Chapter 5
Serious Games, Simulations, and Case-Based Reasoning

The affordability of technically robust computers, the extensive availability of wireless online access, and the current high demand for distance education courses all make *now* the time to merge gaming technology with higher education science courses. *Why?* We argue that this format is both pedagogically significant and instructionally effective. Research indicates that today's students are expected to spend as many, if not more, hours engaging in simulated games than they are in formal face-to-face instruction (Foreman, 2003; Neal, 2003; Prensky, 2001; Rejeski, 2002). Based on the sheer success of gaming in general, it stands to reason that students may naturally gravitate toward this media. Abell and Lederman (2007, p. 85) state that "Motivation is an internal state that arouses, directs, and sustains students' behavior. The study of motivation by science education researchers attempts to explain why students strive for particular goals when learning . . ." Brophy (1988, pp. 205–206) defines *motivation to learn* as "a student's tendency to find academic activities meaningful and worthwhile and to try to derive the intended academic benefits from them." It can be argued that students' interest in gaming technology would likely segue into an eagerness to work within this environment. Therefore, this format is expected to provide intrinsic motivation encouraging learning. Extrinsic motivating factors, such as the potential for deeper learning and higher grade rewards combined with the expected intrinsic motivation may ultimately dictate the usefulness of such educational technology in the future.

So what are computer games and why are they so appealing? Overmars (2004a, p. 3) defines a *computer game* as "a software program in which one or more players make decisions through the control of game objects and resources, in pursuit of a goal." Not only do computer games provide specific goals, but good games also have clear rules and appropriate sub-goals (or levels) that once completed lead to the ultimate success of a player, or *winning* the game (Overmars, 2004a). Because the final task within a game is designed to be challenging, it typically builds upon previous learning obtained through the achievement of sub-goals. This design allows players a way to build their knowledge throughout the progression of a game, and to develop new skills within the game environment. Ultimate player success (i.e., "winning") requires the player to demonstrate a specific learning/skill level which allows them to achieve the ultimate goal. The sub-goal->ultimate goal design found in most computer games has several advantages. It allows the player to

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- *Obtain rewards based on achievements:*
  - To succeed in each sub-goal (or level) of a computer game, the player must demonstrate a specific knowledge/skill (i.e., achievement). The achievement varies among games and game types, but examples include attaining a specified score, demonstrating certain skill sets, or obtaining a specified object through the display of gained knowledge. The tools required to achieve such feats, as well as the reward, must be provided within the game at an appropriate level and at the appropriate time in order to engage the player. Unique and varied rewards may be provided at specific levels or sub-levels, based on gained knowledge/skill within the game.
- *Evaluation and repetition:*
  - A player's performance, i.e., success or failure, at each sub-goal allows an evaluation of their knowledge/skill at each level of the game. Since success at a lower level is required for players to move to higher levels, individuals may repeat a specific level multiple times. The immediacy of this evaluation and repetition offered in games is an excellent learning tool. It allows for each individual to spend the amount of time they need on a particular topic while keeping up the challenge of the task. Therefore, before winning most games, the player may have failed multiple times. Such high failure rates can be extremely productive. Because of the high probability of failure, players naturally focus on what they did wrong, what they could have done better, and how to get to the next level. In this way, failure is programmed into games as part of the process that leads to success.
- *Build upon previous knowledge:*
  - Games are typically designed so that skills or knowledge acquired at a lower level must be utilized in order for a player to move forward to a higher level. Therefore, as a player moves closer to the ultimate goal within a game they have built up an arsenal of knowledge and skills that can be utilized. Additionally, experience gained throughout the game should help the player determine how best to approach and obtain the ultimate goal.
- *Control their investment in the game:*
  - Players determine how much time and energy they spend on a particular portion of the game. For example, a player may wish to stop at a specific sub-goal or continue to progress further within the game. This format also creates logical start/stop points within the game, facilitating the player's ability to stop and continue within a specified game for long periods of time.

