R&D Challenges in Games for Learning

Introduction

This document presents a research and development plan, or "roadmap," for the development and application of games for learning in education and training settings. Developed as part of the Summit on Educational Games held October 2005 in Washington, DC, this roadmap is designed to raise awareness of key research challenges and opportunities for educational games, provide stakeholders with a coordinated understanding of these, and to encourage dialog and interdisciplinary partnerships.

The Summit on Educational Games (www.fas.org/gamesummit) was convened by the Federation of American Scientists, with support by the Entertainment Software Association and the National Science Foundation, to explore ways that the features of games could be applied to address the increasing demand for high quality education and training, and ways to address barriers to private sector investment in learning games-related research, product development, and new product and service introduction. The Summit's 100 participants included business executives from the gaming industry and the education software industry, researchers and academic experts on technology and pedagogy, teachers, game developers, experts on competitiveness policy, and government policy makers. Summit panelists were asked to react, critique, and offer additions and modifications to a preliminary R&D roadmap distributed to the Summit participants. The roadmap was subsequently revised and expanded to reflect the discussions at the Summit.

The research priorities described here are derived as a subset of the research priorities identified in the 2003 Learning Science and Technology (LS&T) R&D Roadmap produced by the Federation of American Scientists' Learning Federation Project, www.fas.org/learningfederation. The LS&T Roadmap describes a vision for next-generation learning systems, and outlines a national research plan to radically improve approaches to teaching and learning through information technology. The LS&T R&D

Roadmap was produced over a two-year period with input and advice from over seventy researchers from industry, academia, and government through their participation in focused workshops, interviews, and preparation of technical plans. Comprised of a series of five component roadmaps, the Roadmap provides as assessment of R&D needs, identifies key research questions and outlines a chronology of R&D activities designed to spur innovation in technologies for education and training.

Gaming environments were viewed by many of the LS&T R&D Roadmap contributors as an opportunity to break the "tell-test" paradigm prevalent in education today and vastly improve the more elusive aspects of the educational process; namely, motivation to learn and to continue learning over one's lifetime. In addition, modern video games may develop higher order thinking skills, such as problem solving, strategic thinking, analysis, planning and executing, resource management, multi-tasking, decision-making in a fast paced environment, and adapting to changing work scenarios. Moreover, the advent (and availability) of immersive environments for entertainment purposes is likely to grow considerably in the next few years, and have important applications in learning.

Clearly, computer games hold special interest to a generation who has grown up with them, and as such, they show promise as educational tools. Whether this is due to the inherent challenge built into game play, the richness of graphics presented to the user, the skills demanded of the player, the opportunity to interact with other users, the story or context in which the game is couched, or some other feature is worthy of study. Exploiting the inherent motivational aspects of games and simulations for education and training must be based on a sound understanding of which features of these systems are important for learning and why.

The following sections summarize key areas of research to understand how this powerful new medium might be used to support learning in education and training settings. Two research focus areas are described: 1) design of games for learning; and 2) adapting simulations to learning environments.

R&D challenges in design of games for learning focus on research and empirical studies to understand better what features of games can be used to improve learning outcomes,

and guidelines based on that research to enable the community of developers to build effective educational games. R&D tasks include:

- Understanding the features of challenges that are crucial for motivation and learning
- Understanding how stories/scenarios contribute to motivation and learning
- Understanding the impact of immersion and engagement on learner motivation
- Linking gaming features to goal orientation
- Understanding the features of game playing that contribute to development of higher-level thinking skills
- Understanding how games can be integrated in classrooms and formal learning environments to support learning goals

R&D challenges in adapting games to learning environments focus on the design of games and simulations so that they support learning and development of automated tools to streamline the development process and reduce development costs. R&D tasks include:

- Understanding the degree of authenticity/fidelity needed to support learning
- Dynamically constructed narratives that permit the learner to make decisions that directly affect the direction and/or outcome of the story
- Designing simulated actors with specific skills, knowledge, or personalities
- Incorporating educational scaffolding
- Reporting and use of assessment and learner modeling data

Among the most critical development challenges is the need for tools that make it easy to create learning games and simulations quickly, and at low cost. Flexible development tools would give the Nation's diverse education and training institutions the ability to tailor game-based instructional systems to meet local needs. Such tools could also reduce development costs for educational product and service providers. A key issue involved in creating such development tools is developing standards and protocols that enable interoperability among game and simulation environments, chunks of learning content, and individual objects within the game environment.

