

# Wave Hero: An Educational Game for K-12 Students

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**Abstract:** Educational video game designers are faced with many challenges. Today, most commercial video game systems are capable of handling high-performance interactive 3D graphics. Such advances increase competition between educational game developers and corporate gaming giants. Science Technology Enhancement for Appalachian Middle-schoolers (STEAM) is a GK-12 project funded by National Science Foundation. Wave Hero is a game developed for this project, which uses an educational game engine called STEAMiE. This game, which is based on a popular game called Guitar Hero™, teaches students about propagation of energy through a medium in the form of a wave. Concepts related to developing Wave Hero as an educational tool for the STEAM project is described in this paper. Specifically, these key elements include interactivity, familiarity, incentives, reduction in aliasing, flexibility, re-playability, and portability are discussed.

## Introduction

Wave Hero teaches students about propagation of energy through a medium in the form of a wave. In particular, it teaches key concepts such as transverse waves, compression waves, wavelength determination, velocity, frequency, mediums, resonance, and particle properties. The Ohio Academic Content Standards for Science were used to develop this educational game. Wave Hero uses visual demonstrations throughout the game so that students can see how key parameters affect the wave and its medium. Wave Hero was developed under the Science Technology Enhancement for Appalachian Middle-schoolers (STEAM) GK-12 project funded by the National Science Foundation (NSF). It makes use of an existing technology developed specifically for this project, namely

the STEAMiE game engine. STEAMiE was developed to overcome limitations of existing game engines (Nykl, Mourning, Leitch, Chelberg, Franklin, & Lui, 2008) such as Second Life, which must overcome issues of technology in the classroom or Macromedia Flash which is often limited to a 2D virtual environment. With STEAMiE, the technical aspect of the game development process was accelerated so that attention could be favorably given to the educational benefits and design goals of Wave Hero.

Throughout the game development process, many elements of existing popular commercial console (home) video games were examined and compared against scholastic and educational video games that are freely available. Wave Hero was designed with a set of game design principles so that its educational effectiveness would be maximized. It is assumed that K-12 students would rather play console games rather than playing educational video games, even if they were free. Therefore, Wave Hero was modeled after a modern commercial video game called Guitar Hero™. This is advantageous because students build upon their playing experiences while learning scientific concepts. Due to the popularity of the console games, it is also assumed that students will want to play the games multiply times (re-playability), which is desired in the learning process.

One may ask why video games are an effective medium for educators to use in their classrooms. The PEW Internet & American Life Project (2008) discovered that 97% of teens aged 12-17 play video games in some manner. Additionally, they found that 86% of these teens play video games on commercially available console products like Microsoft's Xbox™, Sony's Playstation™, or Nintendo's Wii™. The study also found that a large percentage of these gamers (73%) also play video games on their desktop or laptop computers. With the overwhelming success of the commercial video game industry, and its influence on today's K-12 students, it is clear that education has much to gain from computer game technology.

## Game Structure

Students learn new concepts through three principal game phases in Wave Hero, namely the learning phase, the quiz phase, and the song phase. These three phases are based on a reward system where the final phase is the reward for successfully completing the first two. Furthermore, this system relies on the assumed competitive nature of students to desire earning a successful completion of all phases if they witness their classmates doing the same. Similar experiments in competitive interactive classroom activities were conducted in 2002 at Texas University and were well-received (Mountain, J.R, Wells, R.L. 2002).

### Learning and Quiz Phases

During the learning phase, students absorb new material through visual demonstration, digital interaction, or through narration. Fig 1 demonstrates a typical screen of the learning phase. The principal purpose of this phase is to engage the students in active learning of the material. While this mode is reinforced by the other two phases of the game, it is important that the educational material is presented in a fun and interesting way, where they do not see it as a typical classroom-style lecture. The learning phase typically takes students a few minutes to conclude. At this point, the game smoothly a transition back to the title screen or continues to the quiz phase.