Therefore, within a computer game the developer creates an environment in which the player is challenged and rewarded, allowed to self-evaluate their performance and obtain results/feedback, as well as able to obtain definitive knowledge leading to ultimate success. Each of these gaming components can be directly applied to the instructional design of distance education higher education science courses. For example, students are expected to gain specific knowledge, demonstrate that knowledge, and develop higher level knowledge that is based on previously acquired knowledge. Through the educational process, student success is evaluated by performance in the form of assigned grades and feedback.

The course content for all higher education courses is determined by specific student learning outcomes provided for the course. Depending upon both institution and course specificity, student learning outcomes may be defined by either the college and/or the individual instructor. Regardless, in higher education courses, the instructor typically determines how and when the student will be presented with the material, and how and when student knowledge will be assessed. Student's failure or success on various assessments throughout the course is considered indicative of student learning. Therefore, not unlike players in video games, students in higher education science courses are asked to demonstrate/apply specified knowledge and ultimately achieve a particular goal based on performance.

Considering that the general principles guiding the development of computer games are well aligned with instructional design theory, it is not surprising that computer game technology has captured the attention of educators. Gaming formats blending both entertainment and learning have been dubbed *Serious Games*. These games have been designed as learning tools, typically focusing on one or several learning outcomes. Because the game goals are limited only by imagination and technology, unique educational opportunities in otherwise limited real-world research experiences can be provided through this format (Rikard, 2004).

Although the development of gaming scenarios by educators may first appear to be a daunting task, evidence is mounting that such a task can be reasonably completed at higher education institutions. Because video games encourage students to explore material in a proactive and exploratory nature, this learner-centered approach fosters the development of self-reliant learners, the type of learner that typically gravitates toward distance education instruction (Taradi, Taradii, Radic, & Pokrajac, 2005). Keeping in mind that Serious Games typically supplement online instruction rather than replace it, we explore how gaming technology may be appropriately applied to support distance education science courses in higher education.

Gee (2003) draws parallels between principles that make video games successful and those required for effective learning including the following: context appropriate information, appropriate challenge level, proper motivating factors, and predictability. Because effective learning should correlate with student success in online courses, success in the educational realm dictates analyzing the acquisition of knowledge. Educators widely refer to different levels of knowledge based on specified categories. We will discuss how each of the four major types of knowledge based on a taxonomy of learning outcomes (Anderson et al., 2001): factual, conceptual, procedural, and metacognitive can be achieved through this format. Summaries of these knowledge categories are listed below (Pintrich, 2002).

- *Factual Knowledge*
  - knowledge of terminology, specific details, and elements
- *Conceptual Knowledge*
  - knowledge of interrelationships among basic elements including classifications and categories, principles and generalizations, theories, models, and structures
- *Procedural Knowledge*
  - knowledge of subject-specific skills, techniques and methods, and criteria for determining when to use appropriate procedures
- *Metacognitive Knowledge*
  - Self-knowledge, strategic knowledge, and knowledge about cognitive tasks including appropriate contextual and conditional knowledge

