Algae City - An Interactive Serious Game

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Abstract

Algae City is an interactive and educational game that is currently being developed in the Unity Game Engine. It is designed towards educating middle school students, from 5th to 8th grade, about the possible implementations of algae as a replacement sustainable resource and an environmentally-friendly solution to many of the world's pollution, energy, and other existing and potential problems. This game is also meant to provide students with a more integral hands-on learning experience to replace the dull classroom lectures. The detailed game modules are discussed in this paper, together with the design strategies that seamlessly integrate the learning content with the standard curriculum and bring a balance of learning and fun in Algae City to promote STEM education.

Introduction and Background

In modern learning, there are not enough interactive and entertaining methods to keep students engaged in educational material. The material is taught through generic PowerPoint slides or mundane monotone lectures. While this style of teaching is not particularly ineffective or discouraging, variation and immersion could increase learning and the students' enjoyment of learning. Apart from the classes simply not being enjoyable enough, the actual content itself has also struggled to represent important STEM values to kids in grades K-12. Studies have shown that the percentage of students taking pure science classes have regressed from over 50 percent to under 21 percent in the last decade [1]. The objective of this project is to get kids in this age range more involved with areas in the STEM field using a desirable and enjoyable learning style. This project also aims to educate users about using algae as a renewable resource. This is an important concept to convey because, while algae are a common microorganism known to all, it is rare that people make the connection that algae can play a significant role in impacting the future of this world. Focus on algae has risen for many reasons. For example, algae are abundant throughout the globe, they can be used to reduce dependency on fossil fuels, and they can mitigate greenhouse gases [2]. These are just a few examples of the many benefits of algae that this project aims to explore. Algae City is an interactive and educational game that hopes to implement a fun and amusing way to teach younger students about the benefits and usages of algae for a sustainable environment. Rather than traditional teaching methods, the students will be able to play through various modules within the game that offer multiple ways to convey this important information that will never seem repetitive or stale. This type of learning structure promotes systematic thinking as well as critical problem solving in an environment that can be perceived as a simple game [3].

When making a serious educational game like Algae City, two fundamental pillars must be considered: educational value and immersion. This integration of work and play has been identified as “flow” by psychologist Mihaly Csikszentmihalyi and is characterized by elevated enjoyment and focused concentration on a task [4]. This strategy of teaching combines the elements of a game to achieve the optimal balance between fun and learning [5]. Additionally, the best way to maximize this flow variable is through a very strong immersion factor. If the game is too unrealistic, it is harder for the player to relate to the scenarios. As a result, it is more likely that they feel as though what they are learning is completely fiction. Despite the fictional environment the game takes place in, the concepts and efforts of the player are entirely real and thus show the user firsthand the process by which algae can be used in many different beneficial instances. An additional aspect of increasing the immersion factor is to make the surrounding elements of the game as realistic as possible. This development strategy is inspired by previous works aiming to approach the same goal [6]. This strategy for balancing educational value and immersion is fully implemented in Algae City and will be discussed in detail throughout the course of this paper.

Game Overview and Design

Algae City features four main modules and up to five possible smaller mini-games. The four main modules each expand upon an important concept about algae development. These modules are as follows: water purification, production and growth, transportation and cosmetics. The five mini-game modules are focused on important concepts that have limited information available or are still in development. These modules help expand the scope of algae in the view of the player, and focus on the alternate uses that could be achieved in conjunction with the more obviously impactful. These mini-game modules are as follows: materials and surfboards, pharmaceutical gels, batteries, food and nutrition, and livestock, pet and fish feed. When designing these games, two major priorities are considered: fun content and educational content. A balance of these two qualities would make an optimal environment, and this balance is therefore the focus of the game design process.

An important aspect of the learning component is supplementing the curriculum that the target audience is learning throughout their school year. The goal of this game is to provide a large emphasis on algae and teach concepts related to algae. The best way to do this is through a connection of the concepts including environmental sciences, chemistry, biology and math that are already taught. Therefore, not only can these ideas be enhanced, but by using familiar topics to teach the new topics, learning can overall be enhanced. The flowchart in Fig. 1 expresses the goals and focuses of the Algae City game.

