Quantum Spectre

Teon Edwards, Erin Bardar, Jodi Asbell-Clarke, and J.L. Larsen, EdGE at TERC
Teon_Edwards@TERC.edu, Erin_Bardar@TERC.edu,
Jodi_Asbell-Clarke@TERC.edu, Jamie_Larsen@TERC.edu

Abstract: *Quantum Spectre* (QS), part of an NSF-funded research study looking at engagement and learning in STEM games, is a puzzle-style game designed for the web and mobile devices where players use mirrors, lenses, and more to guide laser beams to colored targets. The science of light represented in QS is accurate, and we are collecting data to measure how players proceed in the game as part of understanding how people learn to deal with the scientific phenomena represented. QS also has level builders so players and educators can construct new puzzles. The story of QS's design is one of balancing the science, the learning, and the gameplay.

Introduction

In the depths of space, containment fields are degrading and spectres are threatening to break free! To re-establish containment, you must solve the laser puzzles that power the tanks (see Figure 1)*. Use mirrors, lenses, and more to guide laser beams to colored targets in this scientifically accurate and wildly cool laser game. Watch out for the spectres… they will haunt you!*

Figure 1: Scene from QS Intro

Designed for the general public, *Quantum Spectre* (QS) is a puzzle-style game. Each level requires the player to direct one or more laser beams to targets while (potentially) avoiding obstacles. That alone is not so different from other "laser and mirror"-puzzle games out there. What makes this one unique is its scientific accuracy, the crafting of the puzzles, their sequencing, and the advancement system to scaffold learning, and the integration of a story into gameplay.

Our game design philosophy is all about making games that people want to play in their free-choice time, while also engaging those players with science concepts, inquiry, and thinking. Through our games, including QS, players are offered opportunities to explore scientific phenomena in environments where they can develop intuitive understandings of scientific concepts. We are funded by the National Science Foundation to design a series of web and mobile games that focus on high-school science concepts drawn from U.S. standards for science education. In addition, our situated learning designs compel players to create their own learning environments and experiences—learning that is scalable and measurable.

About *Quantum Spectre*

In each QS puzzle, the player places and orients items from an inventory of optical elements, such as flat and curved (concave, convex, and double-sided) mirrors, lenses, filters, beam splitters, and more, in order to direct laser beams (see Figure 2). When the appropriate color laser beam(s) have reached all the targets, a level is complete. How well the player scores depends on the number of extra, unnecessary moves made. Replay enables players to look for a more efficient solution, improve their score, and build their understanding. And level sequencing carefully introduces, isolates, combines, and applies puzzle-solving elements and strategies to scaffold both in-game progress and science learning.

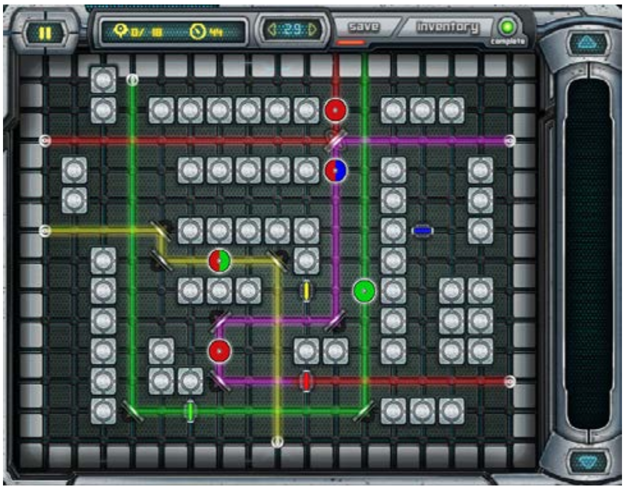

Figure 2: Sample Puzzle

The development team designed QS using a level builder. We are now working with teachers to design an interface to that level builder, which they can then use to create puzzles that support their curriculum. Players will also be able to use the level builder to design their own puzzles, which they can challenge others to solve, rate, and comment upon.

The Design of *Quantum Spectre*

QS is a product from game designers who are trying to make a marketable, free-choice game and educators who are funded by NSF to study how learning a scientific phenomenon in a game compares to learning it in a traditional or an inquiry-based science curriculum. This combination of constraints has led to some interesting design decisions for QS. For example:

Balancing science and gameplay

A laser-and-mirror game designed simply for good gameplay might tweak the physics to create clean puzzles. For example, the paths of laser beams might have simple slopes so that they cross grid nodes at regular intervals. However, this is not what really happens when laser beams interact with scientifically accurate curved mirrors and lenses. In QS, we dictated that the focal lengths of the concave mirrors be “nice”—e.g., one, two, and three grid squares (see Figure 3)—but because the curves of the mirrors mean that the reflection point is not over a grid node—except for the center of the mirror—the further a reflected beam travels, the more its path diverges from crossing the nodes. Challenges like this were things we simply needed to embrace as vital to the science and learning... and as an opportunity for making interesting puzzles.

