Innovative Pedagogical 'Game Design/Creation' Methodology for Sustainability Education

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Abstract

An innovative Game Design/creation/play Methodology (GDM), developed through our research on the HP Catalyst Grant project, in conjunction with International Society for Technology in Education (ISTE) and Sloan Consortium (SLOAN-C), was introduced in the graduate Sustainability Management program courses. This was a pilot to study GDM's impact on student learning, motivation, creativity, engagement, innovation, team interactions, instructor leadership, and how they all contributed towards the Course Learning Outcomes (CLO). GDM was introduced in two different courses in MS Sustainability Management program: SUS601 Introduction to Sustainability and SEM608 Sustainable Buildings. These student-built games were closly tied to and demonstrate the CLOs.

This paper presents examples of instructor and student designed & developed games covering various sustainability concepts. The results from this pilot study are encouraging as the specific feedback from students has indicated that the game GDM is a useful innovative pedagogical tool that does promote student engagement, motivation and learning skills. In addition, this innovative teaching tool should help change the declining and waning interest in STEM+ programs.

Introduction

Faculty and administrators in higher education have been seeking innovative ways to engage and motivate students in STEM (Science, Technology, Engineering, and Mathematics) disciplines [1]. Game play and mini games have been used to help reach students and assist in learning the fundamentals of these disciplines[2]. By providing fault tolerant environments and the environment to approach content at the students own pace, games provide a vehicle for students to experiment and approach course concepts through a sandbox of play.

Games have been shown to have a number of distinct benefits when applied to education [3,4]:

- Fault tolerant (iterate to solution/fail forward)
- Opportunity for continual feedback
- Tools within the game have many purposes
- Builds on prior knowledge and allows for progressing to new levels
- Players are rewarded for persistence
- Players can work at your own pace

Games provide the fault tolerant environment, which is a chance for students to make mistakes in a safe setting [5]. These educational settings encourage students facing obstacles will try again or "fail forward"[1]. . Games provide this opportunity to iterate through a problem, by allowing players to build strategies or test boundaries in the game without the fear of failing [6]. Even if the student does not reach an objective, they can try again until they succeed.

Games are flexible, allowing progress to be measured as players' progress from one level to another [10]. Similar to traditional educational environments, game play promotes and rewards student that gain experience and advancement towards higher levels of expertise [11]. This "leveling up" provides motivational queues and a consistant monitoring or feedback of academic progress, which is highly desirable in engaging continued play and assessing the student performance [2, 11].

This leveling and feedback in educational games also promotes students demonstrate persistency in order to seek and achieve goals within [9]. Persistence is the hallmark of gamers and is often times the very attribute that is lacking in STEM students, as mathematical and complex problem solving are a major part of the curriculum [1]. In order to engage and understand complex concepts in STEM, students must remain persistent through the process and combine the right building blocks in order to achieve the desired outcomes for the course [12]. Game environments reward such persistency and levels within the game act as these stepping stones towards knowledge transfer and scaffolding of ideas [8].

Games take on many forms, but single player games that feature a campaign style individual play allow students to work at their own pace in order to achieve goals within the game [4]. Problem based learning often resembles this similar self-paced process found in games, which encourages and facilitates the independent progression through course materials and concepts in order to afford and allow more or less time for specific goals within the game [13]. These affordances in time and achievement create a custom experience for the player and facilitate the learning process for each student [1, 2, 6].

The Bridge to Game Design for Teaching and Learning

In game design for education, or what is referred to as the Game Design Methodology (GDM), students are commissioned to create their own games in order to demonstrate specific course concepts based on course learning outcomes [12]. The GDM carries many of the benefits of game play with the added intensity and engagement of game creation as a vehicle for discovery process [2].

The GDM process involves the clear goals for the activity, whether it be a single assignment or perhaps and final project, teaches concepts through simple game play, shows the tools for design of very basic game assets, and provides structure for the various elements of the student built game. These elements include characters, objectives, procedures, rules, dramatic elements, and game assets [15, 16].

Stages of the Game Design Methodology:

- Faculty provide a list of term based on course learning outcomes
- Students play simple games to learn basics of game design
- Faculty gives examples of how course concept might be used
- Students begin the four phases of building games: Conceptualization (planning), Early Implementation, Implementation, and Presentation
- Faculty give guidance, assessment, and correction at each phase
- Utlize the http://nucatalyst.com website for resources

For the development process, students are usually given a clear set of terms or concepts that are derived from the course learning outcomes and are expected to be demonstrated in their games. This gives the student (or student team, if team project) the opportunity to study or research the topics ahead of time and start to conceive of possible implementation of these concepts. Teachers should be ready to field questions with examples of how the students might consider course concepts as game elements, since this leap will not initially seems obvious. Some teachers have created example games of their own or components of games to quickly demonstrate the possibilities for game design.

At this point, in order to quickly teach the basics of game design, the teacher will provide examples of simple games (usually, turn-based games) that provide a slow motion view of a game, so the students can see how the various game elements are realized in an actual working game. For a game like a simple battle game, students see that the players first pick characters, based on different resources in the game [12]. To demonstrate the procedures of a game, student role a dice (probable two 6-sided die) to see who will go first, then they move the characters,

execute their battles or attacks, and then clean up the left over pieces or prepare for the next turn. To demonstrate rules of a game, the simple game shows that the interactions between battling characters, like range of weapons and damage that is caused represents the interactions that govern play. The assets of the game are somewhat obvious in they represent the actual pieces, maps, dice, cards, or game sheets [14, 15]. Last, the dramatic elements are taught through the play of the simple game as students are able to experience the interchange between competing forces and backstory that create compelling game play [16, 17].

To assist students and teachers the GDM is normally presented in four phases: Conceptualization (planning), Early Implementation, Implementation, and Presentation. Each phase is designed to allow student and faculty to develop the game and assess progress through the process. Conceptualization is based on brainstorming idea, naming the team, naming the game, and beginning to speculate on how game mechanics will relate to course concepts. Students often need guidance from the teacher on how to think about the integration of concepts, however students will often quickly decide on the type or theme of their games in this stage. The themes or type of games will often vary greatly, but it is important to note that much of the motivation and engagement will rely on students having the latitude to select themes that interest them.

In early implementation phase involves defining objectives for their games, listing possible characters and objects in the game, starting to design simple game assets (maps, game pieces, character sheets), and defining the procedure of their student built games [15]. The design tools are kept straight forward and can be as simple PowerPoint slides, drawn objects, and clipart [12] . Additionally, students are asked to play what they have built in order assess whether their game ideas and assets are playable, challenging, and accurately describe course ideas [16].

