ABSTRACT

Tangential learning is the process by which people educate themselves on a topic when it is presented in a context that they enjoy. It is known to be a very effective method of independent learning, and if used properly could replace many current methods of independent study as a means of educating children and young adults.

We present a video game, World of Alchemy, that utilizes tangential learning to educate its players on high school level chemistry, unlike previous educational games that have been targeted at elementary school students and therefore have addressed very basic topics, such as introductory arithmetic and logic. World of Alchemy has a greater focus on ensuring players enjoy themselves than previous educational games without sacrificing its educational components. We target players with very basic knowledge of high-school level chemistry and focus on puzzle-based gaming which will improve both the educational and enjoyment aspects of the game. From our studies, we have seen that shifting focus to older audiences, secondary education topics, and enjoyment in gameplay has promise as a supplemental game system to augment in-classroom learning.

1. INTRODUCTION

Historically, it has been easy to separate games into an “educational” category and an “entertainment” category. Educational games have tended to be aimed at young children and focused on simple topics like arithmetic, geography, and logic. These games are typically played on school computers as part of a teacher’s regular lesson; it is uncommon to see young children enjoying these games on their own time, and even less common to see older children and young adults playing these games. Older players tend to recognize the narrow focus on education in these types of games and ignore them in favor of games which focus on the player’s entertainment instead. Entertainment games, on the other hand, are regularly enjoyed by players of all ages. These games typically focus on graphics and gameplay, putting the entertainment of the player above all else. Unlike educational games, however, this category often offers no benefit to the player beyond entertainment; for this reason, games in this category are often viewed as frivolous from an educational standpoint.

It is worth noting that not all entertainment games are completely devoid of educational value; many such games, especially those set in historically accurate settings, may encourage the player to look up further details on information presented in the game that is not directly related to the player’s progression through the game. Nor, for that matter, are educational games completely devoid of entertainment value; they could hardly be called games otherwise. Yet, the fact remains that many gamers, especially older players, will generally ignore educational games, and may even ignore educational aspects of entertainment-focused games.

Older players can be encouraged to learn even while playing games that they find entertaining through a process known as tangential learning. We define tangential learning as the process by which people educate themselves on a topic when it is presented to them tangentially during other activities they enjoy. In the context of video games, this means presenting the player with an entertaining game that includes information the game designer wishes to introduce to the player, while giving the player substantial in-game rewards for acquiring that information. To achieve this goal we have implemented a chemistry-based game we call World of Alchemy, which focuses on adventure-style, puzzle-based gameplay to facilitate our learning objectives.

Targeted for players with a high-school level chemistry background, World of Alchemy allows players to construct and decompose compounds at will, manipulating their basic elements through an easy to use crafting interface and inventory. Compounds can be further combined into more high-level items like clay pots or metal sheets. These items and compounds are then used to solve chemically-accurate puzzles, which are presented to the player through a three-dimensional “dungeon” adventure.

2. RELATED WORK

This section explores related work in the field of educational video games, with a special emphasis on chemistry-based games. Section 2.1 focuses on what tangible educational benefits games can have, such as self-motivated learning or tangential learning. Section 2.2 examines why games marketed explicitly as educational software are historically not as successful as other consumer games. And section 2.3 discusses notable games developed specifically as learn-
ing games, with a particular emphasis on chemistry-oriented games that may have some overlap with this project.

2.1 Learning in Video Games

Kurt Squire and his colleagues studied learning via the game Civilization III [6]. For reference, Civilization games are strategy games that focus on building up civilizations (e.g., Romans, Mayans, etc) from the Stone Age to the Modern Era and beyond. Players encounter other civilizations during play, and have to manage economic pacts, political alliances, and military conflicts with these other civilizations. Subjects in this study were fifth and sixth graders with below average scores in social studies. By playing the game and collaborating with their peers, the participants were gradually exposed to many historical concepts, such as the names of certain historical military units and various landmark historical inventions like agriculture or writing. By the end of the study, most participants had developed a greater appreciation for history and had acquired much better grades in their social studies courses; all received As while previously having Bs and Cs. One of the participants even began to read history books about them for his own enjoyment. Even though Civilization is a popular consumer game, it managed to expose the players to a variety of real-world concepts, like costs of prolonged military engagements, as well as the historical facts scattered throughout the game and available in the in-game “codex”. While these students had typically fared poorly in class-based instruction, the direct experience, challenge, and fun provided by the game allowed them to explore these concepts directly in their own way, which yielded real-world learning benefits, as indicated by their improved social studies grades. Player motivation to beat the game and continuous tangential exposure to real-world topics combine to make a very effective model for learning.

