Designing Technology-Enriched Cognitive Tools to Support Young Learners' Problem Solving

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To explore the potential of using game technologies as cognitive tools for teaching and learning, in this paper we describe a game-like learning environment for sixth-grade space science that engages students in problem-based learning. We discuss the design of cognitive tools built in the environment, review four research studies that investigated how these tools supported problem solving, as well as outline the design implications. Our research shows cognitive tools play an important role in assisting learners' problem solving and novices rely on using the cognitive tools in support of their knowledge generation. The purpose of this line of research is to examine the use of cognitive tools to facilitate learning and identify best practices for designing effective technology-enriched cognitive tools in learning environments.

KEYWORDS: Cognitive Tools, Problem Solving, Technology-based Learning Environment

INTRODUCTION

Given the popularity of digital games as a form of entertainment and a growing number of adults as well as children reported playing video games daily (Rideout, Forerh, & Roberts, 2010), educators are interested in exploring the potentials of using games for teaching and learning. Recent discussions on *games for good* consider games can lead to "positive social change" (McDaniel & Vick, 2010, p. 7). Such games often incorporate cognitive technologies to aim at motivating learners to learn the educational content embedded in the environment while supporting higher-level cognition. When computer-based tools and learning environments are "adapted or developed to function as intellectual partners with the learner in order to engage and facilitate critical thinking and higher order learning," they are called cognitive tools (Jonassen, 1996, p. 9). Jonassen refers to these tools as "intellectual partners" in learning, because they require active learner engagement and ongoing knowledge construction. Educational games can be designed with the intention to increase learning outcomes and enhance learning experiences. Research has shown cognitive tools have the potential to facilitate knowledge construction, support conceptual understanding, and, most importantly, scaffold higher-order cognitive tasks within complex learning environments (Jonassen, 2006; Pea, 1985; Salomon, Perkins, & Globerson, 1991). For learners who lack well-developed knowledge structures and problem-solving strategies, cognitive tools can provide essential scaffolds that support their solving of complex problems. In this paper, we describe a game-like learning environment for sixth-grade space science that engages students in problem-based learning. We discuss the design of cognitive tools built in this environment, and review four research studies that investigated how these tools supported problem solving. The purpose of this research is to examine the use of cognitive tools to facilitate learning and identify best practices for designing effective technology-enriched tools in educational games or game-like learning environments.

THEORETICAL FRAMEWORK

According to Vygotsky (1978), learners are not necessarily limited to any particular level of cognitive development: Given appropriate scaffolding, learners can work within a zone of proximal development, which can lead to learners working beyond their current limitations independently. Cognitive tools can support learners in such work by providing scaffolding through: (1) sharing part of the cognitive load so that learners can work on higher-order tasks (Jonassen, 2003; Lajoie, 1993); (2) representing abstract concepts in meaningful and concrete ways (Rubin, 1996); (3) modeling effective cognitive strategies or techniques (Kim & Hannafin, 2011; Lajoie, 1993; Yuen & Liu, 2011); (4) guiding learners through cognitive tasks using expert or cognitive tutoring systems (Anderson, Corbett, Koedinger, &

Pelletier, 1995); (5) supporting metacognitive and self-regulation tasks (Lee, Lim, & Grabowski, 2010; Poitras, Lajoie, & Hong, 2011); and (6) challenging learners' knowledge and beliefs (Jonassen, 2006). With scaffolding as a primary function of cognitive tools, it is critical for designers to know how such technologies will facilitate higher-order cognition.

Cognitive tools can facilitate the knowledge construction process. Within the constructivist perspective of learning, learning entails adapting one's knowledge structures, through constant knowledge construction and refinement (von Glasersfeld, 2005) and cognitive tools can serve as both catalysts and facilitators of learning by reducing cognitive overload, and increasing high level cognitive processes. Feedback is crucial for scaffolding conceptual change when learners do not understand a topic. Tools can provide feedback to bring awareness of incompleteness or inconsistencies in conceptual understanding that initiates conceptual change (Hwang, et al., 2011; Yuen & Liu, 2011) and the overhaul of prior knowledge structures in an effort to reestablish cognitive equilibrium.