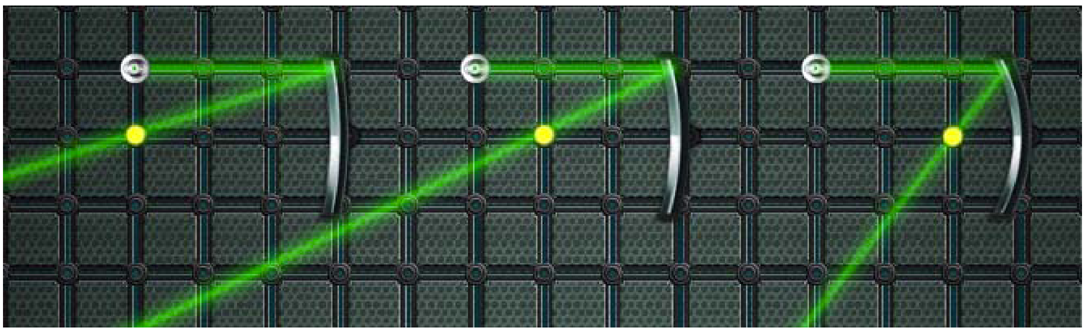

Figure 3: Concave mirrors with focal lengths of 3, 2, and 1 grid nodes

In-game science and learning

The science needed to make a game accurate is more in-depth than the science one expects a player to learn. For example, in science curricula, concave lenses are almost exclusively used with parallel beams coming directly into the lens and diverging symmetrically (see Figure 4a). From a strictly high-school-science point of view, covering this would be enough; however, from a true-understanding point of view, it is extremely limited, and from a game point of view, it is both boring and impractical.

In QS, the player controls the placement and orientation of the lenses, and laser beams travel along many different paths, so laser beams will be hitting the lenses at a variety of angles (see Figure 4b). The game must be able to deal with this, from the underlying physics to the puzzles that scaffold a player's experience, isolating the key learning without breaking the game and building a depth of understanding by taking advantage of the more complex situations.

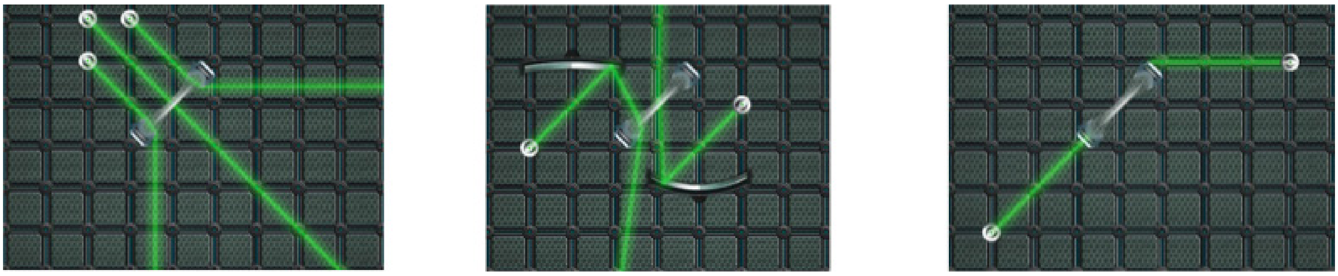

Figure 4: *Quantum Spectre* setups showing (a) "curriculum" parallel beams diverging, (b) beams at unusual angles, and (c) beams stopped by caps on the lens' ends.

At the same time, there have to be limits, and the selection and scaffolding of these limits are key design decisions. For example, on an optics table, laser beams can typically pass through the flat ends of concave lenses, but this is not the intended use of such lenses. By preventing this in the game with caps placed on the ends of the concave lenses (see Figure 4c), the designers are trying to isolate what makes a concave lens so interesting and important—the curvature of its surfaces.

Integrating the story

From the beginning, the game was designed to have a story, but it was not until feedback from early play testing that we realized how important (and useful) this would be. The design breakthrough that added the spectres to the game came from a combination of factors, including the need for the game to allow for trial and error while encouraging more efficient strategies. Later, design research provided information about players' perceptions of the spectres, resulting in another iteration of game design. The spectres and advancement system were designed—and tested—together, making the story an integral part of the game—making it *Quantum Spectre*.