An Empirical Test of an Educational Video Game to Teach Energy Literacy

Kavin Nataraja
Purdue University
knataraj@purdue.edu

Nicholas Head
Purdue University
nhead@purdue.edu

David Whittinghill
Purdue University
dmwhittinghill@purdue.edu

Introduction

This paper presents the results of a pilot study conducted using a new educational tool to help promote energy literacy in students. The tool is named MAEGUS, an acronym that stands for Measuring Alternative Energy Generation via Unity Simulation. MAEGUS is a Unity-based educational game that simulates sustainable energy technologies such as wind turbines and solar arrays[9]. In 2013, MAEGUS's efficacy as a learning tool was tested in a pilot study with college students, the details and results of which are provided later in this paper.

Background

MAEGUS was developed to provide an entertaining way to implicitly teach concepts in physics, mathematics, and energy literacy. Energy literacy is defined as including "a 'citizenship understanding' of energy that encompasses affective and behavioral aspects" [4]. Energy literacy goes beyond simple content knowledge; it also requires an acceptance of responsibility for being aware of energy generation and alternative options[4]. Consumption of nonrenewable resources increases every year and many countries that do not have access to nonrenewable resources are energy impoverished[8]. Energy impoverished countries are defined as countries that lack access to a stable nonrenewable energy source and must instead rely on energy sources such as biomass. A lack of awareness of alternative options can help contribute to energy poverty and so the promotion of energy literacy can help alleviate the growing need for energy sources[6 8].

The need to teach energy literacy has become an integral part of education reform in many countries. For example, the Colorado School of Mines developed an Energy minor in 2009. Classes in this minor used formal lectures to teach highly technical energy concepts but also integrated hands on activities and experiments that students found appealing[10]. In other examples of energy education curriculum, students were found to be motivated in energy education classes that provided direct benefit to their society or communities[2]. E-learning also was found to be a desirable aspect in energy education curriculum[1]. These aspects influenced the conceptualization of a hands on e-learning activity that could be integrated into energy education curriculum and taught students how their communities could benefit from sustainable energy concepts: MAEGUS[9].

The Game

MAEGUS is a serious game, a game that's chief function isn't strictly restricted to entertainment. A serious game can also serve an educational role by having players practice skills such as problem solving or creative thinking during gameplay[3]. Students can interact with scenarios and environments they normally would not have access to using virtually simulated environments in digital games and applications[5 7].

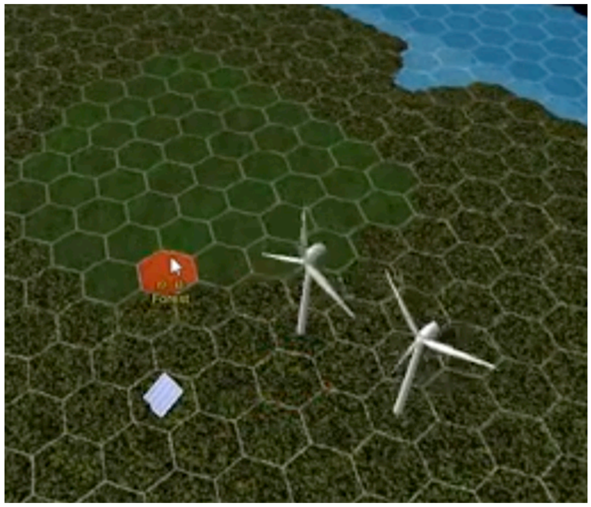

Figure 1. Development version of MAEGUS showing Scenario 1.

MAEGUS is a turn-based energy management game that uses scenarios and physically accurate energy production simulations to teach the concepts behind sustainable energy[9]. Players are given the role of a city's energy manager and must complete scenarios in MAEGUS using a monetary budget to build sustainable energy technology to reach certain output goals. The scenarios in MAEGUS are levels that simulate environments with different weather effects and terrain. A temperate plains scenario may feature stable wind speeds and solar concentration while a mountainous area would feature higher wind speeds but a lack of flat terrain to build energy technologies.