The kind of cognitive reorganization evoked by conceptual change requires metacognition and self-regulation. Metacognition is the process in which learners are thinking about their own cognition and make conscious efforts to reorganize their own understanding. Cognitive tools can prompt and engage learners in metacognitive tasks throughout a learning activity. Increasing metacognitive activities has been shown to lead to higher recall and retention (Lee, et al., 2010; Poitras, et al., 2011) and deeper understanding (Bannert & Reimann, 2011) as learners become more aware of and take charge of forming their conceptualizations. Self-regulation refers to the control learners have over "setting goals, selecting appropriate learning strategies, maintaining motivation, and monitoring and evaluating academic progress" (Ramdass & Zimmerman, 2011, p. 196). Cognitive tools can support self-regulation through structuring the learning experience, providing scaffolds, and guiding students toward metacognitive tasks (Bannert & Reimann, 2011; Efklides, 2008; Lee, et al., 2010).

For young learners, engaging in higher-order cognitive and metacognitive tasks is very challenging, yet developing problem-solving skills is an important education goal. Gee (2003) argued good commercial games incorporate "learning principles that are all strongly supported by contemporary research in cognitive science" (p. 1) and video games can foster learning. Well-designed games keep players motivated by incorporating such attributes as challenge, curiosity, control, fantasy, mystery, role-play, representation, goals, and sensory stimuli (Garris, Ahlers, & Driskell, 2002; Malone & Lepper, 1987). Such game attributes are often accomplished through various features and tools built in a game environment. Game-based learning environments that can foster intrinsic motivation with these attributes are an important aspect of McDaniel and Vick's (2010) notion of *games for good*. Cognitive tools can be a simple learning game or features of a complex game-based learning environment that learners seek out when they need assistance in completing the learning tasks. For young learners, such tools are important and necessary scaffolds in assisting them to construct their knowledge and develop critical thinking skills.

RESEARCH CONTEXT AND DESCRIPTION OF THE COGNITIVE TOOLS

In this section, we examine the design of cognitive tools in *Alien Rescue* (AR), a problem based learning (PBL) game-like environment for sixth-grade space science (Liu, Horton, Olmanson, & Toprac, 2011; see also http://alienrescue.edb.utexas.edu). AR engages students in solving a complex problem that requires them to use the tools, procedures, and knowledge of space science while learning about our solar system. In *Alien Rescue*, students are situated in the role of a scientist whose goal is to find suitable planetary homes within Earth's solar system for six alien species, each displaced from a distant galaxy with different characteristics and habitat requirements. In this role, students explore a 3D virtual learning environment, utilizing various tools to conduct background research, record information, generate and test hypotheses, and articulate problem solutions. Based on the information gathered, students must develop a recommendation for where to place all the aliens within the solar system.

In this game-like environment, a collection of technology-enriched cognitive tools is available to assist students' problem solving. The major functions of these tools relate to Lajoie's (1993) four categories of cognitive tools that can: (a) share cognitive load in problem-solving process, (b) support cognitive processes, (c) support cognitive activities that would otherwise be out of reach, and (d) support hypothesis testing (see Table 1). Learners need such tools to assist them in accomplishing the tasks laid out in *Alien Rescue.*

For the first category of tools, a set of information databases, delivered via a combination of text, graphics, 3D models, animation, and video, is provided that is essential for learners to form initial problem

Table 1. ***Descriptions of Cognitive Tools Provided in Alien Rescue.***

Tool Categories	Tool Functions
Tools sharing cognitive load	
Alien Database	Provides information via 3D imagery and text, on the aliens' home planet, their journey, species characteristics, and habitat requirements.
Solar System Database	Provides information on selected planets and moons within our solar system. Data is intentionally incomplete to support the ill-structured nature of the problem-solving environment and foster the need for hypothesis testing.
Missions Database	Provides information on past NASA missions, including detailed descriptions of probes used on these missions.
Concepts Database	Provides instructional modules on selected scientific concepts using interactive animations and simulations designed to facilitate conceptual understanding.
Spectral Database	Allows students to interpret spectra found in the Alien Database.
Periodic Table	Allows students to look up information on the elements.
Spanish/English Glossary	Provides Spanish translations of selected English words found within the program.
Tools supporting cognitive process	
Notebook	Allows students to generate and store notes on their research findings.
Notebook Comparison Tool	Helps students to compare information from multiple notebook entries so that students detect similarity and difference among the information in each entry.
Tools supporting otherwise out-of-reach activities	
Probe Design Center	Provides information on real scientific equipment used in both past and future probe missions. Students construct probes by deciding probe type, communication, power source, and instruments.
Probe Launch Center	Provides an interface for launching probes. Students check designed probes and choose which probe(s) they want to launch according to the budget.
Tools supporting hypothesis testing	
Mission Status Center	Displays the data collected by the probes. Students analyze and interpret this data in order to develop a solution. Malfunction of equipment can happen, and poor planning may lead to mission failure and waste of budget.
Message Tool	Allows students to receive and deposit the text messages received from the Interstellar Relocation Commission Director and aliens. The Message Tool also includes the Solution Form.
Solution Form	Serves as a submission tool for the solutions. Students submit their suggestions and rationale for the alien habitat. Teachers can review and critique these solutions.

