

The educational value of the Sol Y Agua digital game into middle school science class

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Abstract

This paper focuses on finding the added educational value that the Sol y Agua game provides to science students in the El Paso TX context. Hong et al. (2009) created an evaluation index for assessing the educational value of digital games which includes seven categories: Mentality change, emotional fulfillment, knowledge enhancement, thinking skill development, interpersonal skills, spatial ability development, and bodily coordination. Sol y Agua is an educational digital game developed at the CyberShare Center of Excellence at the University of Texas at El Paso. The game is a role-playing adventure game that focuses on the environmental and water sustainability problems in the El Paso area. The game was created to be part of a lesson plan for middle school science classrooms. Along with practices that include computational thinking skills, the game provides students with opportunities to develop reasoning, simulation, and a better understanding of the soil and water properties as well as their usage within the community. Based on the Evaluation Indices for Assessing Educational Digital Games, a game provides elements that allow players (students) a mentality change, emotional fulfillment, knowledge enhancement, development of thinking skills, and spatial ability. The ultimate goal of the game is for students to design a park for a specific population, children and elder people. To achieve this, the game provides students with the opportunity to identify the different types of soil (desert, mountain) different types of trees, and their water and soil requirements.

Keywords: digital games, assessment, science class, middle school

INTRODUCTION

Digital game-based learning (DGBL) is an educational approach that uses digital games as technological tools to engage, motivate, and involve students in their learning process through hands-on experiences with interactive digital platforms. DGBL has increased in the last decade; this increment is partially the result of researchers' interest to understand how digital games can be used in educational environments to engage and motivate students to assimilate educational content (Hwang & Wu, 2012).

These competencies also called 21st century skills, are desirable for any student as they help them to be successful in the technology and information era. Games also allow students to enjoy educational strategies and get the fun learning through DGBL. Hwang, Hung & Chen (2014) found students' enjoyment in creating digital games around an educational topic by having students tasked to create digital games and to evaluate their peer games. They learned the topic in-depth, created digital games, played games, and evaluated them using a rubric given by the teacher. This strategy challenged the students to learn the topic while using DGBL.

According to Hong, Cheng, Hwang, Lee & Chang (2009) digital games can be used in the classroom not only because of their motivational value, but because games include interactivity; games are centered on the user or player, and students can learn by playing games. Virk, Clark & Sengupta (2015), educational games provide players (students) with tools to construct causal relationships along with the game. In that sense, educational digital games are created to provide students with conceptual and procedural knowledge related to a particular discipline. However,

learning can be enhanced if the digital games are used in the class in addition to other educational techniques and exercises (Yong, S., Gates, P. & Harrison, I., 2016).

For Ninaus, Kiili, McMullen, Moeller (2017) serious games (educational games) and game-based applications can not only be used to motivate and engage students but also as an innovative tool to train students and adults in mathematics. They conducted a study using a digital game to promote students' acquisition of fractions knowledge. The study found that the use of a digital game provided help to provide students with fraction content knowledge and that using the game also provided students with an innovative platform to assess student's performance. In this specific case, a group of researchers evaluating the game, however for teachers it is complicated to conduct a research study to evaluate the digital games they know.

In this light, it is highly recommended the use of a scale (Hong, Cheng, Hwang, Lee & Chang, 2009) to measure different aspects in digital games like mentality change, emotional fulfillment, knowledge enhancement, thinking skills, interpersonal skills, spatial ability, and bodily coordination. Using this scale, teachers from all educational levels and disciplines could evaluate digital games to their posterior use in their classes as learning tools.

SOL Y AGUA GAME

According to their creators, "The Sol y Agua game has a theme of water sustainability and stewardship with an emphasis on information analysis, negotiation, and decision-making. The game immerses students in themes concerning biodiversity, sustainability, and the human impact on the environment. The activities challenge students to make informed decisions regarding water sources, maintenance, environmental factors, and sustainability, among others. The students learn the impact of humans on the environment through data analysis and run experiments in a virtual laboratory with real data. Data visualization allows students to interpret data in new, fun, and meaningful ways. The game has an emphasis in promoting minorities in the Southwest United States towards pursuing careers in Science, Technology, Engineering, and Mathematics (STEM), where they are largely underrepresented".