Merrilea J. Mayo analyzes the benefits of games over traditional classroom education, and how these concepts might be applied to education in science, technology, engineering, and mathematics [4]. In her analysis she describes how motivation and participation are key differences between learning something in a game versus learning it in a traditional lecture. A game provides instant feedback and immersion in a given scenario, whereas students in a classroom tend to sparsely interact with the material. Player control over learning tasks are also cited as another important factor; player motivation to complete an immersive task of their own choosing leads to greater net benefits in learning. The player seeks out what they want to know, rather than being spoken to about something they are not involved in and may not have any interest for. Interactive instruction in subjects like physics proved to be particularly effective for this very reason. The amount of time people invest in gaming and the benefits of interactive activities for learning make video games an excellent platform for delivering educational content. In fact, games like Supercharged! or Virtual Cell (both discussed in the article) yielded significant benefits in learning over lecture-based instruction, since players were allowed to explore electromagnetism and cell biology, respectively, in very engaging contexts at their own pace.

2.2 Failings of Educational Games

In their article on the boom and bust of educational games, Klopfer and Osterweil describe the history of educational games and the failings of some notable educational games [3]. The main point they make about poor educational games is that they tend to focus on just facts and lists of features, rather than developing actual gameplay. These types of games try to market themselves towards some ambiguous definition of academic curricular standards, and often feature rote memorization in drill-and-practice exercises. The most successful educational games are those that are actually intellectually challenging, and these games focus on actual problem-solving and creativity, rather than appealing to some nebulous idea of academic advancement. Player enjoyment is also an effective component for learning games. Thus a balance is necessary when designing a learning game. By focusing solely on fun activities the learning opportunities may be wasted, and if the game focuses solely on being educational it may bore the player, hampering the learning process or even causing them to abandon the game altogether.

2.3 Notable Learning Games for Chemistry

During the course of our research we have found that there were not many successful chemistry-based games, especially when compared to mass-market history- or physics-based games, such as the Civilization series or Kerbal Space Program. Generally these chemistry games tended to be simple quiz or memorization affairs, or featured chemistry as a very tangential component. We did come across a few notable chemistry games, namely Legends of Alkhimia, Elemental, and Foldit. Legends of Alkhimia is a chemistry-based adventure game where puzzle solutions are derived by working on compounds within the game’s chemistry lab interface [5]. Alkhimia communicates laboratory practices and the process of scientific inquiry quite well. This game seems to be at about the same granularity of knowledge that we want to work on, but we have focused more on how specific elements and molecules interact with each other, as opposed to laboratory practices. Our design also tries to be more accessible to less chemistry-oriented audiences.

Elemental is an atom assembly game developed at the UK’s Bournemouth University [1]. Players have to “shoot” subatomic particles into a circular game area that resembles an atom and then “catch” them in their appropriate atomic region, with the goal of creating elements with progressively higher atomic numbers. Particles that leave the circular area (i.e. the player was not able to catch them) increase the ambient radiation level, and once radiation reaches a certain level the player loses. Elemental suffers from repetitive gameplay, and is very direct in its learning goals. Being too direct may cause an aversive reaction in the player, since the game is clearly just an educational tool with weak gameplay. Our design seeks to address this issue of directness by placing puzzles and goals in an adventure-based environment that may mask their learning-oriented nature.