representations and engage in the problem-solving process. In the second category, the Notebook and Notebook Comparison tools are designed to support cognitive processes in that they allow students to record, organize, save, and retrieve information gathered through the complex problem solving process. In order to overcome memory limitations, the Notebook initially guides students towards what notes should be recorded for later retrieval. As learners progress through their problem-solving process, Notebook tool becomes less structured with obvious scaffolds faded (see (b) in Figure 1). The Notebook Comparison tool enables students to compare different Notebook entries simultaneously in order to find similarity and discrepancy among their research results. With the tools in the third category, the Probe Design and Launch Centers, students can gather data from the planets and moons in the solar system, which is intentionally missing from the other aspects of the environment, by designing their own probes. To create the probes, students need to choose probe type, power source, communication tools, and instruments within a given budget. This design process of exploratory probes enhances student motivation by providing a playful experience and the autonomy about their own research. The tools in the final category, the Mission Control Center, Message tool, and Solution Form, guide the scientific hypothesis testing process. Students can observe, analyze, and interpret the data returned from the probes along with important information stored in their Notebook in order to offer a recommendation for the aliens' new habitats through the Mission Control Center. All these tools are available for use at any time through two layers of the interface –a persistent layer with tools (e.g., Solar System Database, Concepts Database, Notebook) always available at the bottom of the screen (see Figure 1 (a), (c), (d), (f)) and five individual rooms (e.g., Alien Database, Probe Design Center, Probe Launch Center) students can navigate to using arrow keys (see Figure 1). Simultaneous access to essential tools is important when students need to organize the large quantities of information effectively for reducing cognitive overload. For instance, when a student discovers that Mars has thin atmosphere in Solar System Database, she can simultaneously open the Concepts Database to learn the "atmosphere" concept while taking notes using the Notebook tool. Or, while a student is researching about an alien species, she can look up elements in the Periodic Table using Spectral Database to view spectra for that species and then takes notes using the Notebook tool. Tools such as probe design and probe launch are designed to provide a sense of fidelity and realism, while tools such as Alien Database is intended to create a sense of imagination and fantasy. Although *Alien Rescue* provides these tools to support problem solving, the decision to use which tool(s) and when depends on the students' problem solving strategies and decisions.

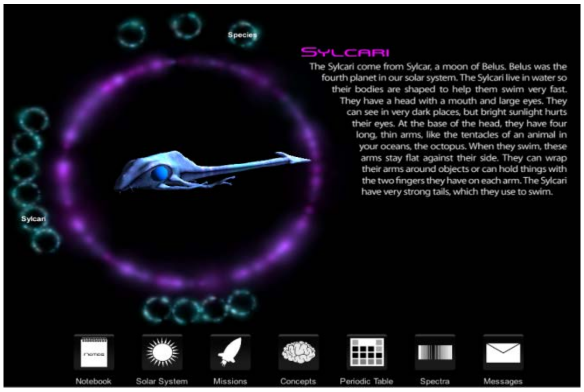
Our research examining the effect of *Alien Rescue* on student learning and their motivation has shown that students significantly increased their science knowledge from pretest to posttest after using the environment, they were motivated and enjoyed the experience, and a significant positive relationship was found between students' motivation scores and their science knowledge posttest scores (Kimmons, Liu, Kang, & Santana, 2012; Liu, Horton, Olmanson, & Toprac, 2011; Liu, Rosenblum, Horton, & Kang, 2013). Of particular focus of this paper is the design of cognitive tools in AR to facilitate learning and enhance motivation.