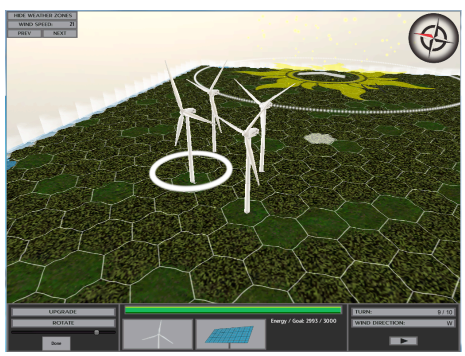

Figure 2. MAEGUS current version with weather zones

In MAEGUS, players must effectively utilize their budget to build and maintain sustainable energy technologies. Players must place their energy installations so as to maximize their energy output. Wind turbines must be built in regions where wind speeds are high while solar arrays must be build in areas of high solar concentration. These areas are visualized with "weather zones" as seen in Figure 2.

MAEGUS also features a day/night cycle, with each turn simulating a full day/night cycle. Solar arrays cannot generate energy during the night but wind turbines will generate energy throughout the turn. Turns are an abstract concept in MAEGUS and in the final version of MAEGUS will represent a time longer than a single day. Sustainable energy technologies will also require maintenance, a monetary fee that will be deducted at the beginning of every turn automatically. Players must balance their purchases and upgrades to allow for maintenance fees in upcoming turns.

As seen in Figure 2, the player has access to two sustainable energy technologies: wind turbines and solar arrays. These technologies can be built and upgraded by the player to improve energy output. Players can upgrade the individual aspects of their wind turbines and solar arrays that correlate with variables in their respective energy generation formulas. For instance, wind turbine blades can be increased to increase the area of the swept blades and increase energy generated by that turbine. Properly learning the variables that go into the energy generation formulas is how MAEGUS teaches sustainable energy concepts.

$$P = \sum_{i} pvA_iCp_i$$

P = Total power
p = Air density
A_i = Swept area of each turbine's blades
v = Wind velocity
Cp_i = Power coefficient of each generator

Figure 3. Wind energy formula used in MAEGUS

Players must learn how to manage their monetary budget, their sustainable energy installations and the variations of the scenario's physical simulation of weather and the landscape itself. This pilot study, conducted in 2013, tested an early version of the MAEGUS simulation to assess its use as an educational tool. Though MAEGUS is still in development, the software was determined by the authors to be ready to begin a pilot study. Features that were included in the pilot study version of MAEGUS were the accurate physical generation of wind turbines and solar arrays, turns, and upgrades as these features are the primary mechanisms MAEGUS uses to implement its pedagogy.

The Study

The MAEGUS pilot study is partially inspired by Darling's Racing Academy study conducted in 2008[5]. As part of a new course curriculum, Darling had engineering undergraduate students from the University of Bath play an auto racing game. Gameplay sessions were integrated into workshops that were held throughout the course. At the beginning of the course, students were administered a pre-test questionnaire about their knowledge of various automobile dynamics. In the actual game, students created drag racers and customized various parts of the racer such as the engine. The tweaks on the automobile's parts led to faster or slower cars based on the part's performance. At the end of the course, students were administered a final multiple-choice test on the concepts with which they interacted in the game. Comparing the post-test to the pre-test, Darling found that the game increased students' knowledge of automobile dynamics and was a positive factor for learning in the curriculum[5].

Participants in the MAEGUS pilot study were given a pre-test survey, asked to play the MAEGUS game, and then took a post-game survey that was identical to the pre-test survey. In order to properly calculate the energy literacy of the students, the actual test was based off the procedure used in DeWaters' 2011 study[4]. Dewaters used a multiple-choice questionnaire that targeted the participants' affective, behavioral, and cognitive processes regarding energy usage. In order to see a change in energy literacy measured, the MAEGUS study used a pre-test survey and similar post test. The results of both tests were compared to determine a significant difference in energy literacy.

The sample population consisted of 25 undergraduate students from Purdue University's Computer Graphics Technology department. After signing the release form, participants began the test by completing the pre-test survey, which can be found in Appendix: Testing Materials. The test was a self-report survey that consisted of 4 Likert scale questions, and 2 open ended questions. Using the scale, it was possible to measure how confident participants were in their understanding of sustainable energy concepts. The open-ended questions illustrated the participant's knowledge of the different variables needed to properly generate solar energy and wind energy. Participants were then graded dependent on the total combined score from the Likert scale questions and by the number of correctly listed variables for the open ended questions. The pre-survey established the participant's pretest knowledge that was then compared with the results of the post test later on in the study.

