Instructional Games and Virtual Worlds for Effective Learning and Assessment

Presenter. Debbie Denise Reese, PhD
Summary. Evaluate and integrate instructional games and virtual worlds for learning and assessment using NASA-/NSF-funded science environments. *Selene* and *MoonWorld* illustrate how, why, what, and when.

Virtual and game-based worlds hold great promise for teaching, learning, and assessment (e.g., Borgman et al., 2008). Educational professionals—practitioners, curriculum coordinators, professional development providers, and administrators—must build a knowledge base to support selection and implementation of virtual and game-based worlds for learning and assessment. This session uses two science learning environments to enhance awareness and inform educators' recommendations for selection, implementation, and integration of virtual and game-based worlds for learning and assessment.

Rationale

Games can be powerful learning tools. When educational games succeed as **games**, the players learn a game world and gameplay. However, if the game world misaligns with the instructional content, players will learn the content, but they will learn it **wrong**.

To counter this and other issues, we must create a knowledge base about learning and assessment in games. That means research. But for the research to be the best it can be, the research community must include you, the teacher, and your students as well. We invite you to join us as we conduct research using the new *Selene* game and virtual world *MoonWorld*.

Reese is a senior educational researcher in the Center for Educational Technologies' game division. During this meeting she will introduce you to some of the issues surrounding instructional use of game-based technologies. You will empower yourself as a knowledgeable consumer and research partner as you begin to answer questions like these:

- What should I look for in an educational game?
- How can games be designed to support my state and local standards?
- Where/How do games fit within an instructional unit?
- How can games be used to assess learning?
- What is flow, how does it compare to fun, how does it relate to educational games, and how can it inform my practice and help my students to make positive life choices?
- How can my students and I join the community of researchers studying educational games?

Two Complementary Learning Environments

The two learning environments, *Selene* (an instructional gameworld) and *MoonWorld* (a virtual world simulation), are companion learning technologies. *Selene* players create the Earth's Moon, then pockmark it with lava flows and craters. *MoonWorld* players conduct lunar geological fieldwork on a virtual Moon.

Selene

Learners playing the instructional game *Selene* construct the Earth's Moon to learn how it formed and changed over time. Players accrete mass, accumulate enough heat to melt and differentiate the Moon into layers, and then flood it with lava and pepper it with craters. Players discover the processes of accretion, differentiation, impact cratering, and volcanism and supporting processes like gravity, velocity, kinetic energy, and density.

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Selene, a casual game about lunar science, is designed to help players construct viable, robust, and coherent knowledge about our solar system's fundamental geological processes.

***Selene* makes complex concepts intuitive.**

Selene's gameworld, game goals, and gameplay align with the targeted content. *Selene* also aligns with National Science Standards (http://selene.cet.edu/?page=educators).

MoonWorld

MoonWorld explorers conduct lunar geological fieldwork in a virtual world simulation based on the Timocharis region of Earth's Moon. *MoonWorld* explorers apply *Selene* concepts while acting authentically as lunar scientists at 16 field stations on the Moon's surface, gathering topological scientific measurements and making morphological descriptions. Explorers' activities are constrained by the parameters of their biological life support system. Once back at the lunar research facility, explorers analyze their data, rock samples, and also explore and manipulate parameters of the biological life support system by planting and managing life-sustaining crops.

Research

Selene

Selene: A Lunar Construction GaME is a CyGaMEs environment. CyGaMEs stands for Cyberlearning through Game-based, Metaphor Enhanced Learning Objects. The CyGaMEs approach applies cognitive science analogical reasoning theory (Gentner, 1983; Holyoak & Thagard, 1989) to the design of instructional games that prepare learners with concrete experiences. These experiences guide learner discovery and application of targeted concepts (e.g., Reese, 2009b; Reese & Tabachnick, 2010).

Facilitating Knowledge Construction

Apt prior knowledge scaffolds new learning (Gagné, Briggs, & Wager, 1992). Activation of prior knowledge is so important to learning that instructional designers since Gagné specify it as a primary and preliminary event of instruction (Gagné et al., 1992; Smith & Ragan, 2005). It is well documented that learners lack apt prior knowledge across science domains. This is because many scientific concepts are defined and abstract. If they concern physical processes, these typically occur at levels too large, small, quick, or slow for human sensory perception and interaction. Some examples are Newtonian physics (Hestenes, Wells, & Swackhamer, 1992), chemistry (Johnstone, 1991), and genetics (Baker & Lawson, 2001; Banet & Ayuso, 2000). When learners lack apt prior knowledge, instruction should provide experiences that serve as prior knowledge (Merrill, 2002).

Today learning scientists conceptualize interventions and processes that enable learners to anchor knowledge acquisition as *preparation for future learning* (Schwartz & Martin, 2004). A CyGaMEs environment like *Selene* enables learners to construct viable inferences about targeted concepts (Reese, Diehl, & Lurquin, 2009). This makes learning science more intuitive.