Research Challenges in the Design of Games for Learning:

While there are numerous claims that games can be applied to learning, relatively few attempts can be found where principles of pedagogy were explicitly followed *a priori* in design. Fundamental questions still exists regarding games; that is, how can gaming techniques be employed to (consistently) teach effectively. To answer this, it will first be necessary to develop a clearer model of what constitutes a learning game to organize research, what kinds of learning games are best suited for particular learning tasks and define in detail those characteristics of games which might improve learning. In general, the answer seems to be that games are motivating, but it is not entirely clear why. For example, games are challenging, they typically include competition (either against a human opponent or a computer generated one), they are often story-based, contain compelling characters and they typically "keep score". Which, if any, of these features are essential to learning still remains to be answered. In addition, game play can support valuable skills development, such as exploration, experimentation, collaboration, management of complex information and changing scenarios, and decision making under pressure with incomplete information. How can these features of games be used to meet educational goals? Six key research tasks are described in the following paragraphs.

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Research Task: Understanding the features of challenges that are crucial for motivation and learning

The challenges created by successful video games are so compelling that players will spend dozens, sometimes hundreds of hours wrestling to achieve a series of often difficult goals. Players are willing to try repeatedly to gain the mastery of a topic needed to get them to a new level of the game. We need to better understand the nature of challenges, why they work, and how to take advantage of the motivational aspects of challenges to design effective educational games. Several studies have found that incorporating challenges into learning has motivational benefits. The Cognition & Technology Group at Vanderbilt (CTGV) found that using an interactive video environment that presented students with challenges (the Japser Woodbury Problem Solving Series; see CTGV, 1997) resulted in better attitudes about mathematics, coupled with gains in planning skills and comprehension for problem-solving challenges (Bransford, Brown & Cocking,

1999). The CTGV also successfully incorporated challenges into learning in the SMART Challenge series. Findings revealed that challenges were motivating to students and resulted in enhanced learning over environments that did not contain them. In addition, challenges encouraged students to compare their progress to others and helped teachers to assess what students knew (Barron, 1995).

Research has shown that motivation increases when learners recognize a reason for learning and have a desire to attain the learning goal (Crookes and Schmidt, 1991; Gardner and Tremblay, 1994; Bransford, Brown & Cocking, 1999). The learner needs to care about the learning objectives to be most receptive to learning. Bruner (1960) stated "The best way to create interest in a subject is to render it worth knowing, which means to make the knowledge gained usable in one's thinking beyond the situation in which learning has occurred." The challenges presented in most video game establish clear goals for the player– the player knows why he or she is learning something and there are plenty of opportunities to apply what is learned. We need to better understand how to use the approaches implemented in successful video games to optimize the motivation to learn.

Further work to flesh out the nature of challenges and why they work is needed. Research needs include empirical research demonstrating what features of challenges are crucial for motivation and learning and how best to structure challenges in terms of difficulty. An important outcome of this research will be guidelines for implementing challenges across task/domain types and learner characteristics.

Research Task: Understanding how stories/scenarios contribute to motivation and learning

One of the attractions of game-based learning is its potential to support discovery-based learning. This is an approach to learning that emphasizes students' active exploration of a subject matter that has been emphasized by the American Association for the Advancement of Science and the US National Research Council (AAAS, 1993; NRC, 1996). Discovery-based learning is learning-by-doing. Research has shown that learners remember more and are able to apply their new knowledge for more effectively with

discovery-based learning approaches than with more passive learning approaches, such as reading a text book (deJong, 1998). Discovery based learning has been shown to be most effective when students receive guidance in the form of coaching and hints. However absent proper guidance and feedback, discovery based learning can be ineffective and learners may learn incorrect concepts (Hammer, 1997).

Narrative and stories can play an important role in guiding exploratory learning (Mott, 2006). Video game designers use story to ensure the player experiences a coherent narrative progression. In many video games, story is the "glue" between missions, providing the necessary goals and motivation for the player to progress to the next segment of game play. In educational games, story or narrative can be used to structure the player's/learner's experience so as to achieve specific educational objectives (Riedl, 2006). Narrative can be used to feature challenging tasks, stimulate curiosity by presenting learners with adventures, and provide the necessary pacing to make the learning experience engaging. A key challenge for educational games designers is to achieve the proper balance between plot and achieving learning goals (Mott, 2006).

Research is needed to refine theories regarding how stories/scenarios contribute to motivation. This research should lead to development of guidelines for developing compelling stories for learning, mechanisms to assess the appropriateness of a story for learning, and effective techniques to support rich, highly interactive exploratory learning experiences.