Figure 1. Sol y Agua Game Interface

The game was created to be part of a lesson plan for middle school science classrooms. Along with practices and activities including computational thinking skills, the game provides students with opportunities to develop reasoning, simulation, and a better understanding of soil and water properties and their usage in their community. Sol y Agua is a computer drill and practice, which includes lab simulations and drone flying practices as part of its dynamics. Along with the game, there is a character Owlfonso the owl (see Figure 1) that will help students to scaffold their learning; this character is a wise owl that will give students tips to complete the tasks. The ultimate goal of the

game is for students to design a park for a specific population. To achieve this, the game provides students with the opportunity to identify the different types of soil (desert, mountain) and different types of trees, and their water and soil requirements. One of the requirements is to neutralize soil and water pH levels planting functionality.



Figure 2. Drone tutorial

The game is divided into three different tasks. In the first task, students need to complete a tutorial in which they learn how to use the keyboard to fly a drone. (see Figure 2) The drone will allow them to explore the different landscapes that can be found in the El Paso area (desert, mountains, and the University of Texas at El Paso-UTEP). Flying the drone commences their action of exploring the landscapes to find information that will allow them to advance in the game. During this exploration phase, students could also find hidden objects like a water pipe that will give them some benefits when they are in the last section of the game.

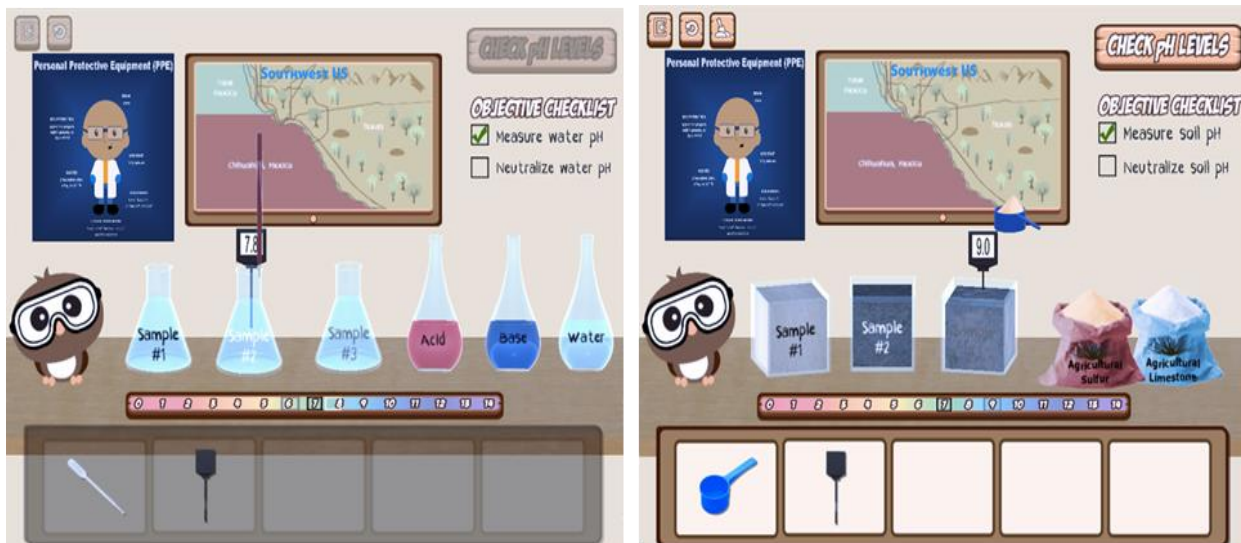


Figure 3. Water and soil sample

The second task of the game is to collect water and soil samples from the three landscapes (see Figure 3). When students have collected the samples, they need to measure the pH level of each sample and add bases or acids to neutralize them in order to make them useful to plant. In this section, students work in a visual laboratory simulation. This simulation provides students with knowledge about how to use a pH meter, and how they can neutralize the samples.

The third and last task is to design a park (see Figure 4). To achieve this, the players (students) need to select one type of landscape; it is worth mentioning that each one has a different population target for the park. They will decide if they prefer the creation of a park for children or the elderly. Students have to learn how to manage a budget to buy water, plants, and trees. Depending on the target population, the selected trees will give them points, they also have to consider the distance between them and the amount of water they require/need. All these facts will be considered for having a high score. In this way, students learn what types of trees are better for each type of landscape and the distance where it should be placed.

During the academic year, some activities include different technological applications and software that allow students to learn science topics in novel ways. Some of the programs that are used in the class are python, Data visualization with Excel, and others. The Sol y Agua game is intended to be used in addition to lectures in the class.