This knowledge taxonomy includes both lower level knowledge, such as factual and conceptual, as well as higher level knowledge, including procedural and metacognitive knowledge. Gaming formats can be designed to incorporate each of these knowledge levels and offer opportunities to enhance higher level learning processes, such as strategic knowledge (classified as metacognitive), which may be difficult to incorporate into other teaching methods. Pintrich (2002, p. 220) defines *strategic knowledge* as "... knowledge of general strategies for learning, thinking, and problem solving." Multiple interactions, promoting various types of knowledge gains, and cumulating in higher level knowledge gain occur within gaming environments. Variations of learner interactions are controlled both by the game design and student choice, and potentially include learners interacting with computer-based agents, each other, and/or an instructor. The availability and format of such a set-up offers players the ability to repeat tasks, make new choices, and to vary collaboration within the platform. Each of these has the potential to enhance the learning process for the player and emphasize different knowledge categories. Bakas and Tassos (2003) demonstrated how 3D virtual environments can effectively challenge student misconceptions. This study used an outerspace 3D environment to address specific astronomical concepts appropriate for 11–13 year-old students. The goal of this exercise was to determine if the virtual environment helped enable students to "visualize" planetary movement (aiding in their understanding of this concept) as well as their understanding of other identified common misconceptions. Students engaged in this activity while "looking" through a "space ship" window within the environment. Bakas and Tassos (2003) found that after completing the exercise children indicated fewer misconceptions and in many cases replaced those misconceptions with scientifically valid explanations. Although this research example includes learners younger than our target population, the theory is expected to hold true for higher education students as well. The North Carolina State University Serious Educational Games research group has used a variety of case studies as the narrative/back story for video game design (Annetta et al., 2008). Initial results indicate that this format is a promising educational tool.

Dickey (2007) suggests that the narrative design of multiple small questions, or quests, typically found in Massively Multiplayer Online Role-Playing Games

(MMORPG) may provide a model for the effective presentation of specific learning tasks within an interactive learning environment. Dickey (2007) describes a MMORPG as a "persistent, networked, interactive, narrative environment in which players collaborate, strategize, plan, and interact with objects, resources and other players within a multimodal environment." Through the utilization of MMORPGs, students can communicate, interact, and work collaboratively with each other in real time. MMORPGs are designed to encourage, or even require, cooperative learning among individuals for player success, incorporating in player interactions as part of the game design. Therefore, multiplayer interactions and collaborations are an integral part of the game strategy. Therefore, these cooperative three dimensional online environments can easily segue into highly powerful educational virtual learning environments (VLE), which by nature may better prepare individuals for team-centered projects encountered in the workplace (Gee, 2003).

Dickey (2007) identified and categorized the small quest types typically found in MMORPGs and classified them based on knowledge domains required to complete each task. The ways knowledge domains correspond with the knowledge taxonomy previously discussed by Pintrich (2002) are outlined below.

- *Declarative Knowledge Domain:* consists of facts, data, concepts, and principles
  - Aligns with both the Factual and Conceptual Knowledge taxonomy
- *Procedural Knowledge Domain:* requires awareness of how to apply knowledge, principles, and experiences to new situations
  - Aligns with the Procedural Knowledge taxonomy
- *Strategic Knowledge Domain:* awareness of how to apply knowledge, principles, and experiences to new situations
  - Aligns with the Metacognitive Knowledge taxonomy
- *Metacognitive Knowledge:* involves reflection and self-awareness of cognition
  - Aligns with the Metacognitive Knowledge taxonomy

Dickey (2007) suggests that the narrative design of multiple small questions, or quests, typically found in MMORPGs (and Multi-Users Virtual Environments (MUVEs)) may provide a model for the effective presentation of specific learning tasks within an interactive learning environment. Within these environments Dickey (2007) identified and categorized types of specific player-initiated game components called *quests*, and sorted them into specific knowledge domains based on the type of knowledge required to complete each task (summarized below).

- *Declarative Knowledge Domain:*
  - Collection Quests: requires the collection of specific information/objects and/or the performance of a specific task a certain number of times
  - Goodwill Quests: requires teaching and/or assisting a peer (reinforces knowledge)

- *Procedural Knowledge Domain:*
  - Fed Ex Quests: requires player movement from/to particular areas to collect and/or manipulate items, then deliver them
  - Messenger Quests: requires player to pass information from one source to another in order to simulate or learn a process and recount the process
- *Strategic Knowledge:*
  - Bounty Quests: requires player to strategize against and defeat character(s)
  - Escort Quests: requires player to strategize on how to successfully transport a non-player character from place to place
- *Metacognitive Knowledge:*
  - Bounty Quests: requires player to strategize against and defeat character(s)
  - Escort Quests: requires player to strategize on how to successfully transport a non-player character from place to place
  - Goodwill Quests: requires teaching and/or assisting a peer