The primary implementation phases is where students and teachers dialog and construct the main rule sets and include additional technological elements, if part of the course. Rules are the main area where course concepts meet game mechanics. . For example, students may have a power station in their game that demonstrates how cities receive power and how changes to the station's use of natural resources effects sustainability. Students find unique ways to integrate gameplay and relationships into the real world models of the discipline into the game. Demonstrations of course concepts can manifest in the student built games in a number of ways including implicit, explicit, and metaphoric. Implicit integration is where students show the concepts in the game, but hides the mathematics or relationships from the player. Explicit demonstration involves the students clearly showing course concepts directly through game assets, character information, or interaction between game elements. Metaphorical representation occurs when students choose abstract themes and are looking to accurately demonstrate course concepts, but representing these concepts with abstract elements.

Last, the presentation phase includes the reporting and actual demonstration of the student built games. Whether onsite or online, these demonstrations can be facilitating by students showing a complete or partial playing of their games. Normally, the physical version of game can be played in class accompanied by slides, rule sheets, and game elements and the students can walk through the gameplay. Final student reports, representing the student built games, can be developed in a number of ways, but should be a compilation of the various phases of the game

design process with emphasis on linking course concepts to the game descriptions, versions, and explanations. These ideas and game details can include research, references, and the underlying course principles at varying levels of sophistication based on course level or program.

Challenge of Teaching Sustainability Concepts

The primary goal of Environment Protection Agency (EPA) established in December 1970 is to protect the environment focused within the U.S.. From a global perspective, an UN Commission on Environment and Development headed by Gro Harlem Brundtland in 1987 published a report titled 'Our Common Future' – famously known as 'The Brundtland Report'[19, 20] by defining a new term *sustainability*. This famous report defined the term *'sustainable development'* as '*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

This definition and further work in the area led to the three more pragmatic terms now heavily associated with sustainability, namely, 'Environment, Economics and Equity' (famously known as 3 Es; the same concept also expressed as 3 Ps – Planet, Profit and People). Thus the modern definition of sustainability with the 3 Es must become the backbone of any sustainability program. Teaching sustainability fundamentals, especially at the higher education level, earnestly did not start till about a decade ago and today it is not uncommon to see universities promoting their special certification and/or degree programs in sustainability. The topics under sustainability education now cover a whole array of topics – environment (land, ocean, air, forest, etc.), energy (efficiency and conservation), water (efficiency and conservation), recycling, green building design and maintenance (US Green Building Council's LEED certification,[4]), agriculture – and the list continues to expand. Government regulations at the federal and state levels are changing in favor of environment and sustainability in general. The economic (and environmental) benefits of lower energy and lower water consumption, etc., are being recognized as a competitive advantage. Businesses now are on the bandwagon to become 'green' which is also being heavily embraced and driven by stockholders. Businesses now are publishing Corporate Social Responsibility (CSR) reports which focus on the 3 Es. These changes have opened up new 'green' positions in corporations (and in government) and these positions require staff with strong educational background in sustainability. These requirements are driving the need to teach sustainability education as noted above.

Quantification of environment, energy, water related issues and then tying them eventually to equity is a plausible way to instruct. The *games* approach helps both the instructors and the students to become practical in teaching and learning the complex concepts.

'Game Design, Creation and Play' Approach to Teach Sustainability Fundamentals

In National University's MS Sustainability Management Program students are required to complete a team project in each course in addition to homework. Game design projects were introduced in two specific courses namely : SUS601 Introduction to Sustainability (first course in the program) and SEM608 Sustainable Buildings (eight course in the program, there are 9 courses and a capstone project in the program). Each course has its own CLOs and here are some examples from the courses that emphasize the sustainability fundamentals tha were directly tied to the 3 Es:

- Evaluate the environmental, economic, and social dimensions of Sustainable Development (SUS601).
- Analyze the impact of energy and materials resources affect human performance and well being (SEM608)

The innovative approach here is to have the teams design games, create and play them (demonstrate) game that would demonstrate one or more of the sustainability 3 Es.

This approach served and supported multiple purposes. The project needed to be practical enough to demonstrate in a game. As the teams developed the projects from concept and moved towards implementation, they also needed to think about what and how to design and demonstrate the project objectives in their game. In other words, teams were not designing a game totally independent of the subject matter involved in their project. Their project needed to support the course learning objective(s) – so this becomes an integrated approach. The games approach also bring in some 'randomness' (like a dice-rolling or wheel-spinning, etc.) which enables the students to be ready for different strategies resulting in deeper learning of the subject matter.

Games also needed an 'engine' (e.g. spreadsheets) to show the result of a 'game-move' by a player. The implementation of the engine brought out the practical aspects of project implementation. Sustainability topics (water, energy, recycling, etc.) do lend themselves well for implementing an engine to go along with the game, and the results can be displayed in real-time. The students will have to use the right formulae and units for their engine which gets them to dig deeper and explore for a better understanding of the difficult concepts. With the winning game objective set, the players witness their winning (or losing) positions as the game progresses. Examples of these games will be discussed in later sections of this paper.

The main objective in this initial implementation of game pedagogy in the Sustainability program was to study student's perception and its usefulness to increase the student innovation, motivation, and engagement. The caution here is that the students joining the Sustainability program would come from a variety of backgrounds – from liberal arts, to science, engineering and business management, etc. Hence initially studying the adoption process relating to motivation, engagement and motivation are very important.

The implementation strategy to meet the above objectives for game design, creation and play included the following:

- Students' game objective(s) support and demonstrate one or more of the course concepts and learning outcomes including demonstration of one or more of *sustainability's 3 E s*.
- Students work in teams which promotes communication and interaction, like in real work-life project environment. This also promotes inter-learning among students in this new subject area.
- Students identify a game objective(s), players, strategies, rules of play, a game board (virtual electronic or other). This is really a model of a real world situation (see more about this later in the paper) – all directly related to the areas of Sustainability discussed earlier.

- Students get to follow a process with set objectives; the instructor can demonstrate a sustainability game model to help this process
- Student teams present and play their games in front of the class – with Q&A at the end of the presentation; this becomes a real world situation and they have also to explain the "engine" and other sustainability elements.

Methodology

In National University's graduate courses with the intensive and compressed class schedules, a slightly different approach and yet meeting the overall objectives of the GDM was implemented. This approach leads with the instructor first learning to *design and play* a course relevant game, demonstrate the game to the students, let the students actually play the game designed by the instructor in the *very first class* of a course (SUS601).

The advantages of this approach from the instructor point of view is that it puts the instructor not only in a more comfortable position to teach the subject matter in this approach, in addition he/she can make a much stronger case with the experience of having gone through a full working game design and play. The instructor can demonstrate sustainability and game in a more holistic manner: game objective(s), players, design, rules, constraints, etc. and tie it directly to the sustainability course contents.

For students working under the tight NU schedule of one course a month, this instructor demonstration helps them to come on-board much faster and get clarification on many questions they may have regarding game design approach and its relationship to the course content and CLOs. The students also get hands-on experience on a real game that was designed by the instructor.