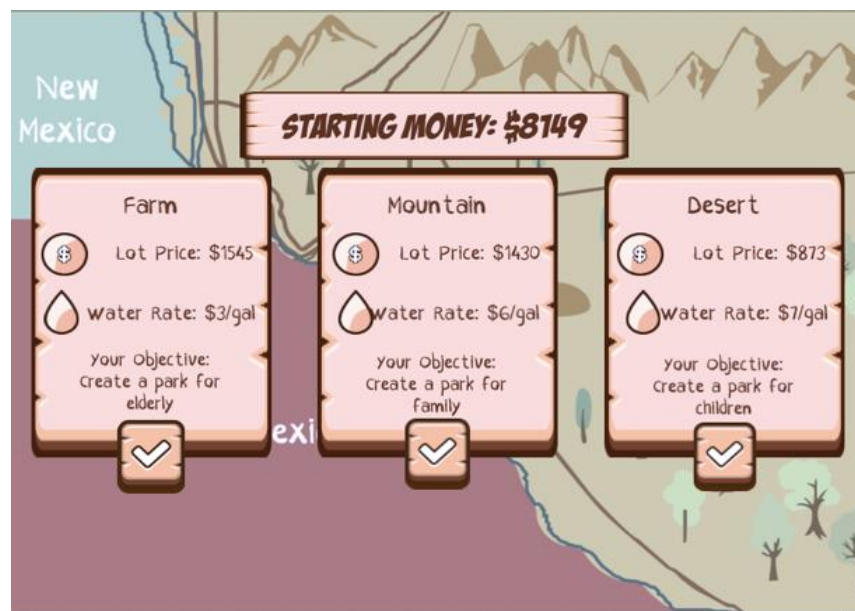


Figure 4. Landscape selection

The educational value of digital games

The implementation of digital games in the middle school classroom can be difficult because the games are not specifically created for a specific classroom. Games are created following a more general approach that would benefit specific disciplines like mathematics, language arts, etc. According to Shaffer (2007), another limitation for implementing digital games is the teachers' belief that games could be more distracting than educational. For that reason, Hong, Cheng, Hwang, Lee & Chang (2009) developed a scale to categorize and assess the educational value of digital games. The scale consists of indices that measure different categories like mentality change, emotional fulfillment, knowledge enhancement, thinking skills, interpersonal skills, spatial ability, and bodily coordination. The first section includes questions that will help the evaluator to identify the general aspects of the game like name, platform, target age, the domain of knowledge, game mode (drill and practice, single combat, stable contest, evolutionary contest, and/or scenario). For each category, the scale includes some questions to assess the value of a digital game. The sets of questions would help the evaluator or teacher to identify specific aspects of the game related to the main categories. As an example, in mentality change, one of the questions asks if the game cultivates perseverance and encourages players to always make things better. One important aspect is some of the questions

include a clarification question; such aids the evaluator to explain the selection of the option. It could also help the evaluator to understand better the mechanics of the game.

Sol y Agua Educational Assessment

To assess the educational value of the Sol y Agua game, the evaluation indices for assessing educational digital games was used analyzing in detail each category identifying the game characteristics (see Table 1), the next section provides a detailed explanation of the evaluation and how each category is fulfilled in the Sol y Agua game.

Table 1.

Game Assessment Category

Sol y Agua Educational Assessment				
Mentality change	Emotional fulfillment	Knowledge enhancement	Thinking skill development	Spatial ability development
Cultivate perseverance and encourage players to always make things better	Satisfy the need for belonging	Construct concepts so players learn to migrate	Cultivate strategic thinking	Develop players' spatial navigation skills
Cultivate planning ability	Encourage cooperation	Familiarize players with certain skills	Cultivate logical thinking	Develop players' ability to perceive an object from multiple angles
Anchoring the sense of trade-off		Develop players' science-related vocabularies	Cultivate critical thinking	
Be aware of the importance of efficiency		Cultivate the ability to solve mathematical questions	Develop memories capacity	
		Develop mathematical concepts	Improve the application of the knowledge one has learned	
		Develop the ability to construct and apply natural science concepts		
		Develop the ability to construct and apply technology in life		
		Develop the ability to construct and apply knowledge in history and geography		
		Develop the ability to understand and apply the concept of supply and demand in economics		

Mentality change

Cultivate perseverance and encourage players to always make things better

This skill is developed during the drone tutorial section. In this section of the game, students need to find information in the different landscapes to be able to advance to the next stage. The perseverance skill is developed because players need to learn how to fly a drone to explore the different landscapes to find pieces of information and hidden objects

Cultivate planning ability

This skill is developed in the last stage of the game. Students need to select a landscape to plan and create a park considering different elements like types of trees, their amount of water, and their likability depending on the final users of the park. The likability will be higher for the different types of landscapes and the final users for the park.