Next, the participants played the MAEGUS simulation. MAEGUS has several different stages with different environmental factors, but for the pilot study all participants played the first stage: a temperate plains environment. Once the level loaded, the proctor of the test gave the player a brief tutorial on the controls of the game. The proctor did not discuss how to generate or maximize energy output in the game. All participants had ten turns in the game to try and reach their energy goal.

Finally, participants were asked to complete the post survey for the test. The post test survey has similar questions to those that are found in the pre test survey. By using similar questions, the researchers can compare the results to the pre survey and find a difference in the participant's energy literacy.

Results

In order to see if there was a significant difference in the energy literacy of participants before playing MAEGUS and after, a matched pairs t-test was used on the results. The null hypothesis for the test was that MAEGUS does not cause a change in the energy literacy of undergraduate CGT students. The alternative hypothesis was that MAEGUS would increase the energy literacy in undergraduate CGT students. An alpha level of .05 was used for the t-test meaning that a 5% margin of error was allowed. Because this was a pilot study, an alpha of .05, along with a confidence level of 95%, was acceptable in determining if there was a change in energy literacy.

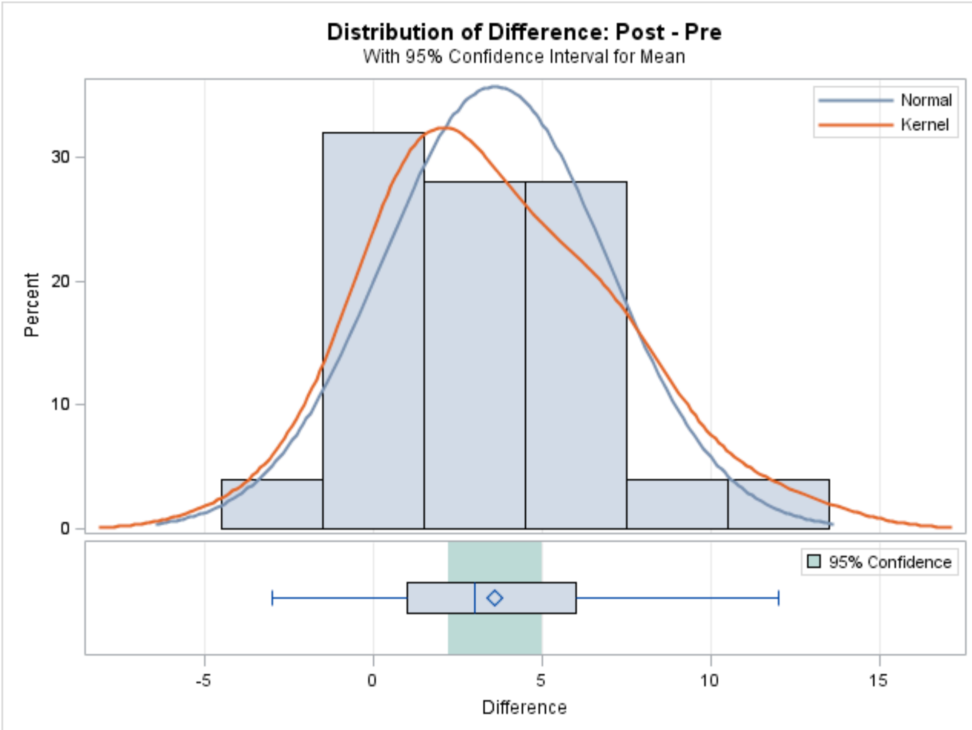

Table 1. Table of Results

The lowest test score for the pre survey was a score of 5. This was one higher than the lowest possible score for the survey, which was a score of 4. The highest test score was 22. The mean result from the sample pre-test survey was 14.92 with a standard deviation of 3.9887. Overall, the data was approximately normal without any outliers influencing the data.

