A Serious Game for Learning Sustainable Design and LEED Concepts

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ABSTRACT

With the growth of the population worldwide and the increased demand on resources, there has been a growing emphasis on sustainability and awareness of green and responsible use of resources. In response to the need for a sustainable built environment, the United States Green Building Council (USGBC) has established the Leadership in Energy and Environmental Design (LEED) rating system, which includes a set of metrics for defining and measuring “green buildings”. Construction professionals and designers are recognized as LEED AP (Accredited Professionals) if they can demonstrate, via the LEED exam, knowledge and understanding of the LEED rating system. In this paper we describe a serious game for learning Green Building design principles and LEED concepts. The game is aimed at undergraduate students enrolled in Civil Engineering, Architecture and Building Construction Management programs, and professionals who are interested in becoming familiar with the LEED system. The game includes five levels that focus on the environmental categories of the LEED rating system for ‘New Construction and Major Renovations’ 2009 version.

INTRODUCTION

There is a worldwide push for the implementation of “Green Building” through increasing efficient use of resources such as energy, water, and materials during a building life cycle. This effort is encouraged in the U.S by the Leadership in Energy and Environmental Design (LEED) Green Building Rating System™. Another important effort is the LEED Professional Accreditation that distinguishes building professionals with the knowledge and skills to successfully steward the LEED certification process. Currently, there are about 170,000 people in the US that have earned the credential by passing the LEED Professional Accreditation exam (USGBC 2010). This number is not sufficient to successfully accomplish the worldwide push for green building to its fullest.

The objective of the project reported in the paper is to develop a serious game for teaching Green Building design principles and the LEED system. The serious game is aimed at undergraduate students enrolled in Civil Engineering, Architecture
and Building Construction Management programs, and professionals who are pursuing the LEED certification. The long term goal of our research is to assess the effectiveness of using a game approach to integrate sustainable design in the undergraduate curriculum.

BACKGROUND

Green buildings and LEED. Green buildings, also referred to as sustainable buildings, are new structures designed with the intent to be environmentally responsible. The U.S. Environmental Protection Agency (EPA) identifies Green buildings as structures that use environmentally responsible and resource-efficient processes throughout their life cycle, in addition to the classical building design concerns of economy, utility, durability, and comfort.

LEED is an initiative to redefine the way owners, designers, construction, operation and maintenance practitioners think about the built environment. The United States Green Building Council (USGBC) a non profit organization committed to the prosperous and sustainable future through cost efficiency and energy saving green building, identifies that buildings are responsible for 39% of CO2 emissions, 40% of energy consumption and 13% of water consumption per year.

The LEED accreditation/certification process requires professionals to continue to learn through webinars, online classes, courses and supporting resources that go beyond the initial exam. The USGBC website offers an insightful four-step process on preparing and passing the LEED AP exam. The main objective of this work is to enhance existing instruction methods with a unique approach: an engaging, fun serious game that supports learning of sustainable design and LEED concepts. The proposed game is not meant to completely replace current educational practices and materials; rather, it will be integrated in green building and sustainable design courses as an additional educational tool. It will also be available to those who are pursuing the LEED accreditation as another training strategy.

Serious Games. In Mike Zyda’s definition, a game is “a physical or mental contest, played according to specific rules, with the goal of amusing or rewarding the participant”, while a serious game is “a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives” (Zyda 2005). Serious gaming repurposes the concepts of videogames and videogame technologies that have been used for commercial entertainment, and uses the gaming approach for training, education, advertising, national defense, general productivity, and more.

The founders of the Education Arcade at MIT stated that there are many intrinsic motivations for learning associated with games. “The threat of failure is lowered. Games allow players to try, make mistakes or fail, and then try again without losing face. Discovery and application of learned skills in new contexts encourages exploration and experimentation. A sense of engagement continues during gaming. Computer games allow players to be stakeholders in the events that occur on the screen” (Klopfer et al. 2010).
Some research has taken place on serious games from a "new media" perspective (Dovey & Kennedy 2006) from psychological perspectives (Reese 2007) (Greitzer et al. 2007) as well as from sociological perspectives (Schuurman et al. 2008). Blunt (2009) demonstrated that students taking specially designed business, economics, and management courses that had an additional serious game component performed better than students that took the course without the serious game component. Wong (Wong et al. 2007) found in an NSF study that non-science major students taught physiology using a serious game methodology performed better than those taught using traditional static text and images. Coller et al. (Coller & Scott 2009) (Coller & Shernoff 2009) taught a numerical methods course centered completely on a serious game in which students wrote programs that would race a virtual car around a track. They discovered that students in this course spent more time out of class working on the material, demonstrated deeper learning, greater intellectual intensity, more intrinsic motivation, and increased engagement as compared to traditional approaches. Further, these students reported greater levels of challenge and concentration as well as greater interest and enjoyment in the subject matter.