As noted above it is very important to tie the game design and play to the CLOs. In addition to the specific CLOs noted above , these additional CLOs also get demonstrated through GDM.

- Develop *critical thinking* concepts and Tools which will be used in the course, including the *different measurement unit systems* used for Sustainability
- Explore, evaluate the *improvements and change*s required to achieve sustainability

As can be seen from the CLOs, some of the key elements and concepts, such as development of critical thinking, improvements and changes to implement sustainability lend themselves well for design and development of a game(s) that strongly link with CLOs.

Sustainability topics, as indicated earlier, go across a whole range of interconnected elements – environmental issues and their solutions, water and energy conservation & efficiency issues and solutions that go across many disciplines including agriculture, buildings, etc. In the 'Introduction to Sustainability' course, the *'game design, creation and play'* assignment was a major homework assignment and the assignment would demonstrate their course team project. They need to demonstrate the concept(s) with a real world problem and its solution. The game design/creation/play carried 15% and the related course project carried 15% of the course grade.

Examples of Games
In the sustainability program, game *design, creation and play* were introduced in two key courses – *'Introduction to Sustainability'* and '*Sustainable Buildings'*. Same set of students took both the courses.

Game Example 1: Home Water Management Plan
The approach taken here by the instructor is first to articulate and demonstrate the game approach in a very objective manner tying it to the CLOs with an example game developed by the instructor.

Instructor designed a real world problem of ***Home Water Management Plan*** game for 3 players (home owners). The tool components of this game are: a game board (designed using standard PowerPoint, Appendix 1-A), an electronic dice (brings the randomness to the game; free from Internet, Appendix 1-B) and an engine (Excel spreadsheet created specifically for this game, Appendix 2). The engine has all the formulae for each of the game board landings in terms of water usage, energy consumption and emissions (per EPA and southern California standards).

On the very first class, the game was deployed on several laptops. After a brief introduction by the instructor, students actually got to play the game and see the results. This put the students in a more comfortable position that game design and play is doable to demonstrate practical aspects of Sustainability in line with the course learning outcomes

Given were the three home owners with their current water consumption rates (quantity and cost) and the various uses of water (as shown in the game board). Each player was also given spending money of $500. The objective of the game is to reduce the water consumption by 20% and they could spend the given resource (cash) for making changes to their current water instruments (faucets, toilets, shower, laundry, landscaping including sprinklers, etc.) to help reduce water consumption. Specific rules of the game were laid out, such as one cannot use the same instrument more than once. The players had eight rounds to play and whoever reached the goal (closest or equal or exceeded) and had most money left would be the winner.

Each player would start their turn in the game by spinning the electronic dice, land in the appropriate box (each box representing a different water use in a home) and then device one of the many strategies to save water.

The engine also had a dashboard (Appendix 3) so the players can see their progress towards the goal - by calculating exactly how much money was spent in each round, how much water was saved, how much energy was saved as a result of water savings, etc. (see details in dashboard in the Appendix 3). It is important to note that the dice spins also bring in randomness forcing new strategies and action for each move.

The game demonstrated the sustainability principles (3 Es), and the CLOs as follows:

Environment - Energy savings results in reduction of greenhouse gases, and thus reducing the impact on environment. When water usage is reduced, energy is saved in water processing in the front end (energy spent to bring the water to the home) and the back end (energy saved due to avoiding water treatment). In California reduced water consumption also means reduced water pumped from acquifers, thus saving the water table.

Economics – Savings in water cost by using less water,

Equity - Using less water makes the water availability in a more equitable manner to a larger population, for the present and the future. A very key and significant factor.

Game Example 2: Building Energy Management Plan

This is an example of student designed games in the 'Introduction to Sustainability Course'. A team of 4 students took on the challenge of designing a game focused on demonstrating the strategies and actions involved in a building energy management plan for an existing building. Energy efficiency is considered to be one of the highest priority strategies in building management, especially for an existing building. For LEED certification, energy efficiency commands the highest number of points[4].

The game boards are posted below (figures 1 and 2).

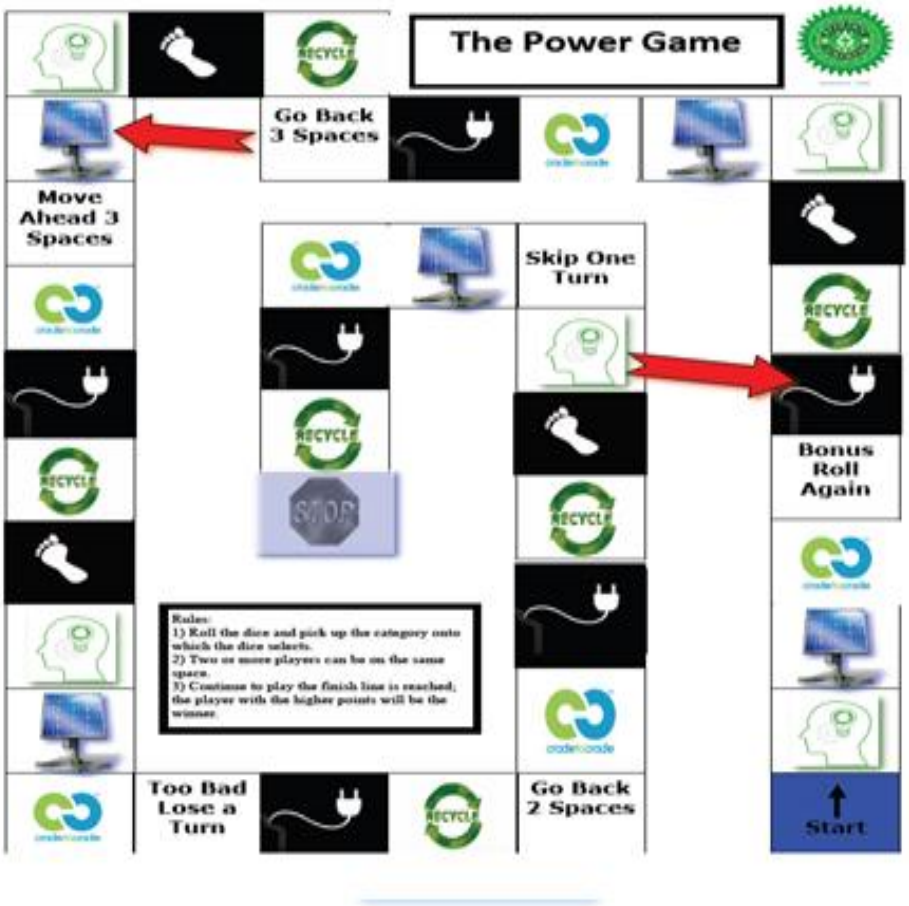


Figure 1 Building Energy Management – The Power Game (Game Board 1 of 2).
[Game Design Team: Yidelka Agosto, Jason Beaston, David Corrales, Nick Maielli; ©]

Rules Noted in the Figure 1 are:

1) Roll the dice and pick up the category on to which the dice selects.

