Little Newton: An Educational Physics Game

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Abstract
Little Newton is a 3D defense game in which the player learns about basic physics concepts by controlling physical attributes of projectiles. The mechanics of the game require the player to learn the basics of parabolic arcs, and friction in order to make use of the projectiles. Educational and learning theories are applied to the design in order to increase the ability of the player to learn how to play the game itself and therefore learn physics concepts in the process, balancing entertainment and educational content.

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Introduction
Games possess an innate motivational potential. They are an activity that the player engages in for no other reason than for the sake of the play itself. According to self-determination theory, if an activity can become self-motivating to the participant, he or she will experience increased incentive to continue the activity for its own sake [1]. When the action of the player is a new skill the player did not have before, the player has gone through an act of learning. In order to harness

the potential of these acts of learning for a purpose other than the gameplay itself, educational games can be designed with mechanics that use educational content as the core action.

Little Newton is a 3D defense game that seeks to teach the player about the basic physics concepts of parabolic motion and friction by controlling physical attributes of projectiles. The player character is Little Newton, who defends himself from an army of evil toys by using apples as ammunition and traps. The mechanics at the core of the game require the player to learn the basics of parabolic arcs, and friction. This connection between physics educational material and the physics of the game itself function to take advantage of the learning potential of the game design, harnessing the motivational properties of play mechanics integrated with an activity that increases learning of the targeted concepts. A version of the game playable through the Unity Web Player extension is available at: http://natalielyon.com/LittleNewton.html

Target audience

The target audience of the game is children in schools at the beginning of their physics education. The age at which a student first begins learning physics concepts can vary in the U.S., especially since physics education can begin in a mixed-science format, typical of middle or junior high schools, or in a first class devoted entirely to physics, more typical of high schools. Therefore, *Little Newton* has been designed with a broad age range of children in mind, but focusing primarily on ages 12 to 16.

In order to fit this demographic, the difficulty level has been balanced to provide an appropriate level of challenge for the age range. The level of challenge increases with one concept at a time, and the progression requires players to master one skill before moving on to the next and ultimately combining skills they have learned. A young student may initially find a level challenging, but sufficient information is provided so that the player can solve each level. When a level is failed, it may be immediately replayed, allowing the player to attempt to find the solution over however much time is needed for the individual. To aid with ease of use, the language is sufficiently simple that reading level should not typically provide a barrier to gameplay.

Furthermore, the art style and narrative content of the game are meant to be age appropriate. The colorful world frames a narrative that supports learning as a fun activity. The villains are made extremely cartoon like through both the story of toys coming to life to try to distract the player character, and through the visual style of the bright colors, simple shapes, and cartoonish outlined rendering. These narratological elements are integrated with the ludological focus of the game, the combination of which has been shown to maximize the enjoyment and immersiveness of educational video games [2].

Throughout *Little Newton* gameplay, the player adjusts the force, mass, and angle of impulse of the parabolic in real time to see the effects and defeat enemies of different types.

Figure 1. Parabolic arc control in gameplay of *Little Newton*

Technological and Game Play Innovations

Good video games are "learning machines," or constructions aimed with the purpose of providing the space and tools for learning to take place. Video game design can use educational concepts like giving information "on demand" and "just in time" in order for the players to learn how to play the game easily and intuitively, without undue frustration. They operate at the outside edge of the player's competency, remaining challenging but doable. They also present information in order, allowing the player to make generalizations to solve increasingly complex problems [3].

Little Newton employs these design features for allowing the player to learn the game mechanics as easily as possible. Since the game mechanics themselves are exercises in adjusting the physics properties of friction and force, mass, and angle of impulse for controlling a parabolic arc, the player can therefore learn these basics physics concepts more easily through playing the game. If a player learns to master the mechanics of the game, he or she has also inevitably learned how to manipulate a parabolic arc and the property of friction, combining the effort usually required for pure learning with the effort expended playing the game. The intersection of design constraints with whatever intention the player brings to the game creates a designed experience, which can be effective learning environments [4].

Typically, when a student is learning these same physics concepts of parabolic arc and friction in a classroom, the primary method of teaching these concepts is through diagrams in a textbook.

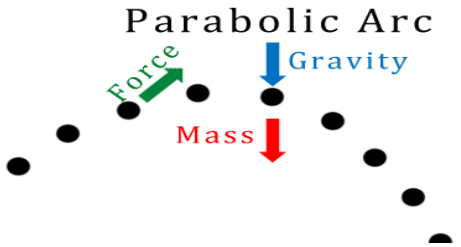

Figure 2. Parabolic arc diagram, typical of physics textbooks.

It is nearly impossible to convey the effects of parameters like Force and Mass on the speed of the object over the course of the arc by this method. By contrast, the method of teaching these concepts through the gameplay of *Little Newton* allows the player to explore what effect each one has on the arc in real time. The player can easily see the effect of each on the shape of the arc previewed by the dotted line when force, mass, or angle of impulse is adjusted. The effect on the speed can be seen in real time as well.

Furthermore, the player must master the control of each of these parameters in real time order to advance past increasingly difficult and nuanced sets of enemies. The combination of the real time controls and the puzzle-like combinations of enemies of different types creates gameplay that is similar to that of traditional tower-defense, but with elements of a real-time strategy game. This unique blend of puzzle and real-time mechanics fosters a fast-paced sense of fun during gameplay. Furthermore, limited ammunition is given to the player on each level, encouraging players to figure out what strategy is most efficient quickly rather than simply by trial and error. Some enemies require precise arc and speed control because of small hit boxes. Some enemies are stationed behind walls, requiring further precision of the arc to reach over the wall. Some must be hit in combination with others, requiring a high amount of control over the speed of the arc. All of these parameters make for many combinations of levels that allow the player the fun of shooting down the enemies in real time with the satisfaction of solving the puzzle of the level.

Additionally, the introduction of new concepts is added one at a time, in a short tutorial type instruction. The concept is then tested by the player in a short level before another concept is introduced. The series of concepts follows a logical progression through the process of learning about parabolic arc and friction.

Through this schema of direct control over physics properties, the gameplay of Little Newton creates a new way to combine learning and entertainment for elementary physics education.

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