Through her analysis Dickey (2007) established a framework for identifying specific game elements and how they apply to hierarchal knowledge levels/cognitive skills. This framework has direct applications for the development and assessment of MUVEs. Currently, no widely accepted standards have been identified for analyzing the quality of, and effectiveness of, VLEs. Dickey's analysis (2007) emphasizes the overriding importance of designing the appropriate level of rewards within VLEs. Overmars (2004a) emphasizes how effective games require "flow" of the activities. The "flow" of a game depends upon the appropriate association between the increase in challenge level and the player's ability. Designing the appropriate level of rewards is an important motivator driving the "flow" of the game.

Lee, Hairston, Thames, Lawrence, and Herron (2002) emphasized the importance of appropriately matching skill level/rewards within VLEs for the maximization of both educational value and student satisfaction. In this study both biology and elementary education students were exposed to computer simulations within their respective courses. Students within both disciplines displayed generally positive attitudes toward the incorporation of computer simulations within the course. However, the biology students did not rank the computer simulation as a useful learning tool nearly as high as the elementary education students (40% vs. 85%). Although this specific discrepancy was not scrutinized on during this study, one possible explanation is the mismatch of knowledge/skill level among the participants. Overmars (2004b) highlighted the importance of properly matching the "gaming" expectations to student skill. The specific computer simulation used in this study appeared to have been more challenging for the elementary education students and therefore possibly more engaging and effective. The biology students within this study were in their second course of a two-semester biology series when completing the simulation. The education content of the simulation focused on hypothesis testing and study design, expectedly an easy task for the biology students at this level. It may be speculated that it was the mismatch between knowledge level or challenge and task that resulted in the large variations in the student's rankings for overall usefulness of the computer simulation rather than the presentation of the material which would account for the great variation in ranking between the two groups.

Problem-based learning (PBL) engages the student, assisting in their development of independent thinking. This learning-centered approach requires not only rote memorization but the application of course material requiring critical thinking and independent learning. The foundation of computer game design echoes these basic ideas of PBL, requiring the player to acquire skills to reach the ultimate goal. Case-Based Learning (CBL), or Case-Based Reasoning (CBR), is a type of PBL in which a fictional case is presented to the student in a narrative form. A case tells a story written from the first person perspective. Shulman (1992, p. 21) defined a *case* as a "... a set of events that unfolds over time in a particular place" (p. 21). The more realistic and relevant a case is, the more engaging it is likely to be to the student. Therefore, whenever possible, cases should reflect authentic problems and tasks modeling the real world. These characteristics make CBL the ideal framework from which to develop educational games.

Utilizing this technology, interactive materials and/or characters within the game can be designed to facilitate learning either individually or for multiple players. The idea of interactive discussions is central to most teaching and learning practices, and is foundational for CBL. Working through a gaming scenario allows the student to participate in active learning and depending upon specific game design may encourage collaborative learning.

Serious Educational Games group at North Carolina State University has demonstrated how the CBL design can be incorporated into the video game design (Annetta et al., 2008). It is a challenging process to try to take a case and recreate it into a game. Doing so requires flexibility and creativity on the part of the game designer(s), however initial results indicate that this format is a successful pedagogical tool. Although the efforts of this group are continually expanding in scope, current case-based studies include games created from a video, from an athletics scenario, from a filed trip experience and from training and development cases. A brief description of each design is listed below.