Measuring Impact on Learning and Engagement

Tasked by the NASA Technology and Products Office to support the NASA eEducation Roadmap (Laughlin, 2006), the NASA-sponsored Classroom of the Future created the CyGaMEs suite of embedded assessment tools (Reese, 2006, 2010) to measure (a) learners' affective responses (i.e., flow and seven other dimensions of experience, see Csikszentmihalyi & Csikszentmihalyi, 1988; Hektner, Schmidt, & Csikszentmihalyi, 2007) and (b) learning (Reese & Tabachnick, 2010). Replicated findings support the effectiveness of these measures for assessment (Reese, 2008, 2009a, in press; Reese & Tabachnick, 2010) and their contribution to formative evaluation (Reese, in press).

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MoonWorld: Situating Learning in Authentic Practice

MoonWorld learners in teams of four avatars virtually explore the surface of Earth's Moon in a Timocharis-like region as they engage in authentic practice as lunar geologists conducting research. The situated and social aspects of *MoonWorld* derive from the precepts of situated cognition (Brown, Collins, & Duguid, 1989; Greeno, 1997).

Outcomes

Awareness prepares educational professionals for selecting and integrating instructional games and virtual worlds into their curricula for teaching, learning, and assessment. Developing background knowledge will help you identify salient characteristics of EFFECTIVE instructional games and virtual world simulations. Cyberlearning is valued for the enhanced ability to track and interpret knowledge and affective change through authentic assessments, assessment embedded within learning activity. In the future educational practitioners and leaders must understand and appreciate how game-based and virtual environments produce authentic measures of changes in player behavior and affective states. Educators must know how to work with and interpret these data and data reports. This session introduces education professionals to components necessary for knowledgeable and mindful selection and integration of game-based and virtual world learning environments.

1. *Curricular integration.* Identify how and where to incorporate virtual world and game environments within the events of instruction.
2. *Connect gameplay to data.* Recognize the connection between gameplay and data.
3. *Specify criteria.* Develop background knowledge to develop your own criteria for evaluating and selecting instructional games and virtual worlds.

Resources

Please see Reese's publications in the reference list. The Carter, Wilbanks, and Reese paper (2009) was prepared for an educational audience, delivered at a Society for Information Technology and Teacher Education (SITE) international conference and should be especially relevant for educators. Reese's published works can be downloaded from publisher or event websites. Reese's unpublished reports and conference presentations will be available for download from http://selene.cet.edu/?page=research. See also the teacher packets:

- PDF: Viewing the Moon—Everything's Relative
- PDF: Nectaris and Rheita Valley

The Game as Component of Events of Instruction

An instructional game does not have to carry the full load of delivering the entire instructional unit. In fact, it is difficult for (a) average and lower achieving students and (b) students who are novices in a domain to apply game-based learning to a targeted conceptual domain (Coleman, Livingston, Fennessey, Edwards, & Kidder, 1973; Squire, 2002). This suggests using games as a component or event within a learning environment. Instructional game designers can look to Gagné's methods and methodologies for guidance in designing for games that serve as components of a larger instructional unit.

It is easier to plan a trip, arrive at a destination, and know you've arrived if you know where you are going. The same is true for designing instruction. Gagné's conceptualization and categorization of learning outcomes enhanced control over the design and effectiveness of instructional design. Gagné's specification of the events of instruction took the field even further (Gagné, 1965, 1972; Gagné et al., 1992). Examination of human cognitive processes led Gagné to propose a sequence of instructional presentation that supports the way people learn:

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The Events of Instruction (Gagné et al., 1992, p. 190)
1. Gaining attention. 2. Informing learner of the objective. **3. Stimulating recall of prerequisite learning.** 4. Presenting the stimulus material. 5. Providing learning guidance. 6. Eliciting the performance. 7. Providing feedback about performance correctness. 8. Assessing the performance. 9. Enhancing retention and transfer.

Although Gagné proposed a consistent set and sequence of instructional events across learning outcomes, each learning outcome requires its own treatment of the instructional events. Subsequent theorists have modified Gagné's events (see, for example, Smith & Ragan, 1993), and others have proposed alternative models. Even in alternative instructional design models, such as those for problem-centered learning environments (Merrill, 2002), the theorists identify events of instruction. Merrill called his "phases of learning" and identified four: "(a) activation of prior experience, (b) demonstration of skills, (c) application of skills, and (d) integration of skills into real-world activities" (p. 44).

Instructional games might be developed for any event of instruction. Some instructional applications might be trivial; others might perform profound service to learners. Activation of prior knowledge is a preliminary step across most instructional design methodologies.

The CyGaMEs approach specializes in this event of instruction: developing apt prior knowledge. That is, CyGaMEs prepare students for future learning by helping students to develop prerequisite knowledge for learning challenging concepts.