2) Two or more players can be on he same space
3) Continue to play till the finish line is reached; the player with the highest points will be the winner.

Figure 2. Building Energy Management (Game Board 2 of 2; Jeopardy Style)
[Game Design Team: Yidelka Agosto, Jason Beaston, David Corrales, Nick Maielli; ©]

Here the game was designed using standards tools – PowerPoint, Excel, and dice. The game had two game boards, one for rolling the dice and the other where actual game was played (similar in format to Jeopardy; the team used conditional programming that exists in PowerPoint). In this game as well, the 3 Es of sustainability were demonstrated:

Economics – making building more energy efficient saving money

Environment – efficient use of energy reduces the need to burn fossil fuels, thus saving the environment

Equity – a well energy managed building results in better working condition and morale for the people working in the building, which may also have another key side benefit of being more productive.

The team picked an actual National University building for this game. This was voted as the best game by the class.

Game Example 3: LEED Certification Game - "Wheel of Sustainability"
In this exercise, the students were commissioned to develop a game that could help to convey the LEED certification concept. This game, called, "Wheel of Sustainability", is designed to help convey the complex topic of LEED building certification in a simpler and more entertaining

manner. This game is developed for three players to participate simultaneously to see the effects of various factors and how they would affect the LEED certification as it relates to the Energy credits. The objective is to achieve silver, gold, or platinum LEED certification on three existing buildings by following the LEED checklist to increase the Energy and Atmosphere LEED certification point total and reduce the amounts of energy used and CO_2 emissions from the building. The focus is on reducing energy usage and CO_2 emissions to make the three buildings more energy efficient.

The different constraints that the players will have to overcome including funding, material suppliers, The Clean Water Act, EPA regulations, lot size, adjacent buildings and neighbors. The resources include employee education and training, USGBC, SDG&E, LEED certified construction companies, SD County Water Authority, and the EPA. The competing forces include green product substitutes that aren't really "green" but are labeled as such, local buildings within the same business field, consumer perception of sustainability, technological advancements, time, competitors and other industries putting a strain on the resources.

Each player chooses a different building that needs to be retrofitted to become LEED certified. Each building has different amounts of current energy usage and CO_2 emissions that they will need to reduce and improve to gain points for LEED certification.

Each building starts with a certain number of LEED credits depending on their current usage and status. The game board is a spinning wheel (see Figure 3) with eleven separate areas. As shown in Figure 3, there are nine credit areas and two additional areas, namely, Bankrupt and Bonus areas adding some additional uncertainity and challenges. Each area represents the sections of the Energy & Atmosphere category. The players are asked to spin the wheel one person at a time. Based on the landing on one of the sections, the players are required to review the four different options presented to make the building more energy efficient. The four options differ in the amount of energy savings that can be applied and only one option actually gives the player the point needed to obtain the LEED credit. Based on the player choice, the LEED credits are updated. After the first player, the second player goes next, followed by the third. The first player to gain the most LEED credits to reach Silver certification is considered a winner.

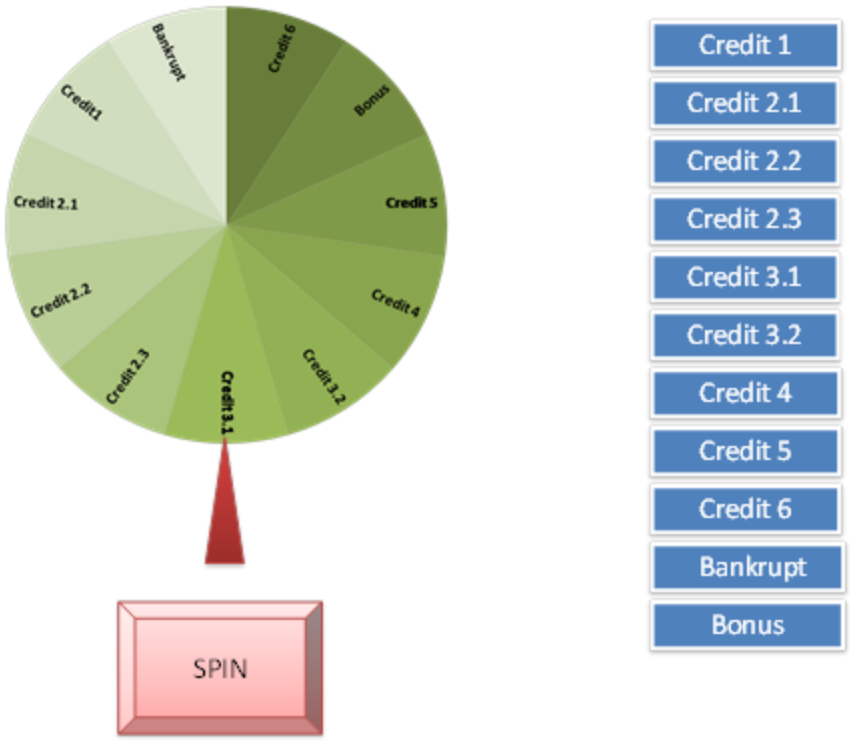


Figure : 3 Spinning Wheel Game Board Design for the Energy and Atmospheric Category

The player spins the wheel and lands on one of the eleven areas, for example, Optimize Energy Efficiency Performance. This opens a new screen that gives the player four options to choose from. These four options are LED Lighting, Motion Activated Lighting, Monitoring System, and Computer Shutoff. Each of these four options has different amounts of CO_2 emissions, utility bill, energy use reduction, and cost. These amounts are not revealed while player 1 is making his/her choice. After the player chooses one of the options, the results appears showing the reduction in the building's energy use, money saved, and CO_2 emissions reduced. In addition, the game engine reveals whether or not the player receives a LEED credit. Based on the results, the player updates the Excel game engine. The associated results are shown in bar graphs. After this is done, the next player spins the wheel and so on until the one of players reaches LEED Silver certification to win the game. As is illustrated above, the choices that the player makes can have far reaching effects on various LEED points earned as illustrated in the screenshot shown in Appendix 4.

The results of the game are shown in Table 1 in terms of LEED points earned, reduction in CO2 output, energy use and utility bill. It is clear from these results, the correct selection yields the maximum LEED point with minimal cost. The players can see the relationship between the capital required to actually enact each specific change, the LEED certification points awarded, and the benefit conferred from the resource expenditure in the energy and atmosphere area of the LEED certification. The more familiar the players become with the relationships between these three areas, the more they can start making informed decisions in real world scenarios.