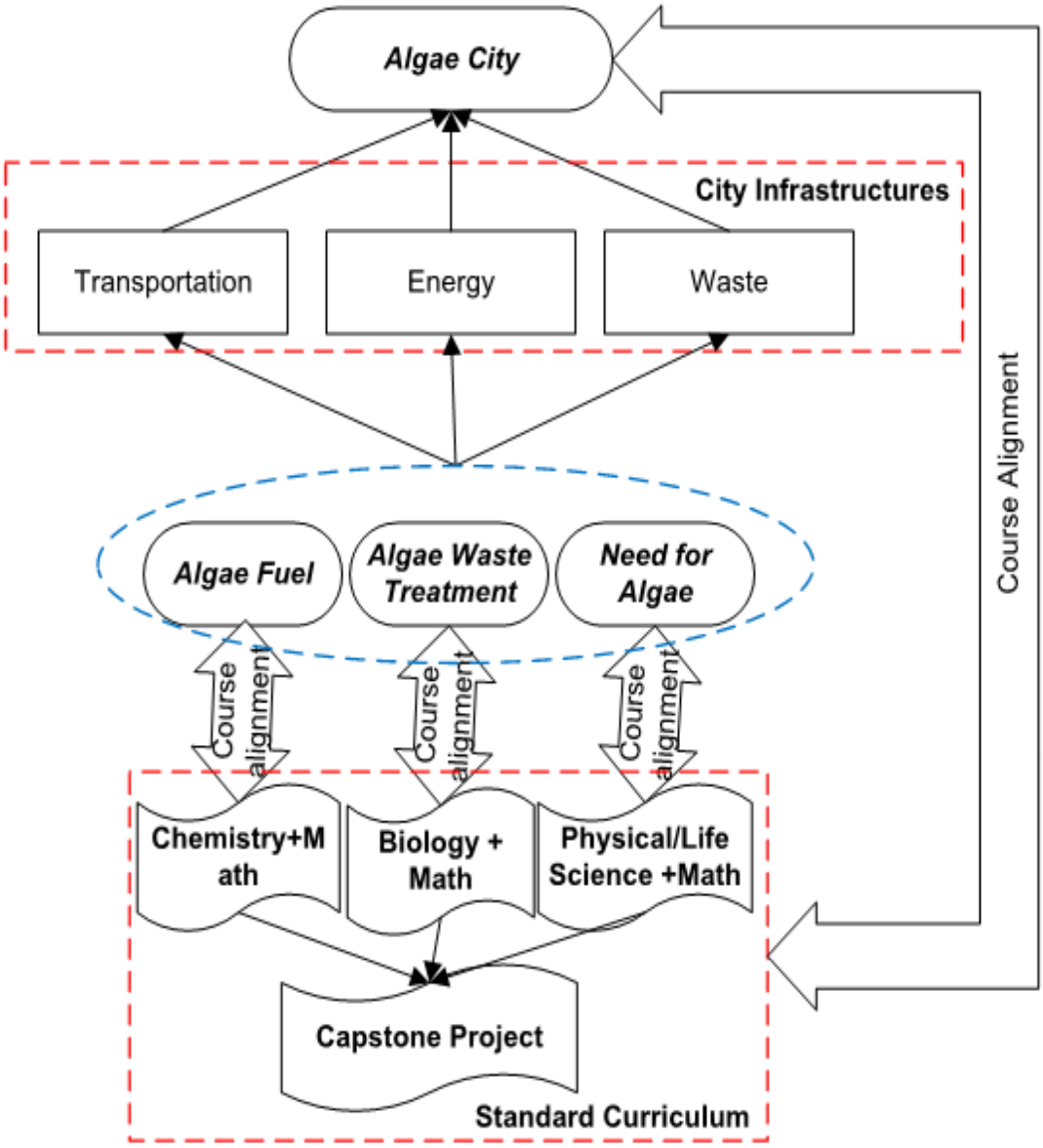

Fig. 1: Flowchart Demonstrating Goals and Scope of Game

The game flow starts as a linear progression which expands to give players various choices later in the game. This game flow is detailed in Fig. 2. The game takes the player through the required modules, the water purification and the production and growth, first. After these modules, the player will be able to access the storefront in order to be able to experience the previously-mentioned mini-modules. These modules can be unlocked based on the score to the other main modules. The cosmetics module is the only full module accessible from the storefront. The storefront and feedback system associated with it shall be explored in greater detail later.

