BacToMars: A Collaborative Educational Video Game for Teaching Biological Engineering

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ABSTRACT

We present BacToMars, a collaborative educational video game that engages elementary school children in creative bio-design. We describe the game, as well as how our iterative and participatory design process is shaping the game's development. We also discuss plans for on-site evaluations at local elementary schools to answer research questions pertaining to collaboration, attitudes, and the potential of video games as a tool for teaching biological engineering to young children.

CCS CONCEPTS

•**Applied computing** → **Collaborative learning; Computer games;** •**Human-centered computing** → *Collaborative interaction;* •**Social and professional topics** → *K-12 education;*

KEYWORDS

Play; children; bio-design; educational games.

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1 INTRODUCTION

Biological engineering and bio-design are burgeoning fields of research that drive advancements in domains ranging from agriculture to space travel. We seek to inspire the next generation of innovators by exposing children to these emerging areas at the intersection of science and technology. However, few tools are aimed at introducing core concepts like traits, cells, and genes to elementary school children. To address this need, we developed BacToMars, a novel educational video game designed to encourage students in elementary school to collaboratively explore topics like genetic design and construction, natural resources, sequencing, logical reasoning, and creative problem solving at an age appropriate level. While inspired by the interactive museum exhibit BacPack [5], BacToMars is designed for a more formal learning environment. In this abstract, we highlight the design decisions and participatory design process behind BacToMars, including a discussion of future evaluation.

2 RELATED WORK

Researchers have discovered numerous benefits to educational [3, 6, 11] and collaborative [1, 8] play, as well as collaborative learning environments [2, 4]. Although existing video games allow players to design organisms (e.g. Spore, Cubivore, Graffiti Kingdom) and interact with biological processes [10], none provide a platform for children to participate in creative problem-solving through bio-design.

Our design of BacToMars draws upon Papert's Constructionist educational framework [9], as well as a widely-known paper on the utility of bio-design techniques for manned exploration missions to Mars [7]. In the game, children experiment with designing bacteria that consume input materials and produce desired output materials essential for survival on Mars. Like various other child-centered video games (Quest Atlantis, Village Voices), we have been developing BacToMars through a participatory design (PD) [12] process in which the target audience takes an active role.

3 GAME OVERVIEW

BacToMars was developed in JavaScript with the Phaser.IO game engine, and is meant to be played collaboratively by four children in a classroom setting, each at their own computer. Each player

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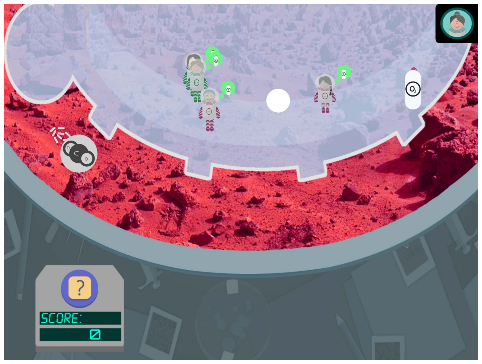

Figure 1: The first level of BacToMars. In this level, children are only allowed to make oxygen.

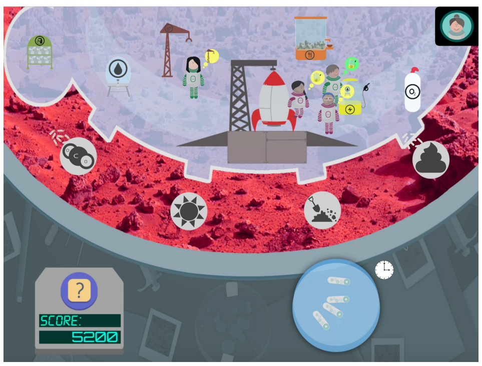

Figure 2: The fourth level of BacToMars. Players may use all five resources to create all six products. The goal of this level is to build the launch pad and rocket so the astronauts can escape Mars.