Research Task: Understanding the impact of immersion and engagement on learner motivation

Another issue that is related to motivation is the degree of immersion or presence experienced by the learner. Immersion is defined as the experience of feeling a part of the synthetic experience (Stanney, 2002). Csikszentmihalyi (1990) refers to immersion as *flow*. Flow occurs when a player is engaged in an activity (physical, mental, or both) at a level of immersion that causes the player to lose track of time and the outside world since the player kept in balance between his or her level of ability and the challenge

presented. Good games promote flow, and anything that causes the player to "leave" the game world (e.g., errors, puzzles that require irrational solutions) interrupts flow. Fullerton and Swain (2004) have proposed a methodology for measuring flow which can be used to guide the design of games.

It has been hypothesized that training effectiveness in virtual environments may be influenced by the degree to which trainees experience feelings of immersion (Knerr, Breaux, Goldman & Thurman, 2002). Research to support or refute this claim needs to be conducted. Moreover, the tendency to experience immersion seems to be an individual difference (Kaber, Draper & Usher, 2002), meaning that some people may be predisposed to benefit from immersive environments in training (Knerr, 2002). Research results should lead to psychometrically sound techniques for assessing immersion and engagement and delineation of game features that foster immersion and engagement.

Research Task: Understanding how to link gaming features to goal orientation

In general, goal setting involves establishing a standard or objective for performance. In learning systems, goals help to focus learners on the task and help them to select or construct strategies for goal accomplishment; hence, they serve to direct attention (Locke & Latham, 1990; Kanfer & McCombs, 2000). The issue is pertinent to gaming in that the tendency for games to “keep score” may actually trigger a performance oriented strategy since the learner’s attention is directed toward how he/she is performing (Kolowski, 1999). This tendency would likely improve immediate performance, but may have a detrimental effect on transfer and generalizability of knowledge. For example researchers have defined learners as being either performance or mastery-oriented. Performance-oriented individuals are concerned with their performance (e.g., maximizing their score in a game), while mastery-oriented individuals are concerned more about their own learning process (Dweck, 1986; Kozlowski, 2001; Covington, 2000). It has been found that performance-oriented individuals are more likely to perform better in training, but worse on transfer tasks, while the opposite appears to be true for mastery-oriented learners. This is typically attributed to the fact that a performance orientation leads learners to figure out one or two strategies that maximize immediate performance, but that they fail to establish more flexible, generalizable strategies.

The impact of goal setting—and its relationship to task demands and instructional design needs further refinement. Research to understand score keeping and it relationship to goal orientation is needed, leading to empirically-validated guidelines for developing games that optimize goal orientation in games.

Research Task: Understanding the features of game playing that contribute to development of higher-level thinking skills

There is evidence that games can support the development of logical thinking and problem solving (Inkpen, 1995; Whitebread, 1997; Gee 2003). McFarlane et al (2002) found that both teachers and parents recognized that games play can support valuable skill development such as: strategic thinking; planning; communication; application of numbers; negotiating skills; and group decision-making. Games provide learners with a broad set of experiences and practice opportunities. In the gamers' world, learners can operate the most sophisticated aircraft and avionics, or operate the most powerful scientific or military equipment, fly through the interior of living cells, or talk with wine merchants on the streets of Ur in the year 3000 BC. The body of what is known about the performance of aircraft or living cells or the society of ancient Mesopotamia is encapsulated in these experiences, not as an abstract set of facts but as a world that has the color, complexity, and challenges of a functioning society.

A key area of research is to understand how well this knowledge and these skills transfer to real-life experiences, especially from one domain to another. (Bransford and Schwartz, 1999; Brown et al, 1983; Bruer, 1993). Research to understand the features of games that support high-level thinking skills and why they work is needed. An important outcome of this research will be guidelines for implementing these features to accomplish specific learning objectives.

Research Task: Understanding how games can be integrated in classrooms and formal learning environments to support learning goals

There are encouraging signs that the concept of games for learning is gaining acceptance among educators. A majority of people believe that games are engaging, that they can be effective, and that they have a place in learning (Van Eck, 2006). A 2006 survey by the United Kingdom's (UK) National Endowment for Science, Technology and the Arts Futurelab found that 60% of UK teachers would consider using games in the classroom for educational purposes and that almost one third have already used them in their classroom (NESTA, 2006).