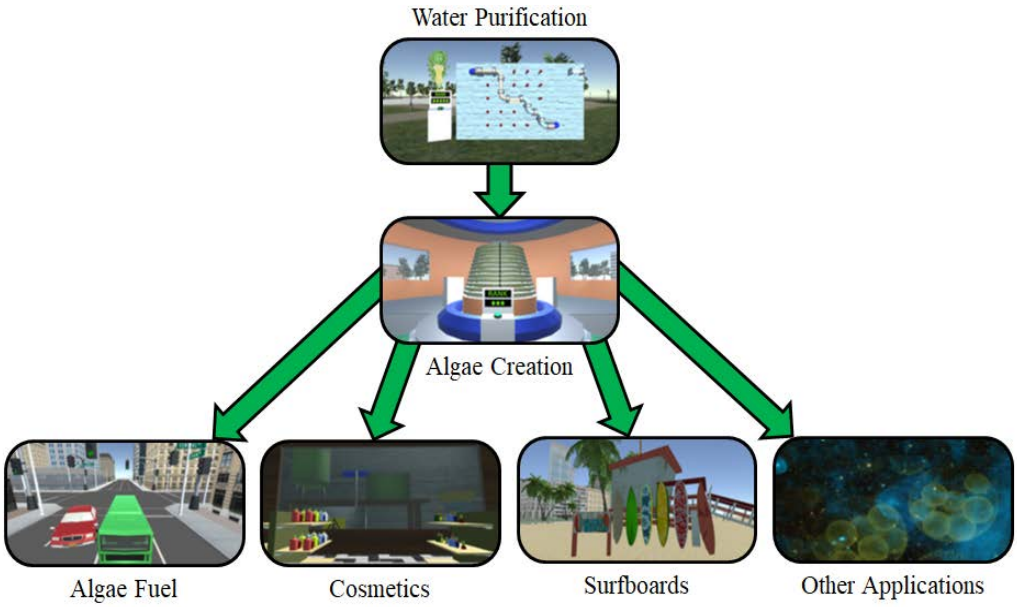

Fig. 2: Flow of the Overall Game

Module 1 - Water Purification: This module specifically focuses on Biology, Math and Environmental Science. These topics are present in the student's curriculum, and are supplemented here. The player starts with a pressing problem that has overwhelmed the city: the lake in the park and the entire water supply of the city is completely polluted. The player begins with the pipe system associated with the lake. The player has to solve a simple puzzle and gets instant satisfaction after the lake turns from a brownish color to a grey to a nice bright blue. This level acts as an introduction and tutorial to the mechanics and complexity of the pipe systems. As the pipe system levels increase to a relatively high difficulty, this initial tutorial level will help keep the player enjoying the game. This initial section of the game lacks educational content to focus on fun and rewards in order to hook the player in and keep them playing the game.

Next, the player progresses into the pipe room where the pipe system of the entire city is located. As the player enters the pipe room they are greeted with a voice-over that addresses the problem they need to face and a brief explanation of the scientific concepts. A TV monitor can be clicked on to give detailed tips and controls to make the game more enjoyable, less frustrating, as well as provide pertinent and detailed information about algae in this application. Three separate pipe design levels make up the entire module. The pipe space is four times as large as the tutorial level and increases in complexity each level. The player is scored based on their reasoning skills, which is determined by the number of pipes they needed to use and the number of algae scrubbers that they could reach. In order to provide the player a refreshing change, and as an educational opportunity, a short retro-style game is implemented after the first level. This game simulates the algae “eating” the carbon-dioxide and nitrogen within the polluted water. This game is quite simple but provides an important chance for the players to be directly associated with the physical biological process that occurs in algae purification. In addition to explicating

how the waste purification works, various types of waste that algae can purify is also demonstrated through the pipe level where the player must choose between nuclear or normal algae scrubbers. The wastes that humans create are what algae need to grow and therefore a symbiotic relationship between the two is formed. These ideas are expressed to the player through the multi-level design of the pipe game. The whole layout of the water purification module can be seen in Fig. 3**.**