Designing a Game from a Video Case

A Racial Ethical Sensitivity Test (REST) is a video-based case in which work-related ethical issues associated with populations of culturally and linguistically diverse students were explored. Six principles common to all reviewed school-based professional codes were identified and included in the game including the following: professional competence, integrity, professional and scientific responsibility, respect for others' rights and dignity, concern for others' welfare, and social responsibility. Results of the REST had been validated as a reliable measure assessing ethical sensitivity to racial and gender intolerance in school situations according to the professional codes of ethics (Brabeck et al., 2000). Researchers at NCSU recreated the original REST information within a simulated virtual environment gaming platform. Five scenarios were constructed utilizing different educational settings. In each case the goal of the student was to identify acts of intolerance that signify ethically insensitive conduct in U.S. schools while acting as an educator.

Designing a Case for Athletics

This study, originally designed in Adobe Flash^{TM} with minor animation and audio clips, was recreated within the 3D virtual environment WolfDen. The case revolves around an athletic director, Dr. Morgan, who has decided to address the issue of Cardiopulmonary Resuscitation (CPR) and first aid training for his coaches and staff. After concerns raised in the NCAA about the growing number of student athletes who have either collapsed or died during practices, Dr. Morgan hires Tonya Spelling (the game player in this case) to coordinate his training initiative (Fig. 5.1). The player is expected to consider a number of issues including time constraints, negative attitudes, and mandatory versus voluntary training in order to analyze and design an appropriate training plan for the department.

Fig. 5.1 Dr. Morgan provides information about the assignment and important background information

Designing a Case for Training and Development

A training case study was developed which was aimed at creating a consulting firm, Garden Supplies Incorporated (Fig. 5.2), within the 3D virtual environment Wolfden. With students playing the role of the consultants, they were provided with two primary business goals: (1) to increase sales by 25% through a solution-oriented

Fig. 5.2 Entering GSI

approach and (2) to improve customer satisfaction by 30%. In order to achieve the two primary business goals, they have to interview the best sales people and their managers, as a way of understanding how they became so successful. Using that information, the consulting firm would then train other sales people to optimize their performance.

Designing a Case from a Field Trip

The "Bug Farm" is a virtual fieldtrip that simulates the student experience of visiting a farm and creating an insect collection. Developed within the 3D format of *ActiveWorlds*©, this virtual experience acted as an online supplemental lab activity for a distance education entomology course taught at North Carolina State University. Students were directed to navigate various regions of the farm "capturing" various insects for their personal collection based on habitat preferences. Within the environment an interactive flashing icon represented the location of each individual insect species (Fig. 5.3). Clicking on these icons activated a split screen view linking to a specified resource file located on an online Web site maintained by the entomology professor. Specific information provided varied slightly among species but always included a photo(s) of the insect (sometimes at various stages), habitat/life cycle information, and taxonomic information. Prior to entering the farm, students were provided with a list of species to identify, a table to insert

Fig. 5.3 Interactive flashing icons indicating insect locations within the virtual farm

photographs of insects as they were collected, and supplemental information on how to navigate within the farm.

Although current literature supports the effective use of gaming technologies in instruction, few specifically describe how student learning is occurring during these experiences. Kiili (2007) proposed a model of student learning in Problem-Based Gaming (PBG) (Fig. 5.4).

This model is descriptive map of how learning occurs in PBGs. Note that player "reflection" dictates the progression of the player's action within the game and is based on previous knowledge and prior experiences related to the game outcomes. Although reflection is often considered an individual activity, in Kiili's model (2007) it may be either individual or may occur among multiplayer communications.

Simulations are closely related to, but unique from gaming platforms in that they are designed to virtually recreate a real-life experience for a student. Simulations, however, may utilize effective gaming components within their design. The U.S. military is one of the pioneers of simulation-based training. The free game *America's Army*© was funded by the Department of Defense. Because simulations offer a "no risk" approach for individuals to practice and demonstrate responses representative of authentic experiences, they are particularly powerful tools for the engagement and assessment of procedural and metacognitive learning processes.