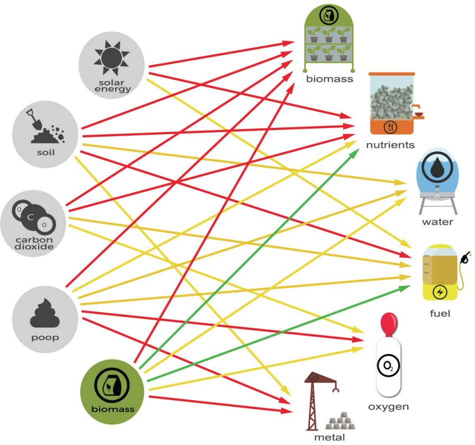

Figure 3: Subset of possible resource and product combinations; Color coded based on how many units are produced by each combination: green = 3 units, yellow = 2 units, red = 1 unit. Green combinations are most efficient.

Figure 4: Preliminary testing of BacToMars with children. The two children pictured chose to play the game collaboratively without being prompted to do so.

takes on the role of a scientist-astronaut who is helping a team of astronauts on Mars survive and build a ship to fly home. The game space includes a shared Martian landscape with a bio-dome that all players see and, to support creative freedom, a private wet lab (on Mars). Non-player characters (NPCs) in the bio-dome carry building materials to the ship they are constructing and consume life-support products such as oxygen and water (Figures 1 and 2), reducing available supplies. These astronauts also provide feedback and suggestions via thought bubble and expression. Included in the wet lab area is a score to reflect the team's overall state, and a help button to trigger text and an animation.

Players use 11 representations of genes to design and engineer bacteria that make essential products for the NPCs. They start by picking two genes: one dictating what resource the bacteria will consume (e.g. soil, CO_2, biomass) and the other indicating what it will produce (e.g. water, O_2, metal). These two genes are combined into a genetic program with varying degrees of effectiveness based on the combination (Figure 3). In advanced levels, players can use biomass as both a resource and a product.

Players then insert the genetic program into a plasmid (i.e. ring of DNA) and add the plasmid to a bacterial cell in a petri dish, which results in the growth of a bacteria colony containing the genetic program (Figure 2). After dragging the petri dish to the appropriate resource on Mars, the bacteria consumes the resource and releases a product. The astronaut figures move around the bio-dome, providing feedback to users and indicating what products are running low, as well as picking up the products players create and consuming them or carrying them to where they are needed.

4 PARTICIPATORY DESIGN

We are using a participatory design approach to the development of BacToMars. So far, 10 children (grades 1 - 5, 4F/6M) alone or in pairs have played the game for a mean time of 19.6 minutes (SD=15.318 minutes) (Figure 4), sharing their opinions on shortcomings and suggesting improvements. We included questionnaires and recorded testing sessions, focusing our evaluation on learnability, educational merit, and engagement. After each session, we reflected on findings and made changes to BacToMars.

Changes made so far and planned for the near future include: the refinement of introductory animations defining the game's topic, goals, and rules (many children commented that the videos were "slightly slow" and one stated "there should be sounds in the game and in the video"), updates to the help system to make it more accessible and inviting (despite confusion, none of the participants used the help button), and changes to astronaut thought bubbles (children weren't sure what the symbols in the bubbles meant and when we mentioned using the product representations on Mars, they thought it would be a good idea).

5 FUTURE STEPS

Our next step is to use BacToMars to explore the following research questions, all aimed at elementary school students in the classroom: (1) Can a video game affect self-efficacy and attitudes in relation to bio-design?; (2) Does identifying with the scientist characters in an educational game have positive educational effects?; (3) How does a multi-player environment enhance collaborative real-world problem solving for children grades 3-5? We will use a mixed methods approach, running studies both in controlled environments and 'in the wild' at local elementary schools.

These studies will help us gauge the potential impact of video games as a central part of elementary curriculum, specifically for teaching topics traditionally considered too complex for young children. We expect that our results will inform curriculum design and serve as the foundation for a new framework of design challenges and guidelines geared toward developmentally-appropriate educational games.

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