Table 1 Summary of Energy Usage and Cost Reduction

Wheel Choices					
Description	**LEED Points**	**CO_2 Output Reduction (lbs.)**	**Utility Bill Reduction ($$)**	**Energy Use Reduction (kWh)**	**Cost ($$)**
Credit 1: Optimize Energy Efficiency Performance	**1-18**				
LED Lighting	6	61.73	$250.65	716.15	$ 1,799.00
Motion Activated Lighting	1	17.96	$72.91	208.31	$ 1,599.60
Monitoring System	2	14.82	$60.16	171.88	$ 500.00
Automatic Computer Shutoff	3	34.57	$140.36	401.04	$ 250.00

Student Feedback and Analysis

Student feedback surveys were done for both the courses in sustainability management program. Figures 4 and 5 indicate the specific feedbacks from the '*SUS601 - Introduction to Sustainability'* course on student's perception of the *game design, creation and play* approach of learning and from '*SUS608 – Sustainable Buildings'*.

Sample Size = 25
Questions Relating to GDM
Rate the following attributes for the Game design and creation activity (rating 1 to 5, with 5 being most favorable):
a. Increased student Motivation
b. Increased student depth of learning
c. Increased student engagement
d. Increased team collaboration and communication
e. Increased 'inter' and 'intra' team positive competition
f. Increased student creativity and imagination
g. Learning was fun through 'game creation and play'
h. Expect better retention of learned material through game creation and playing
i. Games help to demonstrate difficult sustainability concepts
j. Increased tools knowledge and skills (PowerPoint, spreadsheet, game website research, etc.)
k. Game 'creation and play' improved student critical thinking skills
l. Team presentation & game demo is an effective method to communicate with the class
m. The Game theory videos and tools at www.nucatalyst.com was effective and useful
n. Game creation, playing , demonstration is an effective method of learning

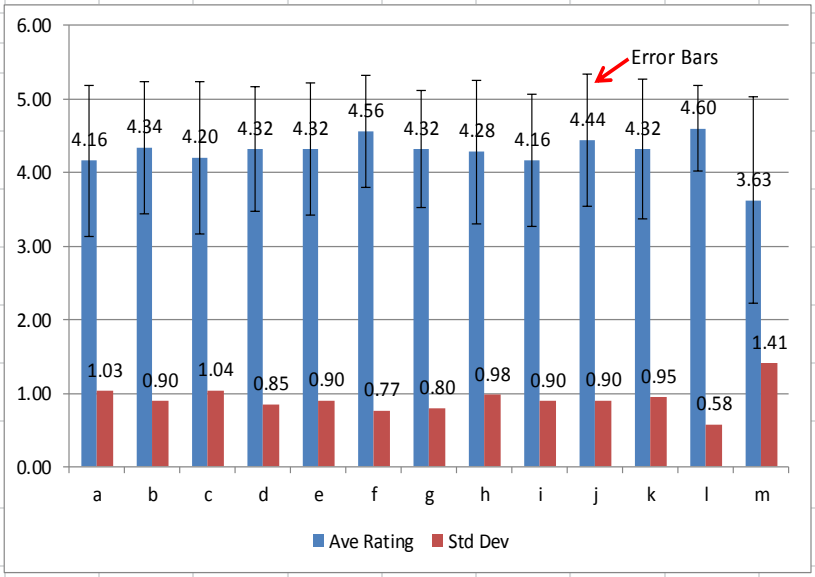


Figure – 4 Student Responses from SUS601 Course

Total Sample size: 22
Question
Rate the following attributes for the Game design and creation activity (rating 1 to 5, with 5 being most favorable):
a. Increased student Motivation
b. Increased student depth of learning
c. Increased student engagement
d. Increased team collaboration and communication
e. Increased 'inter' and 'intra' team positive competition
f. Increased student creativity and imagination
g. Learning was fun through 'game creation and play'
h. Expect better retention of learned material through game creation and playing
i. Games help to demonstrate difficult sustainability concepts
j. Increased tools knowledge and skills (PowerPoint, spreadsheet, game website research, etc.)
k. Game 'creation and play' improved student critical thinking skills
l. Team presentation & game demo is an effective method to communicate with the class
m. The Game theory videos and tools at www.nucatalyst.com was effective and useful
n. Introduction of 'game design/creation/play' linking course learning outcomes in SUS601 was helpful to apply in SUS608
o. Introduction of 'game design/creation/play' in other SEM and ENE courses would be helpful to better understand and apply the subject matter to real world situations.

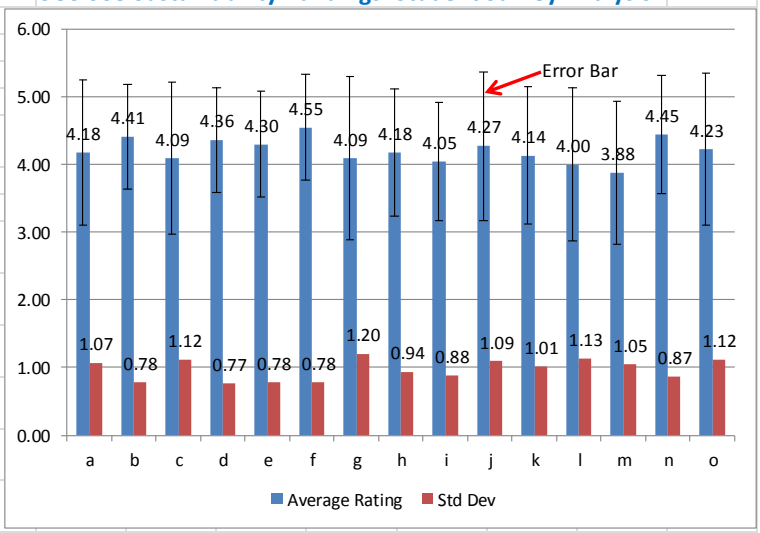


Figure – 5 Student Responses from SUS608 Course

The feedback in both the courses clearly indicates the impact the GDM had in their learning experience. The responses clearly show that the implementation had a very positive impact on the students. The mode for all questions were a '5' (highest), 13 out of 14 questions had a rating greater than 4. The observed trend is similar in SUS608 feedback as well. The feedback on the specific student attributes – innovation, engagement and learning – got very good ratings in both the courses. Many students in SUS608 had the experience of having gone through GDM in their first course SUS601. In SUS608 a more complex problem like LEED certification was demonstrated through GDM.

Based on the student feedback survey, the following were clearly demonstrated in the student developed games:

- Innovation, engagement and learning
  Examples: In the *Energy Management* game and the *Wheel of Sustainability* games, innovation was demonstrated by adopting techniques of well-known games to demonstrate sustainability principles. Engagement by individuals as team members contributing to the success of the games were clearly demonstrated in their final presentation and demonstration game and the Q&A that followed. Students' learning was demonstrated in their game engine calculations (e.g. spreadsheets, responses to jeopardy

style questions) - some of these were over and above the general class discussion topics, yet meeting the CLOs.