Foldit is a rather well-known academic game that abstracts protein-folding as puzzles [2]. The object of this game is for players to form correctly folded proteins, by avoiding anomalies such as “clashes” and “voids”. These occur when certain structures are too close together or far apart, respectively. More stable designs that take advantage of concepts like hydrogen bonds also result in a better score. Collaboration in developing solutions is highly encouraged, and effective solving algorithms often spread quickly among the
player community. However, as a learning game it has some issues. While protein structures are realistically represented, to the average player these may seem like arbitrary puzzle structures. *Foldit* is too high-level for our goals; from a chemistry standpoint it does not seem to deal with any of the specific atomic structures of these proteins, instead just focusing on the puzzle-like nature of a chemically abstract protein shape. Including additional information about the specific structures at play could enhance its learning potential. We attempt to solve this problem in our own game by having item descriptions in the game’s inventory window that lists the chemical composition and functions of the player’s items. That said, *Foldit* is a great example of what this project aims to accomplish in terms of tangential learning. Nearly every structure with which the players work is a real protein fold, and it becomes very easy for motivated players to find more information on the protein one which they are working.

3. SYSTEM MODEL

We present a prototype, *World of Alchemy* for a new type of educational game based wholly on tangential learning. *World of Alchemy* focuses on providing the same level of enjoyment to players as standard video games with additional educational benefits.

*World of Alchemy* is a chemistry-focused adventure game targeted at middle- to high-school age students who have had little to no prior chemistry experience. We choose to focus this game on chemistry for two reasons: first, chemistry had little to no prior chemistry experience. We choose to target at middle- to high-school age students who have something different for a change, as well as allowing for a can be utilized as a break between puzzles, giving the player their characters to beat other players. In addition, combat of games and may get additional motivation from improving players, as many players enjoy player-versus-player aspects allowing. We attempt to solve this problem in our own game by having item descriptions in the game’s inventory window that lists the chemical composition and functions of the player’s items. That said, *Foldit* is a great example of what this project aims to accomplish in terms of tangential learning. Nearly every structure with which the players work is a real protein fold, and it becomes very easy for motivated players to find more information on the protein one which they are working.

3.1 Combat System

As players will be more amenable to learning through our game if they are enjoying the game while they play it, we focus on the gameplay portion of the game, working first to design a fun combat system and puzzle system and then working chemistry concepts naturally into these systems. We allow players to fight both non-player characters and other players, as many players enjoy player-versus-player aspects of games and may get additional motivation from improving their characters to beat other players. In addition, combat can be utilized as a break between puzzles, giving the player something different for a change, as well as allowing for a lightweight review of previous concepts, like using acid to neutralize an enemy limestone golem.

3.2 Graphics

Since the target audience is older, the game features a more realistic looking worlds and characters to be more accessible to our audience. This not only affects the design of our environment, but also our player and non-player characters. In doing so, we aim to foster an immersive setting for a large audience that may not play role-playing games, such as the one proposed, on a regular basis.

3.2.1 Environment

In line with the world’s design, much of the game will take place in ruins. The only dungeon is designed to teach acids and bases. Of acid-base reactions, one of the most commonly taught reactions is the reaction between limestone and acid. Since many historical buildings were built out limestone, particularly those in Ancient Egypt and in Greco-Roman states, most of our game will be set in a desert land. The structures in the game will be directly based on ancient building ruins from the Greco-Roman period in Jordan, particularly the Petra treasury and the fountain meeting area from Jerash. These structures are not massive but also awing in their great architecture, allowing for audiences to immerse themselves through gameplay.

3.2.2 Player Character (PC)

In order to combat the stigma that games are catered towards men, the PC will be a gender-ambiguous character. The PC has been planned with cloaks, as they are traveling alchemists. For stylistic and practical purposes, we have chosen to mask the lower half of the player characters’ faces. Having part of the face visible will allow players to connect with the PCs. However, masking the lower half will allow the resulting model to have a lower polygon count, since we can obscure the detail of the lips and the nose, which generally account for most of the polygon count on the face.

3.3 Non-Player Character (NPC)

The game will first feature NPCs that are simply enemies that try to attack the PC while the player moves around the map. This adds a combative element that aids in immersion and increases engagement. Since the environment is made of limestone, the first NPCs featured will be made of limestone.
3.4 Puzzles

World of Alchemy contains a number of chemistry-based puzzles (Figure 2) which are used to illustrate common chemistry concepts to students. We focus on acid reactions with bases, lack of reaction with transition metals, electro-chemistry, and hydrolysis.

