Picodroid: Designing and Developing a Physics Game using the Kinect Motion Controller

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Abstract: The goal of the *Full Body Physics* project was to create an interactive game-based learning experience that connects middle- and high-school students with critical physics and chemistry concepts using their bodies as a controller. The final product, *Picodroid*, was designed and developed by two successive teams of graduate and undergraduate students in physics, art, education, and computer science, as part of an experiential learning process. Guided by a faculty coach and a subject matter expert/client, the design team made critical design decisions, produced concept art, created the game design document and developed prototypes of two proposed games. The development team, again working with the client, decided to focus on the *Picodroid* concept and carried it through to its finished state. Created for use with the Kinect motion controller and a Windows PC, *Picodroid* challenges competing players controlling "picobots" to assemble subatomic particles to create elements in the periodic table.

Introduction

Contemporary research on educational games have focused on their affordances; i.e., ways to support students' ability to make meaningful connections to the learning goals (Honey & Margaret, 2011, Squire, 2008; Wilson et al., 2009). This does not mean that the educational game itself must equip students with an explicit means to link the content to be taught or learned; rather, it is the interaction with game that allows learners to increase their interest or motivation, and make further inquiry toward new knowledge. In this instance, motivation does not merely imply "having fun" or engaging in fantasy while playing the game; it also entails curiosity about, and development of, life-long interest toward the subject matter (e.g., science).

With the advancement of technology, learning affordance through digital games may be enhanced through the contemporary human computer interaction design approach (i.e., kinesthetic interactions) to anchor students in a context where a set of interaction elements (physical movement, game missions, storytelling, animations) is introduced to create relevance for students. Once learners develop pattern recognition and knowledge connection with the context, designers can then aims to integrate a series of explicit scaffolding strategies to support learning activities into game missions or objectives to raise interest or motivation towards making further inquiry and acquiring new knowledge.

Our project, *Full Body Physics*, incorporates kinesthetic interactions to afford the needs, abilities, and interests of targeted middle school students while instilling a sense of sportsmanship. The virtual kinesthetic games bypass traditional mouse and keyboard interactions, and instead make use of the body as the controller to interact with the computer game and content. This creative and innovative way to interact with computer games has the potential to transform an enacted classroom into an exciting and highly-motivating learning atmosphere that rewards student inquisitiveness and exploration. An additional advantage of allowing and encouraging students to use physical movement within a class setting, concerns the promotion of student health. Many have expressed concern about children not engaging in enough physical activity, childhood obesity, and the elimination of PE classes due to increased demands for reading/math instruction. Studies have also indicated that children ages 8-12 with higher weight status spend more time in sedentary activities, such as traditional video gaming and computer use, than those with lower weight status (Dietz, 2001; Vandewater, Shim, & Caplovitz, 2004; Walker et al., 2006). Because the proposed virtual kinesthetic game incorporates physical (whole body) movement, it has the potential to synthesize learning with healthy physical activity.

Project Purpose

The purpose of the *Full Body Physics* project was to produce a physics-based, kinesthetic video game that utilizes Microsoft's Xbox 360 Kinect interactive controller technology. With Kinect technology users control the game play through the movement of their bodies and voice commands. The design and development teams were challenged to develop a game or games in which middle- and high-school players/learners would engage basic physics concepts in a fun and interesting way, using the Kinect to interact with the world created by the game. The result of this process was Picodroid, a futuristic competitive game that engages students in basic physics and chemistry concepts using their bodies to collect subatomic particles, build elements, and win the game.

Design/Development Process

This interactive game was created by students at Northern Illinois University's Digital Convergence Lab as part of an experiential learning initiative designed to bring together interdisciplinary teams of talented graduate and undergraduate students to solve real problems for real clients. These student teams are supported by faculty coaches and professional staff who are located in the lab.

Experiential Learning projects are typically completed in two academic semesters. Students are recruited, interviewed, and selected by lab staff based on the needs of the project. The first semester consists of students for a design team, and the second semester a development team. The design team focuses on analyzing the needs of the client, looking at best practices in game design, making recommendations regarding technology selection, developing a design document, creating concept art, and developing working prototypes. The design semester culminates with a formal presentation of the design document and prototypes to the client, the lab staff, and the development team. The development team then goes about the business of bringing the concepts and prototypes to fruition, play-testing with the target audience, and presenting the final product to the client.