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Game Genres[1]

Genre	Description
Action	Involves movement, quick thinking, reflexes, etc., in real-time experiences with an emphasis on time constraints for performing physical tasks; focus on reaction time (fast reflexes) and hand-eye coordination: movement, quick thinking, reflexes, etc.; can be multiplayer. Example: *Half-Life 2, Halo2, Swat4, Ghost Recon* (Bailey & Katchabaw, 2005; Fullerton, Swain, & Hoffman, 2004, p. 394; MobyGames.com, n.d.-a; Van Eck & Gikas, 2003, as cited in Van Eck, 2006).
Adventure	A story (a quest or mission) experienced through the manipulation of one or more user-controlled characters and an environment; emphasize exploration, collection, puzzle-solving, exploration and daring; characters are not customizable and don't usually grow in wealth, status, and experience. Example: *Pirates, DaVinci Code* (Fullerton, et al., 2004; MobyGames.com, n.d.-b; Van Eck & Gikas, 2003, as cited in Van Eck, 2006).
Arcade	Quick twitch muscles and reflexes; fast, action packed, interesting graphics, and good sound effects rather than narrative; interaction pattern is usually one player against the game system; gameplay is usually time- or points-based. Example: *Sonic, Pac-Man* (Fullerton et al., 2004; MobyGames.com, n.d.-c; Wolf, 2003).
Fighting	Gameplay mechanics involve two or more players trying to knock each other out; can be multiplayer; usually on consoles. Example: *Mortal Kombat* (Van Eck & Gikas, 2003, as cited in Van Eck, 2006, slide 16).
Gambling	Gameplay involves betting; can be simulation or real; can be multiplayer. Example: *Texas Hold-em* (Salen & Zimmerman, 2004, p. 80).
Puzzle	Thinking and logic to solve puzzles; can include spatial challenges; often with a time limit. Example: *MineSweeper, WebSoduku* (Fullerton et al., 2004).
Racing	Involves using a motorized vehicle to move faster than an opponent to reach a goal or beat a time; real-world simulations or fantasy racing games in which the player is racing and in control; illusion of speed; can be multiplayer. Example: *Need for Speed, NASCAR* (Fullerton et al., 2004).
Role-playing	Character development—one or more characters are created and shaped by the player; characters manage inventory and explore large, expansive worlds; may be real-time or a combination of real-time and turn-based; can be single or multiplayer. Example: *World of Warcraft* (Fullerton et al., 2004; MobyGames.com, n.d.-e; Steinkuehler, 2005; Van Eck, 2006).
Sim: Building	Model real-life situations and/or variables involving resource management combined with building something; distinguished from strategy games, which concentrate on conquest. Example: *Sim City, Sims2* (Fullerton et al., 2004, pp. 396-397; Gredler, 1996; Laughlin & Marchuk, 2005).
Sim: Flight/Other	Model real-life situations and/or variables through realism; player masters realistic and often complex controls and instrumentation to operating realistic vehicles and equipment, such as a NASA shuttle. Example: *Microsoft Flight Simulator* (Egenfeldt-Nielson & Smith, 2002a; Fullerton et al., 2004; MobyGames.com, n.d.-f).
Sports	Gameplay concerns winning the athletic competition by playing; can be multiplayer. Example: *NBA Live, FIFA Soccer, Madden Football* (Fullerton et al., 2004; MobyGames.com, n.d.-d).
Strategy	Tactics, analytical skill, planning, management of units and resources revolving around conquest, exploration, trade, warfare and empire building; usually a player commands groups of units and gathers resources to fund expansion with control over how many units do what activity. Example: *Civilization III, Rome: Total War* (Egenfeldt-Nielson & Smith, 2002b; Fullerton et al., 2004; MobyGames.com, n.d.-g; Van Eck, 2006).

[1] Materials on game genres and learning outcomes excerpted from:
Reese, D. D. (2006). *Foundations of serious games design and assessment* (No. COTF/LVP/Sep-2006). Wheeling, WV: Center for Educational Technologies, Wheeling Jesuit University.

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Learning Outcome	Genre												Outcome Count	
	Simulation: Building	Strategy	Sports	Role-Playing	Simulation: Flight & other Sim	Action	Adventure	Gambling	Fighting (Beat 'em ups)	Racing/ Driving	Puzzle	Arcade	>=3.0	>= 3.5
Discrimination													11	7
Rule: Procedural													11	1
Triarchic: Context													9	1
Problem-solving													8	3
Rule: Relational													8	2
Facts & Lists													8	1
Concept: Concrete													8	0
Labels & Names													7	0
Organized Discourse													6	0
DK: Concepts-in-use													4	0
Sociocultural/ Identity													1	0
Concept: Defined													0	0
Cognitive strategy													0	0
Attitude													0	0
Genre Count														
>=3.5	3	2	1	1	1	1	1	1	1	1	1	1		
>=3.0	10	10	10	10	8	8	7	6	3	3	3	3		

≥ 3.5	
≥ 3.0 and < 3.5	

An Ordinal Matrix Comparison of Genre by Learning Outcome Expert Review Consensus Ratings for Ratings 3.0 and Above and for Ratings 3.5 and Above. Ratings ranged from 0 (low) to 4 (high). A rating of 3 = Genre gameplay provides *many* opportunities to achieve this learning outcome (from about 11% to about 49% of the gameplay). A rating of 4 = *most* gameplay within genre provides opportunities to achieve this learning outcome (above about 50% of the gameplay)

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