RESEARCH FINDINGS

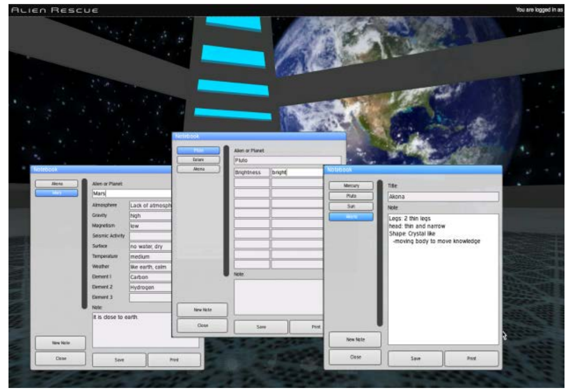
Four studies, each built upon the other, were conducted on *Alien Rescue* that investigated how learners used the cognitive tools to scaffold problem solving, and examined the interplay between the use of cognitive tools and learners' cognitive processes. This line of research included sixth graders (the target audience of the learning environment) as well as more advanced learners (undergraduate and graduate students) to examine differences in problem solving and discern where learners need additional support when using built-in cognitive tools for solving a complex problem.

In the first study, Liu and Bera (2005) analyzed the log data of 110 sixth graders, using cluster analysis, to determine cognitive tool use patterns while students were engaged in the problem-solving process. Log data consisted of the number of times a student accessed each of the cognitive tools and the amount of time the student stayed in each tool. Results indicated that students primarily used tools supporting cognitive processing and tools sharing cognitive load early in the problem-solving process. In the later stages of problem solving, students increasingly used multiple tools, with the most critical being tools supporting hypothesis generation and testing. The findings also showed a positive correlation between performance scores on a content knowledge test and productive use of the tools, with higher performing students using the tools more productively than lower performing students.

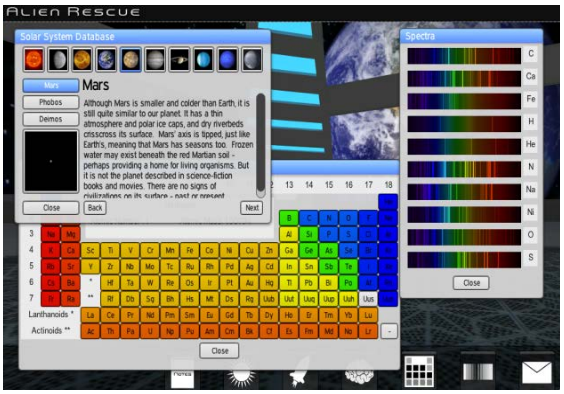
In the second study (Liu, Bera, Corliss, Svinicki, & Beth, 2004), the thinking process of sixth graders (n=161) was examined while they used cognitive tools through the self-reported survey data. In addition to confirming the tool use patterns revealed in the first study, Chi-Square and MANOVA analyses showed different types of cognitive tools were used for different types of cognitive processes and suggested that there was a relationship between tool use and cognitive processing. Furthermore, students' engagement was positively correlated to the frequency of tool use, and students' individual learner characteristics affected tool use patterns. This study found that students exhibited different characteristics in the consistency and activeness of their tool use,



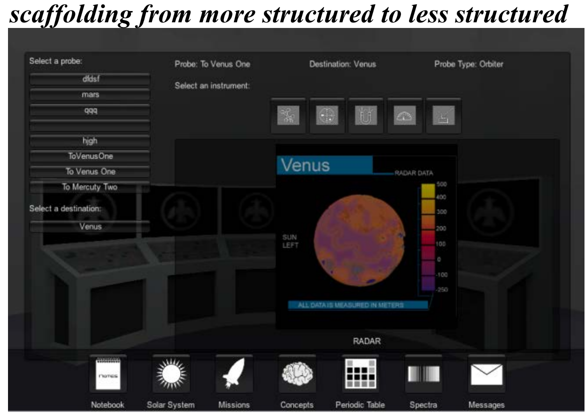
(a) Researching an alien species in the Alien Database