The client for the *Full Body Physics* project was a coordinator for the university's outreach division and the project was partially funded by a grant from the *American Physical Society*. The design team for this project consisted of a faculty coach, an assistant coach/staff digital artist, an undergraduate art student, an undergraduate physics student, and a graduate student in computer science. In June of 2011 the design team began the process by examining the purposes and goals presented by the project description in the proposal created by the client. Game ideas and design specifications were discussed in concert, with one informing the other. The team members proposed and explored many game concepts, and, with the help of the client and a group of classroom teachers, narrowed it to two primary game concepts (Figure 1). The design team then worked to refine these two game ideas and develop rough prototypes using C#, XNA, Kinect Software Development Kit (SDK) beta, and the Kinect hardware for consideration. The remainder of the semester was spent continuing the cycle of design, development, testing, and redesign. The design team then presented their game design document and two primary prototypes to the development team.

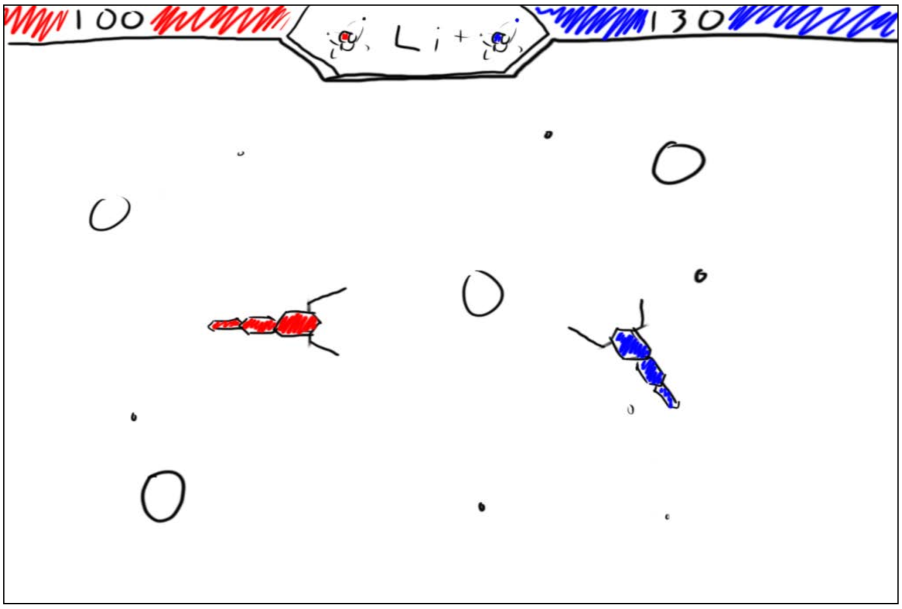

Figure 1: **Early concept art for Picodroid**

In August of 2011 the development team, again made up of graduate and undergraduate (some of which continued from the design team, with the addition of a graduate student from Educational Technology) set about the work of quickly deciding which of the game prototypes to carry forward for immediate development. With the help of the client, the team decided to move ahead on a game concept called *Picodroid* in which players build elements from subatomic particles using picobots in a futuristic laboratory environment. The team continued the development cycle including producing game art, music, and programming as well as refining the game mechanics and player interaction. The game was play-tested in several environments, including a STEM fair, and in several middle school physics classrooms. Play-testing results were used to refine and improve the game. The final game was released as a public beta at a formal presentation in December 2011. A beta version of the game was made available on the lab's website, and is playable using an Xbox Kinect on computers with Windows 7 and the Kinect SDK beta. An Xbox is not required for play.

State of the Technology

There were several technical challenges the team needed to overcome in making a game for the Kinect. Primarily, Microsoft does not officially support educational institution the ability to make Xbox 360 games that utilizes the Kinect. While Microsoft has stated the intent to extend the platform to those outside of the AAA game studios, there is no evidence that this will happen in the foreseeable future.

To best ameliorate this, the team developed the games in C# using XNA Game Studio. XNA Game Studio is Microsoft's development tools targeted at independent and educational game developers. XNA Game Studio is a platform that is able to publish games for the Xbox 360, PC, and Windows Mobile Phones. Additionally, the team made use of the official Kinect Software Development Kit (SDK). While this SDK is primarily targeted at making more natural user interfaces, it allows for the development of PC applications that utilize the Kinect and its features. It should be noted that there is no guarantee that these games will work with the Xbox 360 once the official support is release. In light of this, the team has concluded that this is the best possible development course, given the information available at this time.

Design Standard Decisions

The following design decisions provided standards, based on unified concepts, that the team agreed should apply to any game developed for this project. These decisions emerged through discussions with the clients and subject matter experts, prototyping and play-testing, and examination of the various technologies and their capabilities. They included standards for controls, game scope, player interaction, and fidelity of physics concepts.