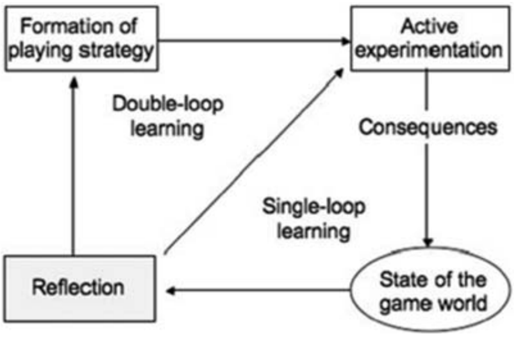

Fig. 5.4 Problem-Based Gaming model describes the learning process with games (reproduced by Kiili, 2007)

Simulations of laboratory procedures and experimental activities have been heralded as a possible solution to the online lab dilemma. The creation of computer simulations may offer a viable option for modeling in class activities virtually. Although valid objections to this type of instruction exist, future educational research should illuminate the pros and cons of such technology for student learning. Current arguments supporting computer simulations are based on the premise that they allow students the opportunity for lab-based experiences that may otherwise be impractical. Time, money, and equipment limitations are all constraints affecting seated traditional labs within higher education. As pointed out by Ma and Nickerson (2006) “Even hands-on laboratories are often mediated by computer, so that there is rarely a pure hands-on experience for students. Therefore, we may really be talking about relative degrees of hands-on, simulation, and remoteness.” (p. 14) Therefore, the role of simulations applies to both traditional and online science lab courses. However, online science labs by nature have additional challenges and limitations to their traditional counterparts including student availability and lack of access to the lab and technical lab equipment. Computer simulations may at least partially resolve these issues by providing students with virtual experiences, controlled by the student and modeled to recreate the traditional lab experience. An additional advantage to simulations is that they can be repeated allowing for risk-free learning. Hofstein and Lunetta (2004) highlighted this advantage by stating “When inquiry empowering technologies are properly used by teachers and students to gather and analyze data, students have more time to observe, to reflect, and to construct conceptual knowledge that underlies the laboratory experiences.” (p. 41) Additional learning benefits of computer simulations have been demonstrated. For example, individuals utilizing computer simulations demonstrated procedural knowledge gains and recalled information relevant to game progression, graphic images, and spoken text more accurately than when the same information was provided as printed text (Belanich, Wisher, & Orvis, 2004). When considering the use and benefits of computer simulations, it is important to clarify that simulations providing students with virtual experiences may, or may not, be followed up by actual laboratory. In other words, simulations may be used in conjunction to real-world experiences either as preparatory, enhancement, and/or reinforcement exercises.

Some higher education institutes have invested extensive time and money into the development of remote labs which utilize off-site maneuverability of on-site technology. One step closer to reality than a computer simulation, these specialized remote labs allow students to collect actual data while performing the experiment at a distance. Therefore, the creation and utilization of remote laboratories are determined, and restrained by, current laboratory and controlling technology. Although current technology limits the application of remote labs, other issues such as considerable time and money constraints to develop such labs may have the most impact on the future utilization of such an instructional method. A literature review on remote laboratories indicated that these problems as well as four major issues including reusability, interoperability, collaborativeness, and convergence with Learning Management Systems would require major commitments to overcome (Gravier, Fayolle, Bayard, Ates & Lardon, 2008).

Today's college students, dubbed the *Net Generation*, have grown up immersed within video gaming technology (Jones, 2002; Fromme, 2003). These individuals are nonplussed by the increased hardware and graphic capabilities of today's PCs and the use of such technologies. These students have come to expect the incorporation of current technology for educational purposes and they have effectively turned their PCs into very robust game-playing machines, particularly for the use of online multiplayer gaming. The success of these MMORPG, such as *EverQuest©, Lineage©*, and *World of WarCraft©*, which are played online by millions of individuals, is astounding and arguably speaks to the promise of harnessing such a format for educational purposes. If the same principles of instructional design are applied to the development of educational virtual environments, these formats may become a powerful pedagogical tool within distance education.

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