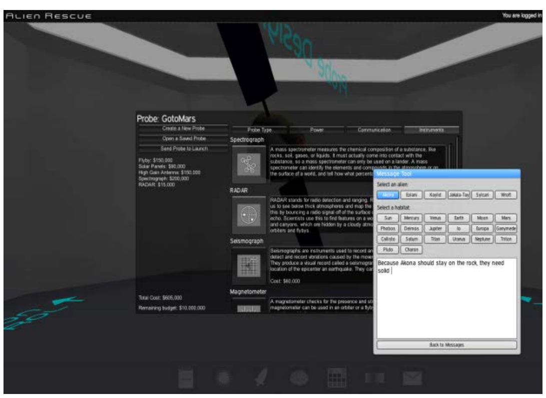
(b) Taking notes during researching on Solar System; the Notebook has three levels of scaffolding from more structured to less structured



(c) Using Solar System Database to collect data and use Periodic Table and Spectra to interpret data



(d) Viewing the data returned from the probe in the Mission Control Center



(e) Designing a probe in the Probe Design Center

(f) Learning the essential concepts in Concepts Database and past NASA missions in Missions Database

Figure 1. **Screenshots showing some cognitive tools provided in *Alien Rescue.***

depending on if they were more metacognitively or information processing oriented.

In the third study, Liu, Horton, Corliss, Svinicki, Bogard, Kim, and Chang (2009) further investigated cognitive tool use patterns and students' performance based on those patterns by employing three sources of data gathered from 61 undergraduate students: (1) log files to find out the overall tool use patterns; (2) a self-reported survey to understand which cognitive tools were used for which cognitive processes, and (3) stimulated recall interviews for insight into why students used a particular tool during the problem-solving process. The results, using Chi-Square, MANOVA, and qualitative analyses, confirmed the findings from previous two studies with sixth graders to further exhibit strong connections between cognitive processes and cognitive tool use. The findings of these three studies provided empirical evidence to support the theoretical notion that technology-based cognitive tools play an important role in assisting students' problem solving and activating cognitive processes necessary for constructing knowledge and active learning.

In a more recent study, Bogard, Liu, and Chiang (2013) conducted a multiple-case study that examined the relationship between cognitive processes the tools evoked and problem-solving operations. Fifteen graduate students were recruited from the areas related to AR environment and subject matter: Astronomy, learning and cognition, and instructional technology. The researchers used a think aloud and stimulated recall protocol to elicit verbal reports of the participants' thought processes as they solved the problem individually in a lab setting. The verbal reports were transcribed and coded by a team of five researchers. Participants were then clustered by how well they solved the problem (determined by a solution score), the number of cycles it took to generate a solution, the frequency of prior knowledge activation, the number of probes sent (a key cognitive tool use), and the number of problems the learner solved. A cross-cluster analysis examined how participants' frequency and application of cognitive processes contributed to differences in performance outcomes, and focused their operations for constructing a mental model of the problem. Highly successful problem solvers enacted self-regulation strategies to keep their cognitive processes focused on developing mental models that guided problem representations that indexed thresholds of knowledge development: 1) Building a procedural model, 2) building a structural model, 3) building an executive model, and 4) building arguments. Until learners had accomplished essential operations associated with the threshold appropriate to their level of knowledge and experience, they could not carry out effective operations in subsequent thresholds. The findings showed that mental model development during problem solving is a multifaceted, ongoing, and dynamic process that is necessary for externalizing problem representations and increasing one's awareness of when and where to apply cognitive process for carrying out effective problem-solving operations. Viewing complex problem solving as the progression of developmental thresholds, rather than just a series of steps in a cycle, should provide a more useful framework for predicting where novices will require support for applying their cognitive energies to support facets of problem representation.

DISCUSSION AND DESIGN IMPLICATIONS

In the above sections, we have described a collection of cognitive tools built in a game-like problem-based learning environment, *Alien Rescue,* and research related to them to draw implications for digital game-based learning. The inclusion of these cognitive tools within the environment is intended to support problem-solving practices among sixth-grade learners who typically exhibit characteristics of novice problem solvers. Our research has shown that students' use of cognitive tools corresponds with different problem solving stages, indicating that strategic use of tools to support various problem solving processes, such as hypothesis testing, can possibly lead to higher performance within the problem-solving environment. This finding highlights the importance of designing cognitive tools to support the range of problem-solving processes that students apply in solving complex problems and to encourage tool use in a way that corresponds to the learners' developmental level (Jonassen, 2006; Pea, 1985; Salomon, et al., 1991). Our findings support the notion of developmental thresholds in the problem-solving process; these thresholds correspond to the increased refinement of mental models associated with problem representation. In the fourth study, graduate students who performed well in solving the problem exhibited high levels of self-regulated learning. This finding suggests the need to conceptualize complex problem solving within learning contexts as a series of developmental progressions. Based on these findings, we have identified several implications that can inform ongoing development and innovation in the design of cognitive tools within learning environments.