Fig 1: Learning Phase



Fig 2: Quiz Phase

In the quiz phase, which is depicted in Fig 2, students are presented multiple-choice questions on material

that was previously covered in the learning phase. Students are given immediate feedback to their correct or incorrect choices that they submitted. This feedback is given both visually by displaying text, and audibly via a musical chime. Additionally, if a student incorrectly answers a question, they are penalized. These penalties are assessed during the game phase. The penalties are also shown on the games progress bar in Fig. 2 as solid red bars instead of musical *notes* from a correct response. Upon successful completion of a quiz, the student is permitted to advance to the song phase (game play). Upon failure of a quiz, the student will be notified and they will be taken back to the title screen without the opportunity to advance. Penalties

### The Song Phase

The song phase, or *gig* mode, offers students the chance to play the virtual guitar through a song track in the style of the Guitar Hero™, which is shown in Fig 3. During this phase, notes and chords appear on the musical scoreboard. The students then play the corresponding notes to follow the song. The student plays these chords using the keyboard to control the *fret buttons* (i.e. the A, S, D, and F keys) of the guitar and the mouse to strum the guitar strings. Sections of music that were missed during the quiz phase, are intentionally left blank while a message is displayed motivating the student to re-learn the missed material. Two forms of performance measurements are provided. The first measure, *success*, is the percentage of hit notes for the entire song. The second measure, *skill*, is a relative performance measure that increases or decreases depending on failure rate of hit notes. Both metrics are docked for blank sections due to an incorrect answer on the quiz.



Fig 3: Song Phase



Fig 4: Tutorial Mode

A *tutorial* phase (Fig 4) is also available so that new players, which can differ in skill, can learn how to play the song phase without going through the educational content of the game. This can be particularly important for educators or other people who might not be an experienced gamer.

### Design

Wave Hero was designed to adhere to a predetermined set of academic standards and game design principles so that its educational effectiveness would be maximized. In particular, Wave Hero is centered on the following of Ohio's Academic Content Standards for Science (2002):

- Demonstrate that waves transfer energy.
- Demonstrate that vibrations in materials may produce waves that spread away from the source in all directions (e.g., earthquake waves and sound waves).

### The Educational Game Paradigm

When designing a video game one may ask, "What makes a good video game, good?" One also may ask, "What makes a good educational video game?" Furthermore, is there truly a difference between these two questions? If one could not tell the difference between a commercial video game and an educational video game,

then you might say that the designer of the educational game has skillfully accomplished their goal of integrating the two pieces seamlessly together, which is a very difficult task. For example, how does one make a video game that is both equally entertaining as well as educational? Furthermore, one must ask is it possible to integrate the two so that the player could not tell where the learning pieces ends and the game-play begins.

Wave Hero was intended to feel more like a *console* video game than an educational video game. While the adherence to certain academic standards is a mandatory goal of this project, their introduction is done in the narrative and animated style of existing commercial video games. This is also the primary reason why Wave Hero was designed as a 3D video game, the format used by most commercially available video games today. Many authors in the field of education also suggest 3D educational games are more effective teaching tools than 2D games (Ark, Dryer, Selker, & Zhai, 1998).

### **The Difficulty Level Trade-off**

In order to maximize re-playability (ones desire to play a game multiple times after one attempt or completion), one must find a balance in difficulty between too hard and too easy. On one extreme, a game that is too easy will result in students quickly becoming bored with the game and losing interest. On the other hand, an excessively difficult game will bar some students from progressing in the game and thus limiting their educational experience. Clearly, one must find a proper balance to prevent either of these two scenarios. Wave Hero offers this balance with a configurable difficulty setting. Additionally, in all fairness one should always make available an “easy” mode for students with limited coordination so that they can become able to complete the game and receive its educational benefits. This is in congruence with the research principle of *beneficence* (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979), which seeks to allow all subjects full access to the potential benefits offered by research (and thus not limited by their coordinative ability to play the video game). Furthermore, for the same ethical reasons, it is not possible to fail-out of a song during the song phase of Wave Hero nor can the user be held back from advancing in the game for any other reason than complete lack of comprehension of the material.

### **Interactive Learning**

With the growing number of distractions in today’s classroom setting, it is important to hold the attention of the students as they learn. Educational video games have the unique potential to present students with interactive learning situations since students are visual immersed (Hogle, 1996). It is proposed that this type of hands-on guided learning will increase the attention span of the students, and thus the amount they learn through the game. Thus, special attention was given to the graphical detailing that was presented to the students while playing Wave Hero.