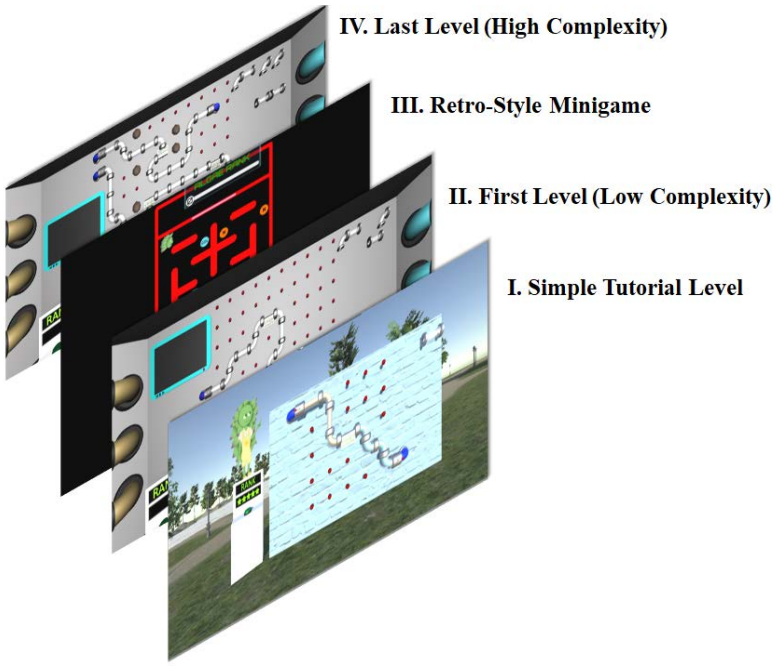

Fig. 3: Layout and Flow of the Water Purification Module

Module 2 - Algae Production and Growth: The next module in the game flow is the algae production and growth module, also known as the algae reactor module. The plot leads the player here because the little bit of algae that they had was used up in order to purify the water supply. This module reinforces chemistry concepts and requires the player to use critical thinking and outside knowledge. The player is tasked with correctly setting different growth parameters of algae, based upon provided information. The different parameters are pH, salinity, light, and temperature. While these properties are covered extensively in chemistry course, the game does not make any assumption about students' prior knowledge. Instead, such information is provided in detail by a tv monitor in the room, aiming to give the player hints about correct values without directly stating it. These values can be set via various knobs on machines in the reactor room. A picture of this interface can be seen in Fig. 4. The player will get a score and feedback based upon which parameters were correct. Overall, this module is tied much closer into 'eternal' learning. After easing the player into the game with the more fun-focused water purification module, this module is meant to test the players knowledge and academic thinking skills. The mood is still kept uplifting with a bright room with windows, while having traditional game

mechanics are included in order to keep the experience enjoyable. Animations, scores, and control are all present here.