Anchoring the sense of trade-off

This skill is developed in the designing park stage. The stage requires players to manage their allocated budget. Players need to trade-off their budget to buy trees and enough water to take care of their park. They need to think about the different types of trees in regards to the amount of water they require.

Be aware of the importance of efficiency

This skill is developed in the designing park stage. For this to happen players should find the most effective ways to select trees and their position. Depending on the selected landscape, there are types of trees that are more recommended, however, students need also be aware of the distance trees need to be to get more likability points. Another important aspect is the amount of available water to drench their trees efficiently.

Emotional fulfillment

Satisfy the need for belonging

This characteristic is fulfilled by playing the game, especially in the exploration stage with the drome. The game provides players with a sense of belonging, the game is developed in the geographical context of the students, for that reason while they are playing the game and exploring the different geographical areas, they could relate their sense of belonging to that area.

Encourage cooperation

The game is intended to be used in class with teams; players within their groups should help each other to reach the goal of designing a park using the resources they have and deciding the best way to use them. In that sense, the game allows players to find the best player from each section, to discuss in order to advance in the game, and to create the park with the best possible tree options depending on the likability issue and the resources they decided to obtain with their allocated budget.

Knowledge enhancement

Construct concepts so players learn to migrate

This skill is enhanced by playing the game and later apply that knowledge in their real laboratory practices. Players do simulations in the game in the virtual lab. In this stage of the game, players should test the ph. levels of the soil and water they gather in the different landscapes and neutralize the samples to a 7-pH level. After playing the game, players will do the same practice in a real laboratory. In that sense, they can migrate the knowledge they learn in the game to a real setting or vice versa.

Familiarize players with certain skills

The skills that players acquire from the game are skills that they also could use in their science classes. In the game, as mentioned before players will conduct simulations of measuring pH levels from water and soil, fly a drone using the keys of the keyboard, and plant trees selecting from the list of possibilities and their special characteristics. For that reason, students have to master these skills not only in the game but also in their class activities.

Develop players' science-related vocabularies

The game was developed around the science class for middle school students. For that reason, players are exposed to science words like acid, base, landscape, water sustainability, and other important elements. While players are advancing through the game, they use science words and see them in the specific context they are used. For example, in the virtual laboratory practice, Owlfonso asks players to measure the pH levels of the samples, then he mentioned the acid and bases to neutralize the samples. In this way, by advancing into the different game stages, players are using science words that they can later use in their daily activities.

Cultivate the ability to solve mathematical questions

The mathematical skills are reinforced during the park design stage. In this stage, players must generate some mathematical operations in order to calculate the number of resources they can acquire to create a park and determine how many trees and how much water they can afford. In other words, they need to calculate the resources they could acquire with the allocated budget they have to create the park with the specific need of the final users of the park.

Develop mathematical concepts

Players must develop mathematical operations like addition, subtraction, and multiplication to plan and equip their park. In this sense, students need to have these basic concepts under control in order to obtain points in their game and win with their teams in the less possible time.

Develop the ability to construct and apply natural science concepts

Players must understand the ideal pH levels of water and soil and apply them to the type of landscape they select. They also need to identify the type of trees that can be planted in the different types of landscape.

Develop the ability to construct and apply technology in life

The game help players to develop the ability to identify how technology can be used in real settings. In the simulations, they use a drone and pH meters. In these activities, the use of technology can help them to understand how technology could be used in real life.

Develop the ability to construct and apply knowledge in history and geography

For the geography knowledge, players have the opportunity to explore the specific characteristics of the desert and mountain landscapes. These landscapes were created following the exact characteristics of the El Paso areas. For this reason, playing the game develops knowledge in geography using the drone simulator. They learn about the different regions in their context and they can identify the characteristics of the soil and water in the El Paso area.

Develop the ability to understand and apply the concept of supply and demand in economics

Players need to use a budget to get resources that are used in the park design. In this way, players could understand how to use the budget in a smart way. In this stage of the game, players learn the importance of budget management and utilization. While they are designing the park, they need to acquire resources with limited funds. Players need to learn the supply and demand concept in order to plan their park but sticking to their monetary resources.