4. SYSTEM IMPLEMENTATION

4.1 Graphics

4.1.1 Environment

The game features a two-floor cave with multiple rooms. The map is designed to reduce “back-tracking”, or returning to a previous room, in order to reduce frustration and to reward progress in the game. The map is one contiguous room that allows the player to return to previous rooms if desired. In order to encourage forward movement in the map, there are pools of acid scattered through the map that discourage the player from walking into these areas by decreasing the player’s health. In the case when a player’s health reaches zero, the player is automatically re-spawned, or returned to the map with full health, and placed at the closest passed “check-point”. These check-points have been placed at the entrance of each room. Once a character has passed a particular check-point, the player will be re-spawned to the latest passed check-point after his or her health reaches zero.

4.1.2 Characters

The current iteration of the game features two characters: the player character, and the limestone golem (see figures below). Both of these characters were modeled, rigged and animated outside of Unity. We chose not to use stock Unity assets as each of these characters interact in a particular manner. Thus, in order to show the full extent of interaction (i.e., visual cues from chemical interactions, etc.), we have created our own assets to best suit our needs. Both characters are low in polygonal count, and utilize Unity-enhanced shaders to achieve an optimal run time while the player is playing the game.

4.2 Items and Inventory

4.2.1 Items

Using the Unity game engine, interaction with items is implemented with a group of control scripts that can be attached to game objects. These scripts include a pickup script, which prompts the player to pick up the item with a key press when they approach. The pickup script then adds the item to the player’s inventory (Figure 7). The data for each item is retrieved from the database upon item creation, and this data includes information on their name, item description, chemical composition, molecular structure, and item inventory icon. Chemical composition determines what elements the item should be broken into when it is recycled from the inventory window, while the molecular
structure stores the structure needed to create the item.

4.2.2 Inventory

The item inventory, element inventory, and crafting window consist of a number of scripts attached to an empty game object. The item inventory stores the player’s items in an array, and icons for each of these items are rendered when the inventory is opened with the ‘I’ key. An item’s name, description, and chemical composition are displayed on the right side of the window when the user clicks on that item’s icon. The inventory also includes a recycle button in the lower right corner of the window, which destroys the item, fetches the constituent elements the item breaks down into, and adds them into the element inventory. The element inventory (Figure 8) simply displays a periodic table like grid, in which elements that the player have discovered are lit up in their CPK color. This CPK coloring is the standard element-specific coloration used by chemists in molecule models. It also displays the number of each element the player owns, which is saved and fetched from the database. The item inventory also allows the player to combine items, for example when combining acid, iron, copper, and a terracotta pot to create a battery. To reverse this process, the molecular crafting (Figure 9) screen contains a hexgrid, on which the real molecular structure of an item is approximated. When a valid set of elements are placed in the correct structure, the player can create an item. All items can be broken down into or reformed from elements, which mimics chemical reactions in real life in which no element ever disappears; it is only changed into a different form.

4.3 Camera

World of Alchemy uses a third person camera view, as opposed to a first person camera view primarily to facilitate our puzzles and combat. Some of our rooms include jumping puzzles, which causes frustration when using a first person camera. In addition, a third person camera view allows the player to see their surroundings in more clarity both in combat and in puzzle rooms. In addition, the primary benefits of using a first person camera, that of being able to aim more realistically and having more immersive combat, is not a focus of World of Alchemy. Although the project contains combat, combat is not the focus of the game, the increase in fun from the immersiveness is counteracted by the decrease in fun from missing valuable clues in the surroundings of the puzzles, which are our main focus.

4.4 Combat, Movement, and Hazards

World of Alchemy implements movement through WASD keys; while the mouse orbit camera is off, W is forward, S is backwards, A and D are turning left and right, and space is jump. While mouse orbit camera is toggled on, A and D are instead strafing left and right. Left clicking shoots a projectile that is also affected by gravity, which the player must take into account while aiming to hit a target that is further away. Health regeneration is also implemented, as an easy way for the player to regain health when they are not actively in danger. Fall damage and acid damage are hazards the player must avoid, and are built into the dungeon in order to ensure that the player can be in relatively close proximity to their goal, without being able to skip puzzles on their way to the end. Being able to see their goal gives players a sense of progress, which contributes to their sense of fun. Players respawn at checkpoints throughout the dungeon if they die.
4.5 Puzzles

World of Alchemy contains four puzzle rooms, which include interactable locations which, when the correct item is used in the location, triggers an event, such as a balloon filling with air or acid flowing down a chute. These scripts are reusable; the interactable script contains references to the valid item to be used and the event to be triggered, which can be assigned differently for each interactable object. The event to be triggered can be subclassed for each new event. World of Alchemy also uses various hints to prevent the player from becoming frustrated with the puzzle; these hints are also reusable, and include particle systems that highlight relevant portions of the puzzle. Another hint that is used is alchemical "graffiti" that correspond to molecular structures of items the player needs to create.