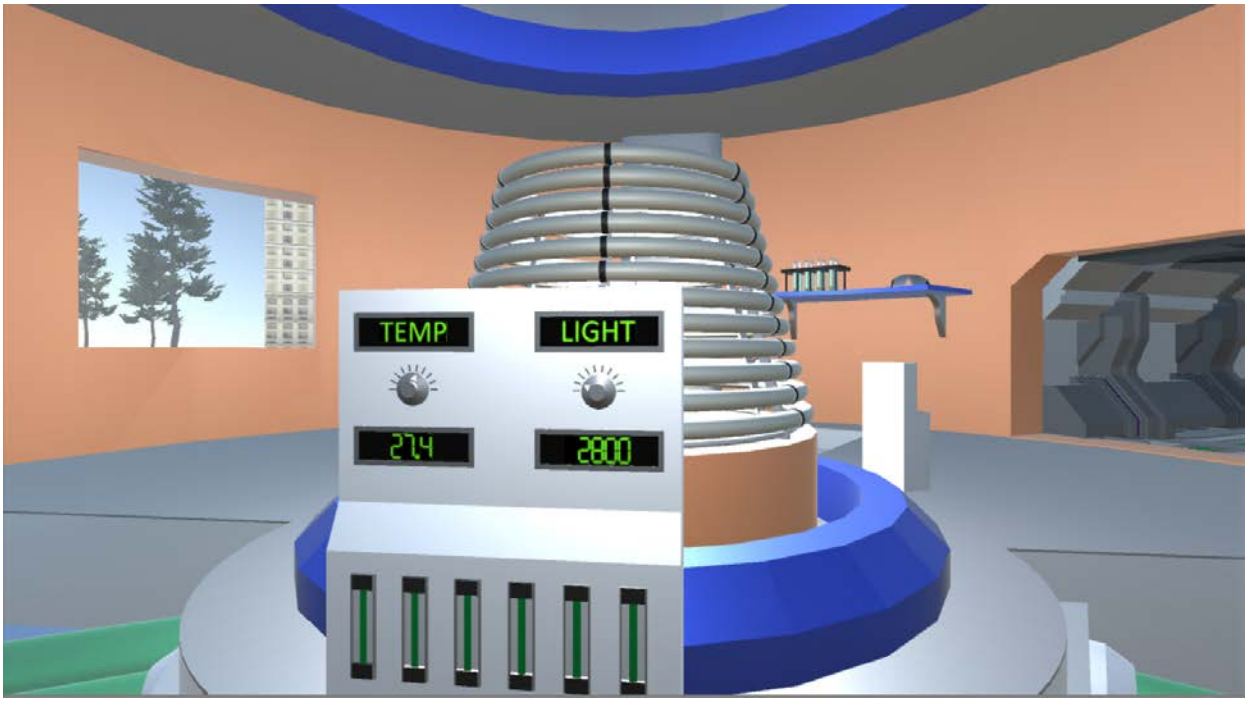

Fig. 4: Algae Parameter Interface

After this module, the linear section of the game flow is completed. The player has options of progressing with the story through the transportation module or going to the storefront for the cosmetics module and the mini-modules. Since the transportation is a major part of the city and the city's pollution, it is part of the main story and will be discussed next.

Module 3 - Transportation: The transportation module tasks the user in driving a public bus around the city using algae ethanol fuel instead of typical fuel. This module focuses on an integration with environmental and life sciences, with a strong focus on algae. Also, a small dose of economics and math using the prices of the algae and balancing of opportunity cost is included. Despite not being directly in the curriculum, these concepts can expand students' horizons. The environmental benefits of algae-based fuels are great as the emissions are significantly less. However, the major negative of this fuel is the expense. The player will therefore get the options to mix quantities of algae fuel and traditional fuel in order to limit expense and environmental impact. The station used to fill the bus can be seen in Fig. 5. After the fuel blend is chosen, the player drives around the city to various bus stops and picks up passengers and collects fares. The player shall be scored based upon the two quantities previously stated. This module takes an interesting approach to the balance of fun and education. The educational aspects of this module take place at the beginning where the player chooses their fuel blend. This requires knowledge of costs and the environmental impacts (which shall be provided in posters next to the fueling station). However, the rest of the game is a fun experience

with a driving simulator. If the player happens to fail due to a poor selection of the fuel blend, they can instantly try again with a new choice.