A variety of serious games focused on sustainability, energy efficiency and renewable energy have been developed. Examples are EnerCities (Knol & DeVries 2011), ElectroCity (2007), EfficienCity (2001), EnergyVille (2011), Clim’ Way (2010), BBC Climate Challenge (2010), CityOne (2011). Several serious games have been developed to teach architectural design and visualization.

To our knowledge, no serious games specifically designed to teach sustainable design and LEED concepts exist. The ‘BIM game’ (Yang 2009) is a serious game that aims to teach some sustainable design principles. Its goal is to educate non-experts about energy related design and living. The specific objective of the game is to use a variety of strategies to reduce the Carbon Footprint while designing a new home. The game focuses primarily on one aspect of green building design and does not cover the LEED concepts and rating system.

Knol and DeVries (2011) argues that the majority of serious games in the field of sustainability and design “have put fun and enjoyment less central in the game concept. Ideally, they should be in the first place games for enjoyment with implicit educational content, rather than learning content translated into a game format”. Our work has three main objectives. First, in an effort to improve on the current state-of-the-art in serious gaming, we plan to bridge the gap between tools for learning, such as educational software, and tools for fun, such as computer games, by creating an application that is not just a game, yet remains engaging, is not a lesson, yet promotes learning. Second, although some studies suggest that serious games can improve learning, there is still limited scientific evidence; thus, there is a need to investigate the role and benefits of serious games in the classroom. An important goal of our work is to advance the knowledge in the field by evaluating the effectiveness of serious games for teaching green building design concepts to undergraduate students. Third, a main objective of this work is to enhance traditional instruction methods with a unique approach: an engaging, fun serious game that supports learning of sustainable design and LEED concepts. The proposed game is not meant to completely replace existing educational practices and materials; rather, it will be...
integrated in green building and sustainable design courses as a preparation, revision and assessment tool. Furthermore, it can be used as another training strategy for those who are pursuing LEED accreditation.

THE GAME

The goal of the game is for college students and professionals to learn sustainable design and develop a solid understanding of LEED concepts, while having an enjoyable experience. The ‘LEED-ers’ game is a role-playing serious game (RPG) in which the student plays as the main protagonist. Figure 1 (left) shows a concept sketch of one of the protagonists; the player can choose to play as one of four different characters (2 males and 2 females). The protagonist travels through 5 environments (game levels) and in each environment he/she acquires in depth information about sustainable design and the LEED rating categories.

In order to maximize the effectiveness of the game, we have researched the elements of video game design that promote engagement and motivation for continued play. Based on literature findings, as well as our own experience, we have defined a set of game design features that are likely to promote user’s interest and enjoyment, and, therefore, learning. These elements include: a shared story context that establishes and support the activities (Lepper 1988; Barab et al. 2005); an overarching goal (Malone 1980; Lepper 1988; Shelley 2006); a gentle on-ramp (Malone 1980; Lepper 1988); multiple levels with variable difficulty (Malone 1980; Clanton 1998); a well defined advancement system and rewards associated with advancement (Shneiderman 1983); opportunities to build new content (Roussou 2004; Barab et al. 2005); ability to progress at the user’s own rate (Shelley 2006); hints not answers (Shelley 2006). We have integrated these features with the three elements of intrinsic motivation (challenge, curiosity, and fantasy) identified by Malone (1980) and Lepper (1988).

