TSLE
3. Address cognitive affordances as a dimension of instructional design
4. Design instructional strategies and learning activities that align with the cognitive affordances of a particular learning technology
5. Train faculty and instructional designers to effectively integrate technology into the teaching and learning process and enrich student learning experiences

Further research is needed to evaluate the validity and reliability of CATS as a design and evaluation instrument. Specifically, content and construct validity will be examined by re-examining the literature on affordance-based design and applying CATS to a range of learning technologies in a variety of educational settings and using interrater reliability for each instance.

References