Controls

By using the Kinect camera as an interface for players to engage in the game, the handheld controller is removed as a medium of game control. This allows for the game to be controlled directly by the player's body. Because of this, it is incredibly important to find a way that allows the game to feel natural, or have a natural way of manipulating the environment. Many of the solutions for these issues are in the gestures the players use to interact in the games. For example, to fire a cannon the throwing motion was selected as a natural analogy to a cannon ball trajectory as opposed to a more artificial motion like an arm movement to the right. In addition, just because you can doesn't mean you should: based on play testing, using feet for repetitive motion should be avoided unless absolutely necessary. It became quite apparent that this quickly becomes arduous and not particularly rewarding.

As the designs for the two primary games evolved, it became obvious that having two distinct motion sets for controlling the games would be confusing if the games were packaged together, so the controls for each were changed to unify the motion sets. While the corresponding motions do slightly different things in each game, keeping the motions consistent allows for easier movement from game to game, a reduced learning curve, and more focus on the game play.

Game Scope

One of the early design standard decisions the team tackled early on was the game scope: whether to create a long, complex game with many layers and deep structure, or multiple smaller games that could be both learned and played quickly. Many existing games were suggested and critiqued as partial models for the game or games described, discussion focused on how these might be played in a classroom environment with 20-25 students, each wanting to both play and assist the players. With turn taking, ease of teacher facilitation, and desire to keep physics concepts explicit and meaningful, the team decided to design 1-2 smaller, lighter footprint games, rather than a long game with involved back stories, complex controls, and potentially hidden physics concepts.

Player Interaction

Reflecting again on the intended use of these games in the classroom, the team decided that the games should be multiplayer, possibly both competitive and cooperative. Several possibilities were discussed including making one game that was competitive and the other cooperative or having settings within a particular game to change the style of play. In addition, features to encourage "crowd" participation in a cooperative sense should be included wherever possible, in which groups of people watching players might provide input and feedback to the players to help them win the games.

Fidelity of Physics Concepts

The most difficult design decisions to make, and arguably the most important, was how to make a game as accurate as possible in regards to the scientific concepts, while giving the game design enough freedom to make the game fun and interesting. The client and subject matter experts both expressed in direct terms that the most important thing was not to convey incorrect scientific concepts in the game (e.g. supporting stereotypes that are not accurate). At the same time, the game needed to be carefully crafted so that those concepts were integrated into a fun and enjoyable gaming experience. There seemed to be no simple answer, and so it involved much back and forth discussion with the client and subject matter experts. It was eventually determined a certain degree of fantasy was acceptable; however, it was important for the team to rely on the client to determine how and where fantasy was used.

Ultimately, the team chose to design a game that best fit the needs of the environment, audience, and situation, by keeping the game scope smaller and more intuitive, the style focused on a multiplayer game with cooperation as a priority, natural body controls, and accurate scientific concepts with fiction game elements.

Picodroid Overview

This game is intended for use with middle school students (6th - 8th grades) and engages participants with the concepts of atomic structure and stability. The backstory puts players in the labs of *Terse Robotics*, a company in the future that manufactures atoms. The players are tasked with testing unique designs for the latest model of *Picodroid*, a robot that is small enough to manipulate subatomic particles. Each player's goal is to build a stable atom before their opponent. A constant supply of protons, neutrons and electrons are provided, and players must pick up the correct particles to create a stable atom. The first player to complete the atom is the winner of the round. While there are multiple game types, the primary game is concluded after one player manages to win three rounds. There is also a more in-depth variation of the game where each game round is played on a horizontal row of the periodic table. This multiple round game mode, while more time intensive than the primary game, allows player to experience larger elements as the primary game is limited to the first ten.

Rules

This game has relatively simple rules, which will allow students to quickly get to the core learning without stumbling over an unintuitive interface and obscure rule sets. The players' goal is to build the atom/isotope that is displayed on the top of the screen. The players must collect the correct number of protons, neutrons, and electrons to build the desired atom/isotope. The screen has a randomly generated sea of floating particles that provide a unique player experience each time and prohibits the players from simply memorizing the locations of the particles. The first player to build the target element wins the round. Players who collect too many of a subatomic particle are penalized by reducing their speed for a short duration. This is accompanied by a visual discarding of the particle to let the player know what they incorrectly collected.

Strategy

The game is indirectly competitive. This means the players should focus more of their own progress rather than trying to hinder their opponent's progress. A decision was made not to allow the players' characters to interact directly on the screen, such as allowing one player to block the other player's progress. One player could attempt to collect all of the particles that their opponent needs, however, this strategy has limited uses as players get penalized for collecting too many of any one particular particle.