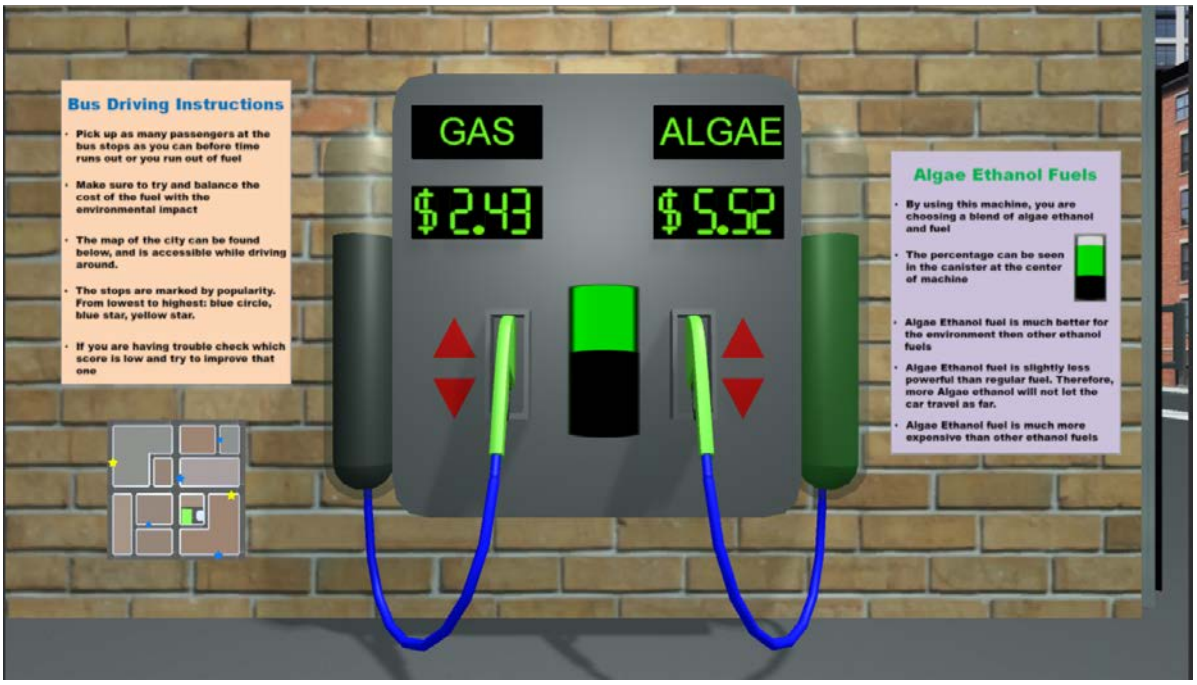

Fig. 5: Algae Ethanol Fueling Station

Module 4 - Cosmetics: Before or after completing the transportation module, the player can access the storefront where they unlock mini-modules and the cosmetics module based upon their algae rank. The algae rank and the process of leveling it up shall be explored later. The centerpiece of the storefront is the cosmetics module. The cosmetics module for this game serves as a way to educate users about how different types of algae can be used to create different types of beauty products. For example, green, red, blue-green and brown algae all have various cosmetic benefits. The purpose behind creating the cosmetics module was to integrate a flavor of entrepreneurship to the game by demonstrating how algae can also be converted into a business. This module is also used to bring awareness to the fact that algae can be used for common, everyday things, like makeup, that people generally do not associate engineering and science with. Including this cosmetics module allows Algae City to reach a greater target audience and get a wider variety of people interested in algae and STEM. The goal is to make Algae City interesting to people of different genders and backgrounds.

The cosmetics module uses a series of fun and educational mini games to explain how algae can be extracted into different components that are used in the production of cosmetics. Through the interactive mini games, the player is able to easily understand the various processes involved in the algae breakdown through firsthand experience. To create a more immersive environment for the player, a makeup store was created as the environment for this module to take place. To

demonstrate the algae decomposition process, an extraction machine was also created that mimics those commonly found in the real world, shown in Fig. 6.

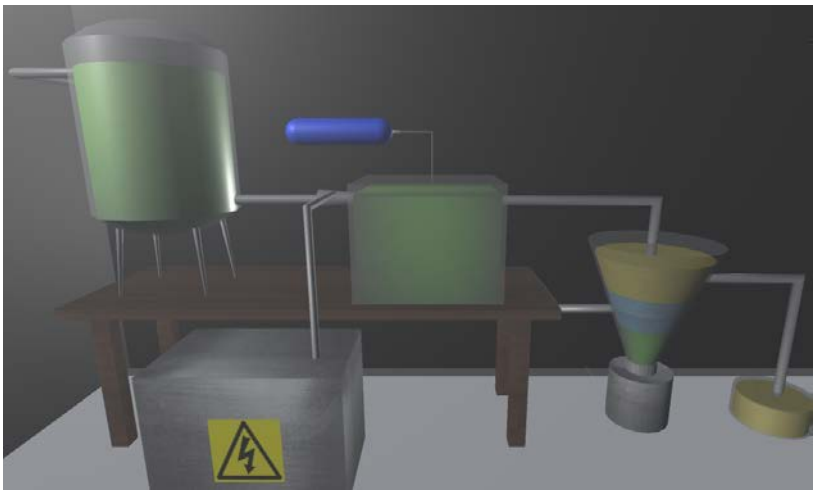

Fig. 6: Algae Extraction Machine

This machine takes algae and separates it into oil, water, and biomass to be used in the creation of cosmetics. A series of mini games are used to highlight each step of this extraction process. The first step is setting the appropriate pH of the solution by collecting carbon dioxide and avoiding the hydroxide. The second step is using electromagnetic fields to split the algae into biomass, water, and oil using quantum fracturing. The third and final step is to sort the components into their respective containers as they fall from a tube above. The final game of this module is a fun game that lets the user make-over the algae character using the cosmetics created from the various types of algae.