### **Familiarity**

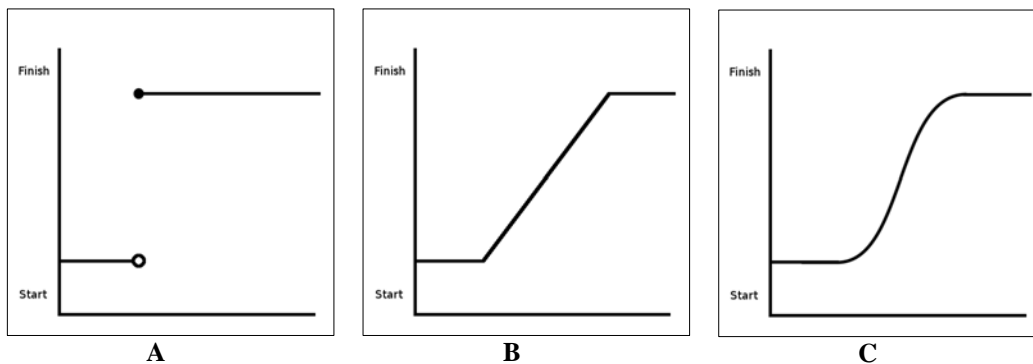
Mimicking popular game designs while making educational games may raise the students’ interest in educational game, thus increasing its success in teaching difficult concepts. Since Wave Hero was modeled after an existing popular video game, it is assumed that students will not struggle in learning gaming controls, which might hinder the learning process. Thus, this gaming familiarity is expected to accelerating the *educational* experience.

### **Incentive to Learn**

Without certain regulatory mechanisms in place, many students will attempt to circumvent the educational benefits of the game to reach the fun part. Simply put, if the student believes that they do not have to read or learn the material in order to be successful at the game, they will likely skip it. Without an incentive (or penalty) system in place, the educational power of the game may be reduced. As a guideline, a designer should try to directly couple the game material (and the knowledge thereof) to the success factor in the game. The competitive nature of the students may coerce them into learning the material so they can out-do their classmates in the game. Some students may also exhibit erratic behavior during the learning phase or quiz phase trying to “guess their way” through the game. This rapid clicking behavior is easily detectable by the game program and the computer or student can be flagged so that a teacher will be notified. Wave Hero utilizes this programming style to ensure that students are rewarded for their participation during the learning phase by entertaining them through the game play.

## Reduction of Aliasing

*Aliasing* is the introduction of sharp, abrupt changes. When these changes occur over time in a video game, they may break a player's concentration, or possibly distract them away from the game entirely. Many computer games employ *Anti-Aliasing* techniques to target and eliminate these problems. Wave Hero combats aliasing by ensuring all changes in the game between modes, phases, and screens are gradual. This is accomplished by linear interpolation techniques such as screen fading. Furthermore, movements of 3D elements on the screen including the camera view are done gradually by use of cubic interpolation where the curve of movement shows both an acceleration and then deceleration to the destination position. These types of gradual movements are more pleasing to the eyes than their abrupt counterparts.



**Figure 5:** (A) a change with aliasing (no interpolation), (B) linear interpolation, and (C) cubic interpolation

## Flexibility, Extensibility and Portability

Computer game needs to be flexible so that it can be customized to suit a wide array of applications. Without such precautions, the duration of the time in which the game is useful may diminish. It is important for the teacher to be able to modify and update the educational content of the game to fit with their lesson plan. Also grammatical and spelling errors in game content may surface long after the development cycle of the game completes, further necessitating the need for flexibility. Wave Hero was designed so that all educational narrative content, quizzes, and tutorial text can be modified without the need to edit source code and rebuild the program. The “script-like” files that accompany the game are fully editable by staff. This allows the game to be used well into the future without computer programming skills. All game music and “chord” sequences are also malleable for the existing three levels as well.

Educational games should be designed for a large target audience. However, limitations in compatibility with different computing environments such as operating systems may compromise that goal. Thus, it is important for educational games to be compatible with a wide array of computer technologies. By design, these games should be portable, meaning that it will run on all of today's popular computer systems with no additional configuration or programming necessary. Thus far, Wave Hero has been tested on Microsoft Windows XP as well as Apple's OSX successfully.

## Conclusions

At the summit of the development phase, Wave Hero appears to be successful at inspiring GK-12 students to learn and exciting educators about using the educational tool in their classrooms. To field test Wave Hero, the game were initially played by students at Miller Middle School in Corning, Ohio. Students were asked to write their comments and suggestions in a journal log. Pilot testing has also occurred at the Shawnee 6.0 (Fig. 6) and 2008 NSF GK-12 Regional Conferences. During these workshops, educators were allowed to play an early version of Wave Hero and offer feedback of what could be improved. It also provided a medium to advertize the multitude of educational software that has been developed by STEAM that educators can download and use in their classrooms at

no cost (<http://steam.cs.ohiou.edu>).



**Figure 6:** Field Testing at Shawnee 6.0



**Figure 7:** Student Engagement

Though initial field-testing is now complete, the educational effectiveness of the game has yet to be studied. Future research will be conducted by STEAM to determine how well the game teaches the concepts related to waves.

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