Aesthetic

The game's audio and visuals are designed to match the story. Due to the futuristic laboratory setting the environment presents a clean and sterile look (Figure 2). Even the character style and animations, which feature some organic inspiration, are designed to have a mechanical appearance. The music and sound effects also take this futuristic approach and are minimalistic and artificial in nature.

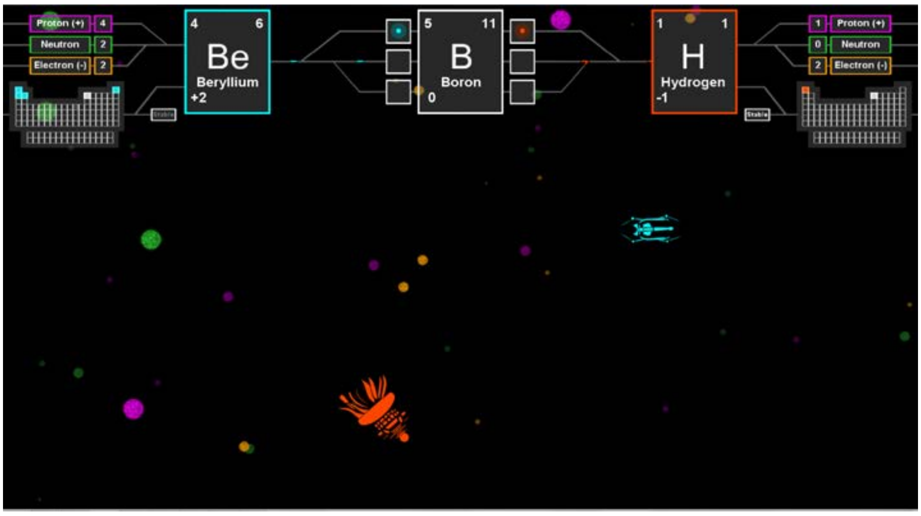

Figure 2: **Final Picodroid interface**

Controls

The onscreen characters are controlled using a combination of the player's left and right hands. The player's right hand controls the direction of the onscreen character. The direction is mapped to the angle of the player's forearm (i.e. the angle between the player's right elbow point and the player's right hand point). The player's left hand controls the onscreen character's speed. If the player raises their left hand higher than their shoulder the onscreen character moves. Initially this was mapped to a scale (i.e. a little high moved slower, while very high moved faster) however this was dropped from the current implementation. Play-testing concluded that players were moving as fast as they could or were stopping to perform a more dexterous maneuver. The observations concluded that a scaled speed was unnecessary to the game and only served to further complicate the controls.

User Interface

The target and status displays are provided though in a periodic table with the name and symbol of an element, its mass number, atomic number, and charge. Using these numbers, players can determine which subatomic particle they need to build the target atom/isotope. The current status displays detail about which atom/isotope players currently have based on the numbers of subatomic particles collected. In addition, an indicator near the players' status indicates how many rounds the player has won.

Lessons Learned

Several important lessons can be taken from this game design and development experience and will be used to inform future experiences. The design and development methodology was particularly successful in producing a quality game exceeding the technical expectations of the project manager. The interaction with the client/content expert was critical, providing the necessary boundaries to ensure the teams produced a game that was engaging, but did not stray from reality in ways that would adversely impact students understanding of the underlying concepts.

By creating a game using a relatively new interface structure (the Kinect motion controller), required even the most experienced "gamer" team members to play, troubleshoot, brainstorm far beyond what they may have done if they were creating a traditional PC or console based game with traditional controls. Creating custom gestures that were simple, somewhat intuitive, and did not distract from the game itself proved to be a challenge throughout the process that required much play-testing and even some frustration.
As in many game design processes, many good game ideas were shelved, including some that were well-structured and even prototyped. Many were sacrificed simply because time did not allow multiple development streams, others because of client preferences. It is likely that some of these might be used as the starting point for a new project.

Moving Forward

Picodroid, now in public beta, will continue to be refined and play-tested for the next several months following which it will be released in "final" form. A research study will then be designed around the game and its implementation focusing on whether students gain a higher or deeper understanding of the underlying chemistry and physics concepts, whether their attitudes towards those concepts are any different after play, and in addition, whether it was a good game from a design and use perspective. In addition to these foci, careful attention will also be paid to how students play the game, how players interact with each other, how viewers interact with players, as well as how the teacher integrates the game and it's concepts into the classroom. To learn more, and to sign up for the Picodroid Facebook site please visit the following web site: http://www.dcl.niu.edu/index.php?q=content/picodroid

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