- Critical thinking skills
  Examples: Strategies for implementing specific actions for energy (or water) for maximum savings and economic return were demonstrated including interpreting the results as they apply to the 3 Es of sustainability. Spreadsheet calculations – part of the Engine - also fall under this category since it they have to follow industry standards and best practices – all based on facts.
- Resource Management
  Examples – Managing spending and using all available options for energy (or water). *'Wheel of Sustainability'* had a spending or resource limit of $150,000
- Constraints
  Examples: Setting clear game rules and following them demonstrates working within the framework of constraints – how many turns for the players, gaining points towards winning or reaching getting LEED points.

As noted earlier, the introduction of games in to the sustainability program is done on a pilot scale basis and much more deployment and analysis are required to completely assess the full enhanced learning potential for students. From an assessment perspective, the average team course project grade in the SUS 601 was higher by 4.7% when compared to the same course given earlier without the game aspect for the project.

Conclusion

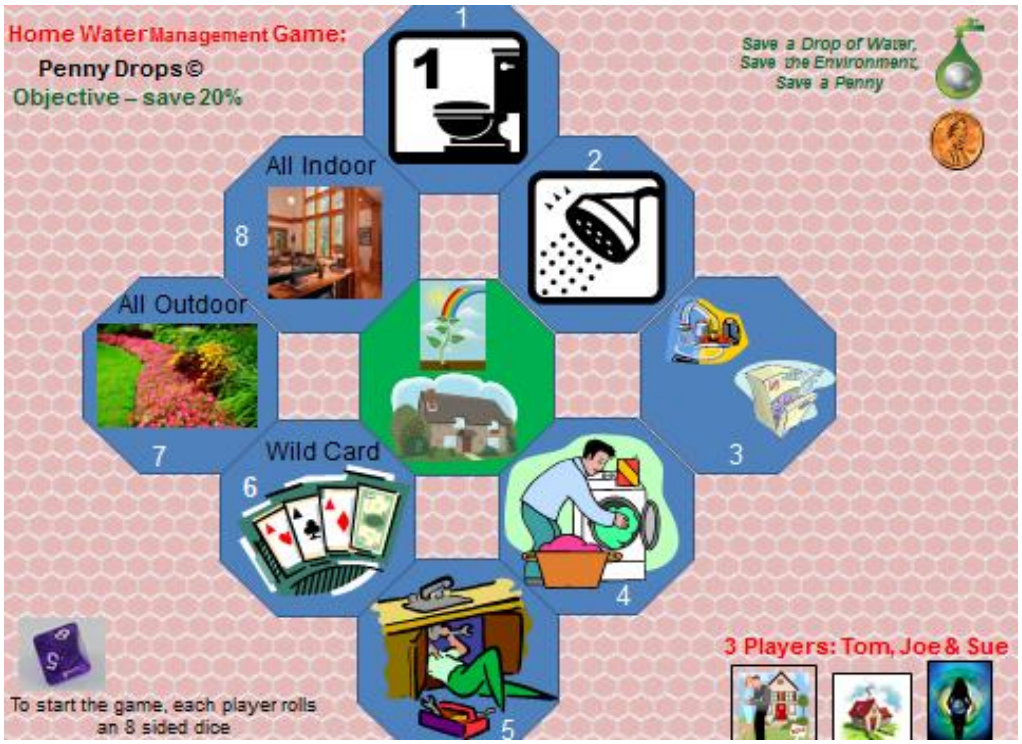
The student built games in this paper clearly demonstrated the ease of learning new complex concepts in a short time frame. This game environment created an active and dynamic environment in class by challenging their imagination, innovation & creativity, and by promoting a competitive spirit. The student built games approach also supports the concept of student-centric learning as they succeed in engaging students and motivate them to learn by presenting concepts in a clear and accessible manner. The game design process is representative of an easy method to teach complex concepts with minimal educational tools.

One of the future goals is to find ways to measure the direct impact of *game design/create/play* on students' performance. This study would involve investigating the variables to be controlled and measured.

In addition to the innovations described earlier in the development of games themselves, the fact that two teams decided to extend and adapt the experience gained in the application and learning of CLOs through GDM to their program capstone thesis is a great sign of innovation to this approach and a true demonstration of STEM+ in action.

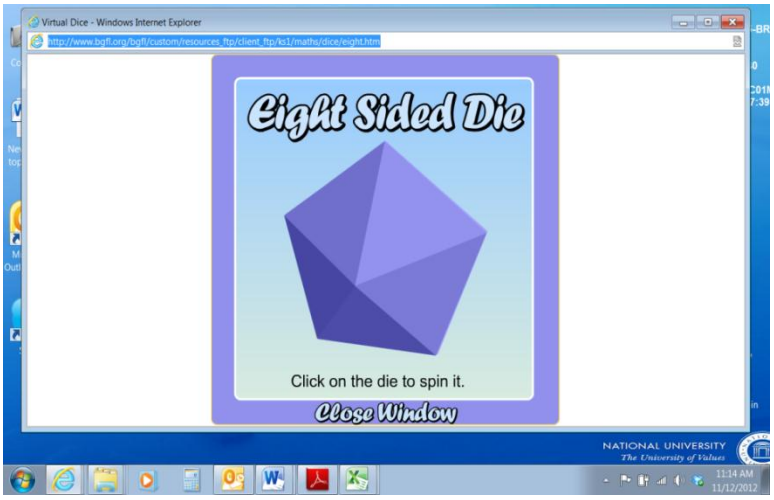
Appendix 1

A. Water Management Plan Game Board (© B. D. Radhakrishnan)



A. Link for 8-sided electronic dice:

http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks1/maths/dice/



Appendix 2

Excel Spreadsheet Engine for the Home Water Management Plan game. ©

TOM's Water Usage and Distribution

				INPUTS	Calculated	
	400	Total gallons per day	INPUT	<STARTING Position>	Expense A	
	280	Indoor gals per day 70%)				
	120	Outdoor gals per day (30%)			Cost of wat	

