FUNCTIONS OF THE MACHINE
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FUNCTIONS OF THE MACHINE RESEARCH DOCUMENT

Introduction

Functions of the Machine is a game-based learning application for high school and undergraduate students about algebraic functions. The game helps students build a conceptual understanding of functions through solving problems that involve machines. By manipulating machine parts and variables, students develop skills in covariational reasoning and other mathematical processes. *Functions of the Machine* is intended for use in any algebra class that includes a unit on functions.

The Importance of Understanding Functions

Researchers and subject matter experts have identified the conceptual understanding of functions and their relation to real-world phenomena as topics of difficulty for students. Whereas students tend to think of a function as a single algebraic formula that must be solved through computation, it is a dynamic system of changing quantities that must be viewed as a process. Additionally, students often have difficulty identifying the measurable attributes of real-world scenarios and representing them with the graph of a function (Madison et al., 2015).

This "minimal process" view of functions can be problematic for students as they transition into calculus courses at the university level. Taking a covariational approach to functions, or "coordinating two varying quantities while attending to the ways in which they change in relation to each other," can help students develop a more complex view of functions as patterns of change within a variety of contexts. This can increase students' calculus readiness and enable them to apply the concept of functions to real-life situations (Ge et al., 2021).

Game-Based Learning

Game-Based Learning (GBL) has been shown to be an effective tool for increasing student engagement and motivation (Jabbar & Felicia, 2015). GBL provides an immersive learning environment that helps meet the needs of contemporary students (Anastasiadis et al., 2018). By providing clear goals, direct and immediate feedback, a balance between ability level and challenge, and a sense of control, GBL supports many of the components associated with student achievement.

GBL has been used effectively to teach STEM, non-cognitive, and life skills (Adame et al., 2017; Lee et al., 2016; McDonald, 2017). This indicates GBL is a useful tool that can be applied to various domains and objectives.

Objectives

By the time students complete *Functions of the Machine*, they will be able to accomplish the following objectives:

• **Covariational Reasoning:** Students can solve a problem by coordinating two varying quantities that can change in tandem.

• **Process View of Functions:** Students can explain that a function is not a set rule that defines a procedure but instead is a generalized input-output process.

• **Graphical Reasoning:** Students can identify attributes of a graph that give meaning to the associated function's behavior.

• **Quantitative Reasoning:** In a problem-solving context, students can identify and relate measurable attributes of an object or situation.

Gameplay

In *Functions of the Machine*, the student must decipher the functions of strange machines designed by an eccentric inventor, Nicole Edisla. The inventor has mysteriously disappeared, leaving behind extensive notes on her machines. Through step-by-step problem-solving, the student is given opportunities to hone their understanding of mathematical functions to get the machines up and running again.

Functions of the Machine contains five levels, each with multiple scaffolded problems. The machines represent functions that have a covariational relationship between their inputs and outputs. Tutorials guide the student through the operation of each machine. If the student enters an incorrect value into the machine, the game provides corrective feedback, and the student is allowed to try again. By solving problems with these machines, the student develops a conceptual understanding of functions. Each problem is more complex than the last, which enables the student to build their understanding gradually as they progress through the game.

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