Monitoring and responding to tool use patterns

Liu and Bera (2005) found that students used cognitive tools in increasingly sophisticated ways during the latter stages of problem solving and that students' tool use corresponded to their overall performance within the problem-solving scenario. Tools can provide expert modeling in which novices can see and mimic (Lajoie, 1993; Vygotsky, 1978). For example, tools could provide a certain level of expert modeling to further structure a student's problem-solving behaviors upon detecting that her engagement in hypothesis generation and testing is likely insufficient to support the development of problem solutions in the latter stages. By applying our understanding of how experts engage in the use of multiple tools concurrently, we can design tools that provide appropriate cognitive prompts to support the development of problem-solving expertise when needed. As cognitive tools engage learners in their zone of proximal development, when the learner reaches a certain developmental threshold, such support fades so the learner can continue work on the higher-order aspects of the tasks independently. Or, when she has reached a developmental threshold, the cognitive tools should provide another level of scaffolding.

Alignment between tools, processes, and student characteristics

Our research supports the strategic use of cognitive tools to support the range of cognitive processes that learners engage in while solving a complex problem and illustrates the relationship between learner characteristics and tool use patterns. The strong connection between cognitive processes and cognitive tool use, as identified by the first three studies, underscores the need to evaluate learning environments and their cognitive tools in light of the specific contexts in which they are applied. Designers should evaluate student characteristics, the qualities of the complex problem, and the problem-solving context in which the problem is presented to ensure that cognitive tools are optimized around the range of cognitive processes required for productive engagement with the problem-solving scenario. Similarly, the research also supports the use of tools that adapt to shifts in competence that correspond to the development of problem-solving expertise. This becomes important in a PBL environment where the problem spaces are complex, given that the tasks are authentic and set within a real-world context. Tools can share the cognitive load so that learners can focus on the necessary tasks and the bigger picture issues (Lajoie, 1993). In order to accommodate learners reaching new developmental thresholds, cognitive tools can provide adaptive levels of scaffolding based on indicators of student performance to ensure that novice and expert students alike are provided with appropriate levels of cognitive support. Further innovation in this area is essential to ensure that the availability and characteristics of cognitive tools within complex problem solving environments align with student needs.

Detection and response to developmental thresholds

The fourth study describes the problem-solving process as a series of developmental thresholds associated with continual refinement of problem representation. Tools can be catalysts for conceptual change in order for learners to have more accurate and deeper conceptual understanding (Jonassen, 2006). As learners reach a new developmental threshold, they will be more attuned and self-regulated in their own thinking. However, even when new developmental thresholds are reached, learners may still need further guidance and support from tools on these new levels. A key area for future cognitive tool development is in the design of technologies that can evaluate and respond to learners' progressions across the developmental thresholds. Tools that support students in making visible the evolution of their problem representations is a potential area of innovation that could be used to guide the delivery of cognitive tools within complex learning environments.

CONCLUSION

This paper described an ongoing line of research concerned with the design of cognitive tool-based scaffolds within a game-like learning environment. Our research provided empirical evidence that cognitive tools play an important role in assisting learners' problem solving and highlighted the strong connections between learners' cognitive processes and their tool use. Our research shows novices rely on using the cognitive tools in support of their knowledge generation. When embedded into a learning environment that represents a complex problem space, designers must also consider how cognitive tools work together and how to address continuing change in developmental thresholds. Therefore, providing well-designed and sophisticated scaffolds to respond to learners' needs and characteristics and their strategic placement is crucial for designers to consider when creating cognitive tools within technology-based learning environments.

AUTHOR NOTES

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REFERENCES

Anderson, J. R., Corbett, A. T., Koedinger, K. R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *Journal of the Learning Sciences, 4*(2), 167-207.

Bannert, M., & Reimann, P. (2011). Supporting self-regulated hypermedia learning through prompts. *Instructional Science, 40*(1), 193-211.