RE-Assigning Misc 5.3% to all indoor first 5 categories to major categories

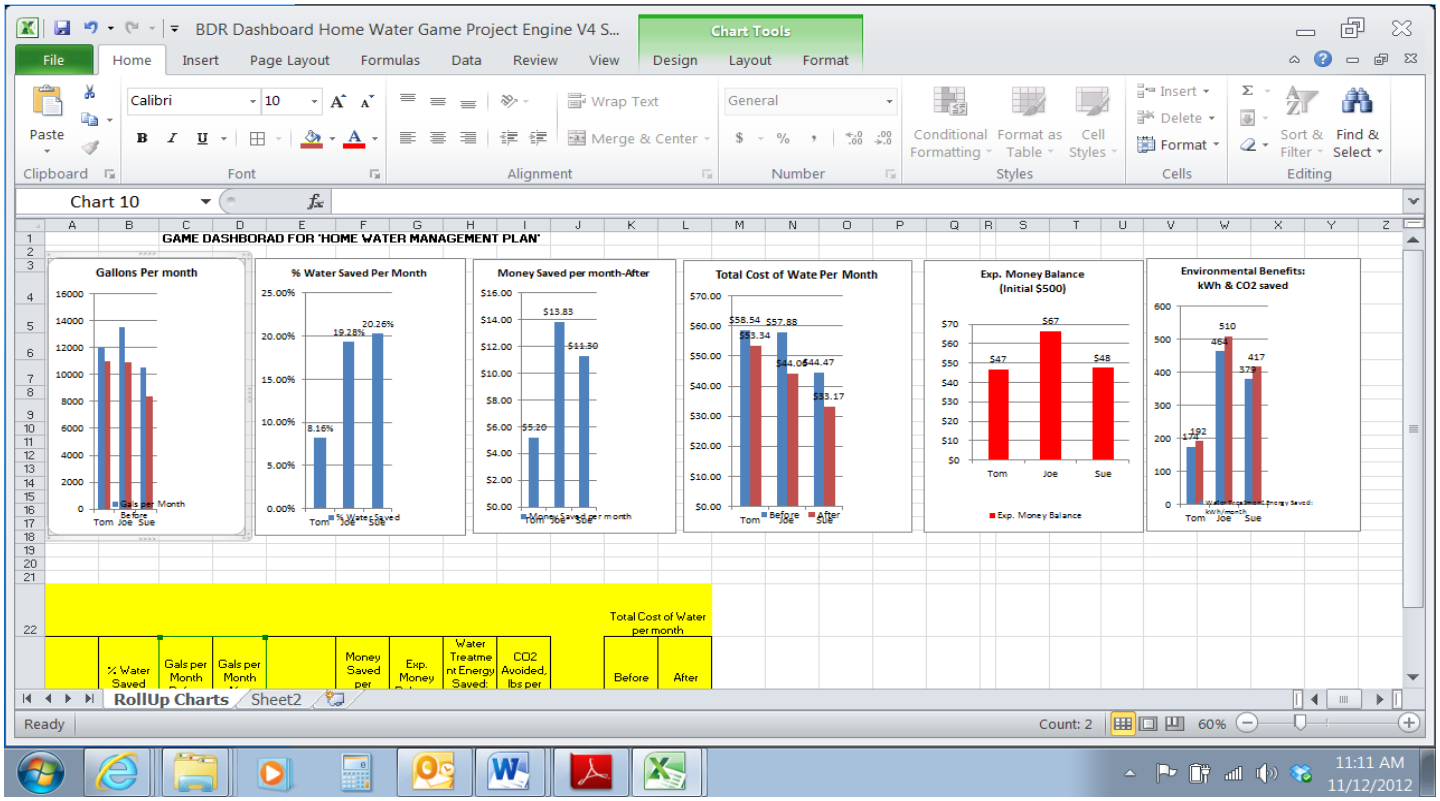
		% Indoor per EPA (Adjusted)	Indoor Gals per day	Outdoor Gals per day	Gals Per Month	% of the total	Gals Annually
1	Toilet	27.8%	77.84		2335.2	19.5%	28411.6
2	Shower	17.9%	50.12		1503.6	12.5%	18293.8
3	Faucet	16.7%	46.76		1402.8	11.7%	17067.4
4	Clothes Washer	22.8%	63.84		1915.2	16.0%	23301.6
5	Leaks	14.7%	41.16		1234.8	10.3%	15023.4
6	Outdoor			120	3600	30.0%	0
7						0.0%	
8	Misc				11992	100.0%	102097.8
		Total	**279.72**	**120**			

WorkSheet for Tom's Implementation of the Plan

Strategy - Area of Change	Round #	Type of Work	Unit Material Cost	Total Material Units	Total Material Cost	Unit Labor cost	Total Labor hrs	Total Labor cost
TOILETS	Round 1	Replace Toilets	$150.00	1	$150.00	$85.00	2	$170.00
	Round 2				$0.00			$0.00
	Round 3				$0.00			$0.00
	Round 4				$0.00			$0.00
	Round 5				$0.00			$0.00
	Round 6				$0.00			$0.00
	Round 7				$0.00			$0.00
	Round 8				$0.00			$0.00
					$150.00			$170.00

Appendix 3

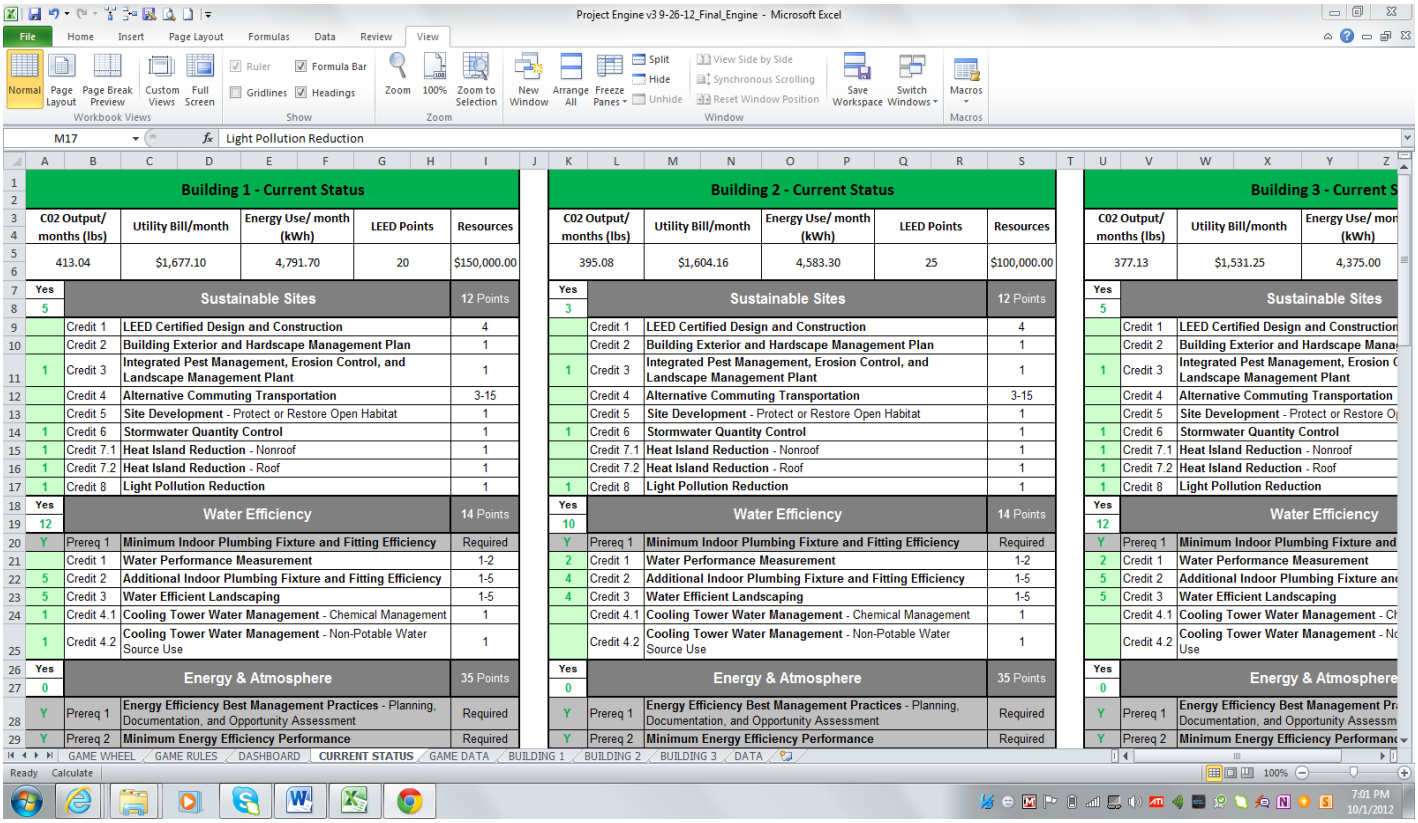
Real Time Dashboard Display showing the Game Outcomes supporting Sustainability. ©



