Rewire: A Game About Neuroplasticity

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ABSTRACT

Twenty years ago, Carol Dweck published a seminal article showing that students with a fixed mindset underachieve compared to students with a growth mindset. Many existing approaches promote a growth mindset by teaching about neuroplasticity, but include little interactivity and dynamism – two important aspects in neuroscience education. We present Rewire, a web-based game that introduces students to neuroplasticity and growth mindset through constructionist approaches. Learners build neural networks using principles from neuroscience, such as Hebbian learning and myelination. In the process, they build an intuition for how the brain changes and grows through targeted effort and practice. In this paper, we reflect on the design mechanics that allow students to discover neuroscience principles, and the game's implications for future work in teaching students about growth mindset.

KEYWORDS

growth-mindset, game design, neuroplasticity, neural networks

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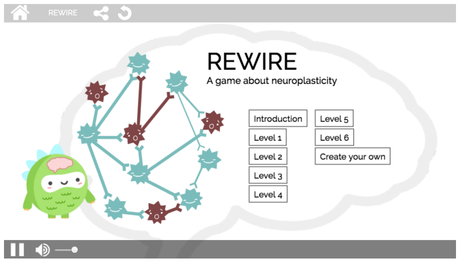

Figure 1: Rewire Home Page: Rewire is implemented in HTML, CSS, and JavaScript, and built on initial code from an open source interactive animation called "Neurotic Neurons".

INTRODUCTION

In this paper, we present Rewire (https://eling8.github.io/bba-final-project), a web-based game that engages late-elementary and middle-school students in the neuroscience principles underlying a growth mindset. Throughout the game, students explore neuroplasticity and its connection to hard work and practice. The goal of each level is to form new neural connections in a character's brain using principles from neuroscience, such as Hebbian learning and myelination. As their character, Muzu, works through challenges and mistakes, students rewire the neural networks within Muzu's brain in order to help her achieve domain-specific learning goals. By engaging with the game, students develop an intuition for the dynamic nature of intelligence and the correlation between effort and learning gains.

BACKGROUND AND RELATED WORK

There is a growing body of literature showing that a student's mindset highly influences his or her achievement. Students who view their intellectual abilities as fixed traits (fixed mindset) receive lower grades and underachieve compared to students who believe that intelligence can be grown through effort (growth mindset) [4].

In light of this research, experts primarily recommend that educators help students foster a growth mindset by teaching them about the science behind brain plasticity, or the brain's ability to change [3][1]. According to Stanford Psychologist Carol Dweck, this helps students develop an understanding that talent and giftedness are dynamic attributes that can be developed [3]. One application of this research is Brainology [2], a computer-based workshop that teaches students about famous experiments in neuroplasticity, such as the London Cab Driver experiment. Additionally, Khan Academy and Project for Educational Research that Scales (PERTS) have also developed growth mindset lesson plans centered around teaching students about the brain and its ability to form new connections.

While a plethora of interventions have flooded the educational landscape, the current methods for teaching growth mindset are highly instructionist, where students are taught about brain plasticity through a lecture or video format. However, previous work has shown that instructionist pedagogy, especially in neuroscience, is less effective than constructionist approaches, where students are allowed to interact with the content material [5]. Brain plasticity is an inherently dynamic process. Because of this, we argue that interaction with these processes via constructionist learning tools is important for understanding how new neural connections are formed through purposeful and meaningful effort.

Additionally, Stanford Psychologists David Yeager and Gregory Walton have pointed out that psychological interventions are most effective when delivered in a "stealthy" manner [6]. In our project, we embed the learning goals in a game-based format so students can discover and build an intuition for growth mindset, without explicitly being taught to have one.

Figure 2: Excitatory neuron (left), Inhibitory neuron (right)

DESIGN

Design Process

We initially prototyped game levels in Google Slides, which allowed us to iterate on the amount of instruction and scaffolding to provide. While this platform allowed for clicking and dragging objects, it did not afford important feedback structures, such as animation and causality. After finalizing our level design and story line, we implemented our game in HTML, CSS, and JavaScript. We built on top of open-source code from an interactive animation called "Neurotic Neurons".

Game Mechanics

The basic mechanics of our game, which is titled "Rewire," are built upon fundamental neuroscience principles. These principles are presented as rules within the game and are gradually introduced through scaffolded levels. By coupling neuroscience principles with the game mechanics, we allowed the affordances and constraints of the game to contribute to the process of learning neuroscience.

The first game mechanic that users learn is how to connect two neurons together. This is achieved through Hebbian Learning, which postulates that "neurons that fire together wire together." When users click on two neurons in sequence, a connection, or synapse, forms between them. This is the primary game mechanic used to create a neural pathway within the game.

In another level, players are introduced to the concept of a firing threshold, which is the principle that neurons only fire when a specific activation potential (the threshold) is achieved. In the same module, players learn about the two types of neurons in the brain: excitatory neurons, which increase the potential of their neighbor neurons, and inhibitory neurons, which decrease the potential of their neighbor neurons. In the game, players pass a level only when the final neuron receives enough excitatory inputs to reach its activation threshold.

We also incorporated growth mindset concepts in order to reinforce the coupling between behavioral actions and brain processes. For example, the first neuron only fires when the character, Muzu, is practicing using effective strategies. The more that Muzu practices, the stronger her neuronal connections become. In the game, stronger connections appear as thicker lines with faster signals; this mirrors how frequently-used connections in the brain become stronger and faster via "myelination." On the other hand, when Muzu is not practicing the learning content, the synapses in her brain gradually weaken and eventually disappear, much like human brains forget skills or knowledge without practice. While not explicitly stated, these game mechanics communicate that certain behavioral actions, such as working hard on math, directly contribute to brain development and learning.

Finally, in order to cater to students with different levels of experience, we designed our game with a low floor and high ceiling. While early levels require little to no knowledge of neuroscience, later levels can explore complex brain architectures, such as the lateral inhibition network (fig. 3).

Figure 3: Lateral Inhibition Network.

FUTURE WORK

While growth mindset is often misunderstood to suggest that any effort will contribute to learning, this is not necessarily the case. According to Dweck, engagement alone does not necessarily indicate that a student is learning – the student must also engage in targeted effort and apply effective learning strategies. Along these lines, we want to incorporate game mechanics that teach players about strategies such as spaced out practice and seeking feedback. Additionally, we hope to develop a classroom integration for the game, to make it a better tool for teachers seeking to promote growth mindset for their students. Potentially, students’ own growth mindset behaviors in the classroom could translate towards Muzu’s behaviors or new skills and interactions within Rewire. Finally, we understand that growth mindsets are often domain-specific. A student might approach math with a growth mindset, but not history. In the future, we want to expand the challenges that Muzu faces to include not only math, but also subjects such as musical skills, creativity, and even habit formation.

CONCLUSION

We have presented Rewire as a game-based platform to explore a growth mindset through learning about neuroplasticity. Our hope is that students and educators can use this game as a tool to understand the dynamic nature of intelligence and ability.

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