Bogard, T., Liu, M. and Chiang, Y. (2013, under review). Thresholds of Knowledge Development in Complex Problem Solving: A Multiple-Case Study of Advanced Learners' Cognitive Processes.

Efklides, A. (2008). Metacognition: Defining its facets and levels of functioning in relation to self-regulation and co-regulation. *European Psychologist, 13*(4), 277-287.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & gaming, 33* (4), 441–467.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment, 1* (1), 20-20.

Hwang, G.-J., Wu, P.-H., & Ke, H.-R. (2011). An interactive concept map approach to supporting mobile learning activities for natural science courses. *Computers & Education, 57*(4), 2272-2280.

Jonassen, D. H. (1996). Computers as cognitive tools: Learning with technology, not from technology. *Journal of Computing in Higher Education, 6*(2), 40-73.

Jonassen, D. H. (2003). Using cognitive tools to represent problems. *Journal of Research on Education on Technology, 35*(3), 362-381.

Jonassen, D. H. (2006). *Modeling with Technology: Mindtools for Conceptual Change*. Upper Saddle River, NJ: Merrill Prentice Hall.

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding 6th graders' problem solving in technology-enhanced science classrooms: A qualititative case study. *Instructional Science, 39*(3), 255-282.

Lajoie, S. P. (1993). Computer environments as cognitive tools for enhancing learning. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 261-288). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Lee, H., Lim, K., & Grabowski, B. (2010). Improving self-regulation, learning strategy use, and achievement with metacognitive feedback. *Educational Technology Research & Development, 58*(6), 629-648.

Liu, M., & Bera, S. (2005). An analysis of cognitive tool use patters in hypermedia learning environment. *Educational Technology Research & Development, 53*(1), 5-21.

Liu, M., Bera, S., Corliss, S. B., Svinicki, M. D., & Beth, A. D. (2004). Understanding the connection between cognitive tool use and cognitive processes as used by sixth graders in a problem-based hypermedia learning environment. *Journal of Educational Computing Research, 31*(3), 309-334.

Liu, M., Horton, L., Corliss, S. B., Svinicki, M. D., Bogard, T., Kim, J., & Chang, M. (2009). Students' problem-solving as mediated by their cognitive tool use: A study of tool use patterns. *Journal of Educational Computing Research, 40*(1), 111-139.

Liu, M., Horton, L., Olmanson, J., & Toprac, P. (2011). A study of learning and motivation in a new media enriched environment for middle school science. *Education Technology Research and Development, 59*(2), 249-266.

Liu, M., Rosenblum, J., Horton, L., & Kang, J. (2013, under review). *Designing Science Learning with Game-Based Approaches.*

Malone, T. W., & M.R. Lepper. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In Snow, R. E., & Farr, M. J. (Ed.), *Aptitude, Learning and Instruction* (Vol. 3). Hillsdale, NJ: Erlbaum.

Rideout, V. J., Foerh, U. G., & Roberts, D. F. (2010). Generation M2: Media in the lives of 8- to 18-year-olds. *Kaiser Family Foundation*. Retrieved from http://www.kff.org/ entmedia/upload/8010.pdf

Mcdaniel, R., & Vick, E. H. (2010). Conceptualizing "Games for Good" as Cognitive Technologies. *Cognitive Technology*, 14(2)/15(1), 5-10.

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

Poitras, E., Lajoie, S., & Hong, Y.-J. (2011). The design of technology-rich learning environments as metacognitive tools in history education. *Instructional Science*, 1-29.

Ramdass, D., & Zimmerman, B. J. (2011). Developing self-regulation skills: The important role of homework. *Journal of Advanced Academics, 22*(2), 194-218.

Rubin, A. (1996). Educational technology: Support for inquiry-based learning. In K. Fulton (Ed.), *Technology Infusion and School Change: Perspectives and Practices*. Cambridge, MA: TERC.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligent technologies. *Educational Researcher, 20*(3), 2-9.

von Glasersfeld, E. (2005). Introduction: Aspects of constructivism. In C. T. Fosnot (Ed.), *Constructivism: Theory, Perspectives, and Practice* (2nd ed.). New York, NY: Teachers College Press.

Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.Yuen, T., & Liu, M. (2011). A cognitive model of how interactive multimedia authoring facilitates conceptual understanding of object-oriented programming in novices. *Journal of Interactive Learning Research, 22*(3), 329-356.