There remain a number of issues surrounding use of educational video games in traditional educational settings. Many of these are common to educational technologies, and include the redesign of curriculum (and perhaps associated standards) to accommodate the change; educating the community and various constituents who have a stake in learning, and training teachers to embrace the new technology and methods.

Currently most computer games used in the classroom are education-oriented games, rather than commercial entertainment; however, there is growing use of commercial games used as part of a larger curriculum. Integrating commercial off-the-shelf video games involves taking existing games, not necessarily developed as learning games, and using them in the classroom. In an informal study Kirriemuir and McFarlane, (2003) found that most commercial games in used the classroom belonged to the strategy and simulation genres of gaming. For example, RollerCoaster Tycoon has been used across a number of subject domains, such as physics (motion and velocity), and business and economics (running a theme park) (Kirriemuir and McFarlane, 2003). Civilization, a historical strategy game has been used in classrooms to stimulate information interpretation and discussion. Squire (2003) used the game as the basis for a unit on world history in urban learning environments and found that the game engaged each student in unique ways, and that the engagement affected the interpretations the students made about history. While initial use of games in classroom settings is generally positive, there is limited research available to inform choices regarding instructional strategy and scaffolding for learners. Research indicates that providing instructional context, matching learning outcomes, understanding learner characteristics, such as familiarity with game conventions, and the quality and nature of debriefing are all

critically important elements of the learning outcome (Clegg 1991; Miller, Lehman, and Koedinger, 1999; Squire, 2003).

The development of educational games that integrate learning with video gaming technologies is increasing. Examples include *Immune Attack*, which teaches basic immunology concepts, developed by the Federation of American Scientists; *Discover Babylon*, which teaches about the development of writing, also developed by the Federation of American Scientists; *Environmental Detectives*, developed by the Education Arcade and *River City*, developed by Professor Chris Dede, the Harvard Graduate School of Education, both teach research-related inquiry skills; *Hazmat: Hotzone*, for hazardous material response, under development at the Entertainment Technology Center at Carnegie Mellon University; and *Virtual U*, originally conceived and developed by Professor William F. Massy. The challenge with these games is that they are very costly to develop as they must compete with commercial video games in terms of quality of graphics, challenges, and game play. Few companies are willing to make the investments needed to develop such games since there is yet no demonstrated market, and to date federal and foundation funding has been very limited.

Research is needed to better understand how learning occurs through game play and how gameplay can be used to support learning in formal learning environments. We need to understand the instructional settings in which games can be effective and the appropriate instructional strategies for teaching with games. In the US, outcome data from large-scale evaluations of educational games are needed to demonstrate that these technologies are equal to or better than more conventional instruction methods. These data are needed to encourage schools to adopt educational games, especially K-12 schools that are focused on meeting education standards. Schools should work with employers and others to develop tests that adequately measure the kinds of sophisticated educational outcomes required in today's economy – such as higher-order skills. Strategies for changing instruction to reflect the kinds of innovations in games need to be explored. Schools will need to adapt their instructional practices and formal learning environments to take advantage of technology-enabled exploration, interactivity, and collaboration encouraged

by digital games and simulations. Examples of best practices should be collected and shared.

Research Challenges in Adapting Simulation to Learning Environments

Research has demonstrated that simulation environments are powerful learning tools that encourage exploration by allowing learners to manipulate parameters and visualize results. Simulation-based learning environments can also provide "anchored" or situated learning environments that can help learners understand the types of problems and opportunities that real experts confront and how they use their knowledge to solve those problems. In academic settings, simulations can enhance lectures, supplement labs, and engage students. In the workplace, simulations are a cost-effective way to train personnel. Synthetic or virtual environments can support games, exploration, assignments with clear goals, or challenges. If they're well designed, such environments will motivate learners to meet the goal, sustaining their eagerness to build the needed skills.

The question is how to use simulations and synthetic environments to improve learning outcomes, while making them easier to build and incorporate into learning environments. Computer video games provide a rich opportunity to present learners with relevant, meaningful learning goals and problems through the use of simulation. However, current knowledge in exactly how to create effective simulation-based learning environments is not specific enough to provide robust guidelines for designers. The issue extends beyond the design of simulations to include how best to structure such environments so that they support learning. Moreover, automated tools to streamline the process are needed since the development of simulation-based learning environments is typically very costly. This section of the roadmap identifies four key research tasks for creating effective simulation-based learning systems.