Appendix 4

Spreadsheet Engine for LEED Certification. ©

[Game Design Team: Melissa Steimle, Farhad Fredericks and Eric Wagner]



Project Engine v3 9-26-12_Final_Engine - Microsoft Excel

M17 fx Light Pollution Reduction

Building 1 - Current Status					
C02 Output/ months (lbs)	Utility Bill/month	Energy Use/ month (kWh)	LEED Points	Resources	
413.04	$1,677.10	4,791.70	20	$150,000.00	
Yes	Sustainable Sites			12 Points	
5					
	Credit 1	LEED Certified Design and Construction		4	
	Credit 2	Building Exterior and Hardscape Management Plan		1	
1	Credit 3	Integrated Pest Management, Erosion Control, and Landscape Management Plant		1	
	Credit 4	Alternative Commuting Transportation		3-15	
	Credit 5	Site Development - Protect or Restore Open Habitat		1	
1	Credit 6	Stormwater Quantity Control		1	
1	Credit 7.1	Heat Island Reduction - Nonroof		1	
1	Credit 7.2	Heat Island Reduction - Roof		1	
1	Credit 8	Light Pollution Reduction		1	
Yes	Water Efficiency			14 Points	
12					
Y	Prereq 1	Minimum Indoor Plumbing Fixture and Fitting Efficiency		Required	
	Credit 1	Water Performance Measurement		1-2	
5	Credit 2	Additional Indoor Plumbing Fixture and Fitting Efficiency		1-5	
5	Credit 3	Water Efficient Landscaping		1-5	
1	Credit 4.1	Cooling Tower Water Management - Chemical Management		1	
1	Credit 4.2	Cooling Tower Water Management - Non-Potable Water Source Use		1	
Yes	Energy & Atmosphere			35 Points	
0					
Y	Prereq 1	Energy Efficiency Best Management Practices - Planning, Documentation, and Opportunity Assessment		Required	
Y	Prereq 2	Minimum Energy Efficiency Performance		Required	

Building 2 - Current Status					
C02 Output/ months (lbs)	Utility Bill/month	Energy Use/ month (kWh)	LEED Points	Resources	
395.08	$1,604.16	4,583.30	25	$100,000.00	
Yes	Sustainable Sites			12 Points	
3					
	Credit 1	LEED Certified Design and Construction		4	
	Credit 2	Building Exterior and Hardscape Management Plan		1	
1	Credit 3	Integrated Pest Management, Erosion Control, and Landscape Management Plant		1	
	Credit 4	Alternative Commuting Transportation		3-15	
	Credit 5	Site Development - Protect or Restore Open Habitat		1	
1	Credit 6	Stormwater Quantity Control		1	
	Credit 7.1	Heat Island Reduction - Nonroof		1	
	Credit 7.2	Heat Island Reduction - Roof		1	
1	Credit 8	Light Pollution Reduction		1	
Yes	Water Efficiency			14 Points	
10					
Y	Prereq 1	Minimum Indoor Plumbing Fixture and Fitting Efficiency		Required	
2	Credit 1	Water Performance Measurement		1-2	
4	Credit 2	Additional Indoor Plumbing Fixture and Fitting Efficiency		1-5	
4	Credit 3	Water Efficient Landscaping		1-5	
	Credit 4.1	Cooling Tower Water Management - Chemical Management		1	
	Credit 4.2	Cooling Tower Water Management - Non-Potable Water Source Use		1	
Yes	Energy & Atmosphere			35 Points	
0					
Y	Prereq 1	Energy Efficiency Best Management Practices - Planning, Documentation, and Opportunity Assessment		Required	
Y	Prereq 2	Minimum Energy Efficiency Performance		Required	

Building 3 - Current S					
C02 Output/ months (lbs)	Utility Bill/month	Energy Use/ mon (kWh)			
377.13	$1,531.25	4,375.00			
Yes	Sustainable Sites				
5					
	Credit 1	LEED Certified Design and Construction			
	Credit 2	Building Exterior and Hardscape Mana			
1	Credit 3	Integrated Pest Management, Erosion C Landscape Management Plant			
	Credit 4	Alternative Commuting Transportation			
	Credit 5	Site Development - Protect or Restore O			
1	Credit 6	Stormwater Quantity Control			
1	Credit 7.1	Heat Island Reduction - Nonroof			
1	Credit 7.2	Heat Island Reduction - Roof			
1	Credit 8	Light Pollution Reduction			
Yes	Water Efficiency				
12					
Y	Prereq 1	Minimum Indoor Plumbing Fixture and			
2	Credit 1	Water Performance Measurement			
5	Credit 2	Additional Indoor Plumbing Fixture an			
5	Credit 3	Water Efficient Landscaping			
	Credit 4.1	Cooling Tower Water Management - Ch			
	Credit 4.2	Cooling Tower Water Management - No Use			
Yes	Energy & Atmosphere				
0					
Y	Prereq 1	Energy Efficiency Best Management Pr Documentation, and Opportunity Assessm			
Y	Prereq 2	Minimum Energy Efficiency Performanc			

GAME WHEEL | GAME RULES | DASHBOARD | CURRENT STATUS | GAME DATA | BUILDING 1 | BUILDING 2 | BUILDING 3 | DATA

Ready Calculate

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