Thinking skill development

Cultivate strategic thinking

Players need to plan a strategy to design a park and use their budget efficiently. They will earn points by selecting the correct type of trees, giving them space between them, and by the likability for the final users of the park.

Cultivate logical thinking

Players should apply logic to their park design, depending on the type of trees and the space between them. They receive likability points, so the goal of the design is to receive more points. If they are in teams, the team with the higher points will be the team that applied the strategic and logical thinking better for the park.

Cultivate critical thinking.

For the duration of the game, players should think about the different elements they are using within the game so they could apply them later in other activities; for example, with the drone, they learn the different types of landscapes. Later in the game, they should decide which landscape is better for their park to fulfill the objective of the park depending on the target people.

Develop memories capacity

Players should memorize the type of trees, the water usage for each one, and the distance they should be in order to receive more likability points when they design the park. For that reason, players need to memorize certain information before playing the game so they can progress and receive more points in the designing park section. For example, there is a file that they need to revise before play the game that includes the desirable distance between the different types of trees. Students should memorize this information in order to receive more likability points while playing the game in the last section (designing a park).

Improve the application of the knowledge one has learned

The game is meant to be part of instruction, so every single aspect covered in the game then is used in real settings. They can apply their knowledge; for example, in the game they conduct a simulation in which they measure the pH levels of the water and soil, in the classroom, they apply this knowledge to measure real soil and water samples pH levels.

Spatial ability development

Develop players' spatial navigation skills

During the drone simulation, players should navigate around the landscape they selected to find information hidden. They should develop the skill to go up and down, left and right in the specific landscape (mountain, desert), and to fly the drone safe between the changes in the ground.

Develop players' ability to perceive an object from multiple angles

During the drone simulation, players see the different angles of the landscapes they are exploring, they can see how the view changes from above or ground level. In this specific section, players are allowed to navigate Centennial Plaza located in the University of Texas at El Paso, the mountain and desert landscapes. During the exploration with the drone, students can move in 360 grades, so they could visualize the characteristics of the different landscapes from multiple angles giving them multiple perspectives of the same object (building) or landscape.

DISCUSSION

For teachers and educators, knowing the educational value of digital games can be beneficial to implement for classroom instruction. Having a tool like the *Evaluation Indices for Assessing Educational Digital Games* could facilitate teachers' decision of implementing, or not, digital games in their lesson plans. According to Shaffer (2007), there are teachers and administrators who believe that digital games can only be a distraction for students in the class. However, this type of scale to measure digital games can be used to evaluate games as part of the lesson plan.

It is significant for teachers to understand the game and to know what they should expect from their students. This gives students the opportunity to play a game that will help teachers to engage students in the class and learn from them. Having different aspects to evaluate can give teachers the opportunity to explore more content to teach using digital games in their classes.

Nowadays, there are a lot of digital games that were created to cover specific content knowledge. However, there are some aspects of those games that could help students to develop other content knowledge or even could be helpful as pedagogical tools to facilitate teaching. In that sense, the use of a scale is desirable to explore all the areas that a game could cover. Doing that teachers could not only know in a deeper scale digital games, but they can start creating a digital file with the game characteristics and the elements that can be used for specific purposes, in that way games could be used not only once but in multiple occasions to help teachers to achieve their educational goals for their specific class needs.

CONCLUSION

The implications for using any digital game in the DGBL approach is that they need to be considered by teachers only if the game provides teachers with meaningful ways to promote the objectives and goals for their classes and lesson plans. There is an unlimited number of games on the market and on the web that were designed to teach specific tasks. However, in order to be beneficial in the class, the teacher needs to conduct a careful revision of the game components to find if the game can be used for the topic they are planning. For that reason, it is useful to have a tool like the one used to evaluate the Sol y Agua game in order to have a more realistic list of the elements that can be enhanced in a class by using a digital game.

There are some recommendations for future research as follows: the first recommendation is to select different games that are created to promote the same kind of skills, to be evaluated together and maybe could be used as complements for the class; the second recommendation is to use a scale like the assessment of digital games in teacher professional development courses with teachers in the same discipline to evaluate digital games and compare their results to have a broader idea of the benefits that digital games can provide them with their classes.

The limitation of the study was that the evaluation of the digital game was conducted by a researcher who is not a science teacher. The evaluation could be benefited if a science teacher shared their opinion of the game in different aspects. Finally, it could be useful to have students' comments about how the game helped them to acquire the aforementioned content knowledge and skills, to have a broader perspective of the benefits that a digital game could have to impact a class.

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