Now that the player has learned about different types of algae and what the benefits are, the player now gets the opportunity to actually see the effects. The player gets to apply the makeup to the algae characters face and wipe it off to see the effects that it has on the algae character. Upon completion of this fun mini game, the player has successfully finished the makeup module.

Learning Integration in Gameplay

An important aspect of learning that is integrated into the game is a supplemental feedback system. The player can get a judge of their performance at any point of the game. Also to ensure that the player stays motivated to continue progressing through the game until the end, a ranking and a reward system was implemented in Algae City. The player receives a rank based on their performance on each of the main modules. The ranking system is defined by a rank of 1 star to 5 stars with each star meaning better performance. A rank of 3 stars is necessary to continue progress throughout the game, but a higher rank would result the ability to unlock the mini-modules at the algae storefront. Each module requires one extra level of the players' algae rank,

or approximately 2.5 stars of performance. Therefore, a good number of these modules will be unlocked by playing the game normally. As stated before, these modules are meant to be more fun oriented but still educational, as they are based upon real-world and commercial uses of algae. These modules cover the topics of algae used in cosmetic production, pharmaceutical gel, food sources, and algae's role as a material in surfboard production. In order to unlock all of these fun modules, the user needs to get a perfect 5 star ranking on each of the main modules. Each module unlocked by the storefront rewards the player with currency which the player can use to buy aesthetic visual upgrades for the city, adding another layer of reward and customization to the game.

Throughout Algae City, the player is introduced to various topics related to Environmental Science and Chemistry. This is demonstrated through the players exposure to algae growth, water purification, biofuel creation, and algae decomposition. The game starts with a Cutscene that is meant to immerse the player into the 3D environment and the role of the character. The Cutscene provokes emotion by going through scenes of a little child coughs due to the smog in the city and fish struggle in the pond due to the excessive water pollution. These Cutscene are meant to draw emotion and a sense of resolve from the player to hopefully complete each module and complete the end goal of improving the city.

In addition to these Cutscenes, a cartoon algae character will be included in order to create a more welcoming and brighter environment for the game. This cartoon will be known as the Algae Character and can be seen in Fig. 7. The design of this character was thought out specifically to evoke certain connections and thoughts. Firstly, the character has no features that would identify the character as either male or female in order to appeal to both demographics. The character will be voiced by a female; however, the voice clips will be altered in order to evoke a gender-neutral character. Secondly, the algae character was given a look that does not match that of a stereotypical scientist. This choice will hopefully make students realize anyone can be a scientist or engineer, not just the "nerdy" students. The character shall also double as a guide that will provide the player with important information about how to play the game as well as giving them guidance when necessary. This character helps expand the world of the game and gives a colorful source of narration to the game, blurring the lines between the fun and learning aspects of the game.

Conclusions

While Algae City is still in development, significant progress has been made. Overall, great research has been put into understanding the benefits and usages of algae for a sustainable city. Game concepts have been carefully designed that have a good balance of being fun and educational in order to keep players interested while still conveying the benefits of algae. These game concepts have been storyboarded and are in the progress of being fully fleshed out.

Fig. 7: Algae Character

Overall, there are four main modules that have been developed: water purification, algae production and growth, transportation, and finally the cosmetics module. There are also mini-modules still in development. These modules serve as a way to increase awareness about the benefits of algae. This is accomplished by portraying that algae can be used in many non-conventional ways, like transportation and makeup for example. These usages are typically not associated with engineering by middle schoolers, a reality that this game confronts. This allows Algae City to have a greater audience and get a wider variety of people interested in algae and engineering. Future work involves testing this game with subject groups of various ages ranging from 5th to 8th grade, gathering feedback, and then making any necessary changes to the game based off that feedback. In the end, Algae City aims to challenge, excite, and educate the player with the overarching goal of promoting STEM education.

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