Research Task: Understanding the degree of authenticity/fidelity needed to support learning

Research associated with creating the appropriate degree of authenticity in the learning has been conducted. For example, Jonassen (2000) discussed the notion of authenticity by pointing out that it does not necessarily mean that the instruction is developed around specific, real-world tasks. Rather, authenticity can best be thought of as the degree to which the learning environment causes learners to engage in cognitive processes that are similar to those in the real world (Honebein, 1993; Savery & Duffy, 1996; Petraglia, 1998). Moreover, authentic learning environments are engaging to learners, and provide them with challenging problems to solve (e.g., CTGV, 2000).

Others have couched the question in terms of simulation fidelity, i.e., the degree to which the simulation needs to be a faithful representation of the real phenomenon or task (Andrews & Bell, 2000). The underlying issue here is related to the transfer of specific knowledge and skill to the actual operational or job environment (Orlansky, 1994; Higgins & Champion, 2000). Specifically, if trainees are learning how to apply a particular skill, then the training (simulated) environment must respond in a manner that is similar to what would occur in the real world. Otherwise, the trainee will receive incorrect feedback and perhaps learn the wrong things. In this regard, Hays and Singer (1991) distinguish between physical fidelity (i.e., the degree to which physical features of the simulation are represented such as knobs and buttons) and cognitive fidelity (i.e., the degree to which the simulation faithfully represents conceptual aspects of the actual task). In addition, realistic sound in a synthetic environment can improve the fidelity of the sensory cues perceived by participants in a simulation (Shilling, Zyda, & Wardynski, 2002). As with other learning environment features, which of these types of fidelity is important in learning depends on the nature of the learning objectives driving the instruction.

Research studies are needed to demonstrate how physical, functional and cognitive fidelity drive learning. These studies will lead to development of libraries of techniques for enhancing the authenticity and fidelity for specific tasks and learner characteristics.

Research Task: Dynamically constructed narratives

Most video games employ narrative systems that are either partially or fully scripted. The stories are completely linear or may use a relatively simple branching structure. Dynamic interactive narratives, in which the player's decisions directly affect the direction and/or outcome of narrative experience (Riedl, 2006) are being explored by several research groups (Magerko, 2005; Riedl, 2003; Young, 2004; Cavazza, 2002; Moire, 2002; Mott, 2006). These systems seek to permit learners to apply their knowledge and problem-solving judgments in potentially different ways while achieving the desired learning objectives. Dynamic interactive narratives have the potential to greatly increase the level of interactivity learners experience while maintaining the control necessary to ensure learning objectives are met.

Research is needed to better understand the design of dynamic interactive narratives, including techniques for sequencing plot elements into coherent, interesting stories and directing characters' actions to achieve educational objectives.

Research Task: Designing simulated actors with specific skills, knowledge, or personalities

Simulated actors (also known as intelligent assistant agents or avatars) can heighten the authenticity of the learning experience by allowing learners to practice higher-order skills with realistic actors who behave in an accurate, believable manner. These computer-generated actors can provide a low cost alternative to more traditional role-playing strategies by reducing the need for human actors. Simulated virtual humans have been successfully used in intelligent tutoring systems to aid learning (Davies, 2001; D'Souza, 2001; Johnson 2004). Lifelike pedagogical agents have been used to serve as students' representatives in learning environments to provide real-time advice to address learners' misconceptions (Cassell & Vilhjálmsson, 1999). Intelligent agents have also been used as learning coaches, simulating the actions of a tutor that engages the learner in conversational dialogue in order to stimulate question asking and teach good question asking skills (Graesser, 2001).

To be effective, intelligent agents need to portray emotions, demonstrate actions that shows thought processes, and behave realistically. These simulated actor's requirements include not only correct exterior design (appearance), but movements, reactions and decision-making that appear natural, appropriate, and context-sensitive (Balder, 1999). A growing community of researchers is exploring more robust behavioral models that span a broader range of human behavior, including cognitive, emotional, linguistic, social, and physiological processes (Traum, 2004; Gratch, 2004; Fleischman, 2002). While there has been some success in modeling important aspects of the causes of emotion, characterizing their effects, especially as realized in behavior, remains an important research task (Ortony, 1992). Designing emotional sensitivity into intelligent agents requires an understanding and representation of the causes and consequences of emotions. These are difficult to understand and model, in part because the emotions are expressed in different ways at the different levels.

A key research need is to understand how humans interact with simulated actors in order to inform design criteria for future development. The knowledge gained can be used to guide design of simulated actors for specific learning applications by programming specific skills, knowledge, or personalities.