Figure 1. Concept Sketch of One of the Main Characters, Miss Verde, the Architect (left); Game Opening Screen

Gameplay and educational content. The game includes five levels; each level is an engaging environment in which the player is exposed to various LEED concepts. In each level the player is given a task to accomplish; upon completion of the task he/she can move to the next environment. The first level of the game is dedicated to the exploration of the credit system and the goal is to provide the student with a good
understanding of the intent of each category. The student can select a category from the rating system (i.e. Site Selection) and focus on one category at a time. Figure 2 shows two screenshots of the first level of the game, specifically the site selection category. The second level of the game introduces the student to the LEED credits and point systems. In the third level the student is challenged with a series of tasks whose goal is to maximize the points in each category. Based on a predefined set of constraints such as, for instance, location of public transportation, brown fields, gas station, parking garages, etc., the student is required to analyse multiple case scenarios and explore multiple options in order to maximize the points. Level four of the game focuses on the documentation aspects and the requirements for gaining recognition for the choices, and collecting the LEED points for the certification process. The student is presented with a case scenario similar to the ones in previous levels, however, at this time the student is required to concentrate on the paperwork and submittals needed to collect the LEED points for the certification, and on the use of Information technology and BIM methodology in order to track the documentation. Level five of the game requires the student to integrate and apply all the skills acquired in the previous levels. The student is given a building project and is challenged with the task of developing an effective strategy for maximizing the LEED points.

The ultimate project goal is to expose students to fundamental LEED concepts in a visual fashion that is entertaining and compelling. It is expected that, through sheer exposure, the concepts will insinuate themselves in the user’s mind thus making her or him more receptive and willing to learn.

![Figure 2. Two Screenshots of the First Level of the Game.](image)

**Technical implementation.** The platform for the game is based on Autodesk Revit, Maya and Unity3D. We use Revit and Maya software to model and texture the buildings, virtual environments and characters and to animate their functionality. Interactivity with the 3D components is programmed in C# using the Unity game development platform. The choice of the Unity platform was based on the following considerations:

- Unity has an optimized graphics pipeline that supports interactive rendering of complex animated 3D meshes and advanced lighting and textures even on computers with limited graphics capabilities.
• Unity interfaces seamlessly with major 3D tools (i.e. Autodesk Maya, Revit and 3D Studio Max) and file formats, and allows for instantaneous import and update of asset files and animations.
• Unity supports a wide range of publishing platforms, including: standalone builds for Mac OS and Windows; web delivery through the Unity Web Player Plug-in (3 MB); Wii and iPhone publishing.

The game is deliverable via web or as an exe or app file, and is being designed to run on hardware and software infrastructure that is already widely deployed in universities. Students will be able to use the game on low-end personal computers (PC/MAC) with low-end graphics cards. Different strategies are being used in order to optimize the game performance. Geometric complexity of the 3D models is kept at a minimum, while retaining visual quality, to ensure client hardware can run the application at interactive rates. Normal maps, a technique for simulating complex geometric detail, is used to add fine detail to objects without adding extra geometry. Level of detail is also employed to find an accurate balance between performance and visual quality on the client machine. Furthermore, light maps are implemented to provide high quality lighting for static geometry without impacting performance.

CONCLUSION AND FUTURE WORK

In this paper we have described the initial design and development of a serious game whose goal is to augment the teaching of sustainable design and LEED practices and principles to undergraduate students and professionals. The overall goal of the project is to provide a demonstration that LEED concepts and sustainable design fundamentals can be taught as or more effectively using serious games than by traditional methods. Future work will include iterative development and completion of the five game levels, and assessment of learning outcomes. Based on student feedback, future consideration might be given to developing a multi-player version of the game. The game is being created using an iterative approach that includes 2 forms of evaluation: formative user-centered and summative evaluation. Formative evaluation focuses on the design features of the game, i.e., usability, fun and engagement, and quality of the graphics. Since game development relies heavily on formative feedback from users early and continually, we are conducting formative assessments throughout the design and development phases of each level. Summative evaluation will be conducted once the game is completed to: (1) assess the overall worth and effectiveness of the game; (2) draw out key lessons learned from the project; and (3) determine the sustainability, transferability, scalability, and relative importance of the initiative in enhancing students’ understanding of LEED and sustainable design concepts. Results of the formative and summative evaluations will be reported in future publications.

Provided that our work is successful, (e.g. students’ learning outcomes are equal or higher than with current teaching approaches) expanding the serious game approach to other engineering/architectural concepts as well as other subject domains seems to be a logical step in which to proceed. Future iterations could also be expanded to provide a mechanism to assess LEED and sustainable design knowledge beyond the specific examples within the game to a more general sense of the domain.
If we are able to show a correlation between this serious game playing and student attitudes and performance in the classes in which it is used, we expect to expand the tasks to other courses, as well as broadening usage in the target courses.

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