For the post survey, the lowest score was 11 with the highest being 23. The mean result from the sample post survey was 18.52 with a standard deviation of 3.5369. At a glance, an increase in scores can be seen in the higher spread and mean of the post survey in comparison to the pre-test survey. The data of the post survey has most of the participants scoring in the upper region, causing a left skew. This showed an increase in scores between the two surveys.

The sample mean of the difference was 3.6 with a standard deviation of 3.3541. In Figure 1, a histogram of the difference along with a boxplot can be seen illustrating this data. Although the data appears to be right skewed, a qqplot and normality test shows that the data was approximately normal. The t-test showed that the mean difference would be between 2.2155 to 4.9845 95% of the time. Because the P value is below the alpha of .05, and the confidence interval is positive and there is no value of zero in the interval, it is possible to reject the null hypothesis. Thus the data provides evidence that MAEGUS increases energy literacy in CGT undergraduate students.

Conclusion

The MAEGUS pilot study showed that under the conditions described above, MAEGUS has efficacy as an educational tool. One important comment that participants had about MAEGUS was that it wasn't a game yet, but instead was just a task or simulation with no game qualities. MAEGUS is incomplete and there are still many features, both visual and technical, that when implemented are intended to improve the game experience of MAEGUS. Future work on MAEGUS will focus on this improvement of gameplay while carefully preserving MAEGUS' educational usefulness.

Acknowledgements

The authors would like to thank Professor Terry Burton for his assistance in mentoring our development team.

Bibliography

1. Acikgoz, C. (2011). Renewable energy education in Turkey. *Renewable Energy*, *36*(2), 608-611.

2. Chen, K. L., Huang, S. H., & Liu, S. Y. (2013). Devising a framework for energy education in Taiwan using the analytic hierarchy process. *Energy Policy*, *55*(1), 396-403.

3. de Freitas, S., Kiili, K., Ney, M., Ott, M., Popescu, M., Romero, M., & Stanescu, I. (2012). GEL: Exploring Game Enhanced Learning. *Procedia Computer Science*, *15*, 289-292.

4. DeWaters, J. E., & Powers, S. E. (2011). Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behavior. *Energy Policy*, *39*(3), 1699-1710.

5. Darling, J., Drew, B., Joiner, R., Iacovides, I., & Gavin, C. (2008). Game Based Learning in Engineering Education. In *International Conference on Innovation, Good Practice and Research in Engineering Education, Loughborough University, England P* (Vol. 70, p. 2008).

6. Garg, H. P., & Kandpal, T. C. (1996). Renewable energy education: challenges and problems in developing countries. *Renewable energy*, *9*(1), 1188-1193.

7. Kapp, K. M. (2012). *The gamification of learning and instruction: game-based methods and strategies for training and education*. Wiley. com.

8. Kaygusuz, K. (2012). Energy for Sustainable Development: A Case of Developing Countries. *Renewable and Sustainable Energy Reviews*, 16, 1116-1126.

9. Nataraja, K. & Whittinghill, D. (2013). MAEGUS: A Sustainable Energy Simulation to Promote Energy Literacy. In T. Bastiaens & G. Marks (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2013* (pp. 2474-2479). Chesapeake, VA: AACE.

10. Stone, C. (2011). Renewable Energy Education at the Colorado School of Mines : A Survey of Development, 1–7

Appendix

Pre-Test/Post-Test

Please answer the following questions using the provided scale, 1 signifying you do not agree and 5 signifying you definitely agree.

1. I have an in-depth knowledge of sustainable energy.

1	2	3	4	5
Strongly Disagree	Slightly Disagree	Neutral	Slightly Agree	Strongly Agree

2. I know the scientific factors that determine how wind turbines generate energy.

1	2	3	4	5
Strongly Disagree	Slightly Disagree	Neutral	Slightly Agree	Strongly Agree

3. I know the scientific factors that determine how solar arrays generate energy.

1	2	3	4	5
Strongly Disagree	Slightly Disagree	Neutral	Slightly Agree	Strongly Agree

4. I am interested in sustainable energy.

1	2	3	4	5
Strongly Disagree	Slightly Disagree	Neutral	Slightly Agree	Strongly Agree

Please answer the following questions to the best of your ability with a short answer.

5. List the factors that affect the output of a wind turbine's energy generation.

6. List the factors that affect the output of a solar array's energy generation.