Research Task: Incorporating Educational Scaffolding

Educational scaffolding, like building scaffolding, is a temporary supportive structure that gradually is moved until the structure is able to stand on its own. The support that is given in educational scaffolding comes in the form of modeling, giving students cues, prompts, hints, and partial solutions. With scaffolding, learners are able to direct their own attention, plan, and control their activities. de Jong and van Joolingen (1998) outline three of the most promising strategies for building such scaffolding: ready access to domain-specific information, game-like assignments driven by questions and exercises, and a learning environment with model progression. Ready access to domain-specific information could be supplementary information that a student accesses upon request during the simulation, such as definitions of key terms. Game-like assignments would be

filled with questions and exercises that actively engage and motivate the learner with interactive tasks.

More work is needed to determine how and when scaffolding should be incorporated into educational games. Students' interest or engagement in a task is clearly important, but it does not guarantee that students will acquire the kinds of knowledge that will support new learning. Learners need to understand an overall picture that will lead to the development of integrated knowledge structures and information about conditions of applicability. (Greeno, 1991). Research needs include studies and demonstrations of techniques that optimize the introduction, format, timing and fading of scaffolding in the learning environment. For example, should game play be stopped in order to provide cues and hints; how much coaching is appropriate; should the learner be allowed to fail? Longer-term outcomes of this research include automated tools that can adjust scaffolding strategies automatically as a function of learner characteristics and on-going performance.

Research Task: Reporting and use of assessment and learner modeling data

Feedback and guidance are essential components of a learning environment. They point out performance errors, correct them, and allow the learner to proceed to mastery. There are many dimensions of feedback and guidance that can be varied: timing, content, amount, specificity, medium, and control. Research is needed to understand how to integrate feedback and guidance into educational games. This has to be done without a negative effect on the motivational features of the game. Once rules are established for feedback decisions, software is needed to allow an author to specify rules for triggering particular types of feedback. Authoring software is needed to facilitate entry of feedback segments that can be intelligently, dynamically pieced together, or presented in a variety of media, for example, text, or spoken by a character.

Making it Happen: Research Management

The research challenges outlined in this roadmap span multiple research disciplines – game design and development, education, psychology, cognitive science, communication, human-computer interaction, software engineering and design, information science – just to name a few. Unfortunately there is no established community of researchers, industrial participants, educators, and educational institutions from which to mobilize the teams needed to undertake the research identified in this roadmap. An effective management plan is essential to build the needed research teams, focus the research, and guide research by identifying where intellectual effort is most likely to bear fruit. The management approach for these activities should complement the current learning science and technology R&D programs to ensure that more applied research and larger-scale demonstration projects are supported. A new partnership melding the talents and resources of government, industry, and private foundations is needed.

There are various R&D models that could be used to carry out different R&D tasks identified in this roadmap. Options include:

- publicly-funded, investigator-driven basic research at universities and government-funded research centers (such as the National Science Foundation Science of Learning Centers)
- government-industry partnerships for prototype development
- private R&D consortia for pre-competitive, generic technology development
- multi-industry consortia on propriety technology development
- formation of focused research center(s) on games for learning
- demonstration pilots funded by Federal or state governments
- demonstrations carried out in government-supported education and training programs (such as NSF's Advanced Technology Education program or Department of Labor workforce investment programs)
- learning game development funded by states with common needs
- private company R&D
- R&D funding from Federal agency in support of mission need (such as Department of Defense or Homeland Security);

- grants in NSF education and human resource programs (such as instructional material development); etc.

Conclusions

There is growing interest in applying the features of digital games and game play to education and training. Game technology clearly has the power to capture the enthusiasm and attention of today's students. The success of complex games demonstrates that they can teach higher-order thinking skills such as strategic thinking, interpretative analysis, problem solving, plan formulation and execution, and adaptation to rapid change. These are precisely the skills that U.S. employers increasingly seek in workers and new workforce entrants, and the skills more Americans must have to compete with lower cost knowledge workers in other nations. Games and simulations can also serve as powerful "hands-on" tools for teaching practical and technical skills, from automotive repair to heart surgery.

Yet, despite the promise game technology holds for improving learning performance to meet the needs of the new economy, textbooks and teacher lectures remain the mainstay of teaching and learning. The Summit on Educational Games held in October 2005 identified ways to address this problem and accelerate the development, commercialization, and deployment of new generation games for learning. This roadmap identifies key R&D needs to ensure we harness the power of games for the purpose of learning. To make progress, these R&D activities need to be acted upon and organized and will require an interdisciplinary enterprise that brings together various groups, both within and across industry and academia.

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