5. RESULTS

To verify the playability and learning components of the game, we asked twenty-nine college undergraduates and high school students that had played the game to take a short chemistry quiz. Most of our participants had had some formal chemistry experience, but few had taken chemistry beyond an introductory high school class. Before each session, participants were asked to take a short eleven-question chemistry quiz with questions that introductory-level chemistry students are expected to be able to answer after completing the acid/base portion of their respective chemistry classes. This quiz was meant to establish a baseline score so we could measure their improvements after playing the game. Participants were not notified of their score after this initial quiz. The quiz questions were based on standardized introductory level college-level chemistry questions from previous AP Chemistry multiple choice exams, and have been verified to be comprehensive by teachers and professionals to whom we spoke. An excerpt from the quiz questions is listed below.

After taking the chemistry quiz, the session proctor explained the instructions of the game, and started the game for the subject. The proctor stayed with the participant throughout the session, observing any difficulty that the subject had while playing the game and answering any questions the subject had about the game’s controls, but did not provide the user with hints or puzzle solutions. After the user finished the final puzzle, the session proctor administered a second chemistry quiz. The second quiz contains the same questions as the first quiz, but the participant was not allowed to access his or her answers from the first quiz. Following the quiz, the participant answered a usability survey which provided their subjective evaluation of the game.

The following sub-sections explore the results and observations of both the quiz and usability survey from the user study.

5.1 Player Scores

The graph in Figure 10 shows the quiz score for each subject before playing the game and the respective score for each subject after playing the game. Our sample size was twenty-nine participants. The average quiz score before the game was 6.83, or 62%, and the average score after playing was 7.86, or 71.5%. A histogram of score improvements is given in Figure 11. A matched pairs t-test shows that the average user’s score improved by 1.03 points, or a 9.4% improvement, with a 95% confidence interval of 0.39 points to 1.68 points (a 3.5% to 15.2% improvement).

5.2 Survey Data

Player response to the game was generally positive, with an average enjoyability rating of 5.8 out of 10. Interestingly, most players seem not to notice that they were learning while playing the game, rating its learning at 4.2 out of 10 on average. Ease of controlling the game was rated at 5.4 out of 10, and the game’s difficulty was rated 4.6 out of 10 on average. Many players praised the game’s novel approach to teaching chemistry, but criticized its graphics, controls, and user interface.

6. DISCUSSION AND LIMITATIONS

Our results demonstrate a small but significant improvement in player quiz scores. From this we conclude that World of Alchemy shows promise as a chemistry based tangential learning game. However, we noted that the greatest improvement was seen in those players who performed close to average on the initial quiz; players who underperformed on the initial test did not possess enough chemistry knowledge to make the necessary observations for learning during the game, and players who performed well initially did not have much room for improvement. From this we conclude that World of Alchemy would be most useful as a supplement to a standard high school chemistry course rather than as a standalone tool for teaching chemistry.

We also noticed that players generally improved most on questions related to memorization of chemical formulas which they had to know to progress in the game, while players did...
not generally retain information which was conveyed that they were meant to observe during game play but which was not required to progress. We conclude that players will not pay attention enough to information conveyed in the game unless learning the information presents an obstacle to their progress.

However, we discovered while creating the game that the adventure style game World of Alchemy was originally conceived as carries significant overhead in terms of art assets, scripting, and level design which do not contribute directly to the learning environment. Given a similar set of resources, it would be most effective to focus on a puzzle oriented design from the start.

7. FUTURE WORK

From the above results and observations, the user comments generally fell into two categories: user interface issues, and puzzle issues. We will comment on future work planned to address the comments from the two categories, and the observations the group noted with concern to tangential learning. We will also address planned expansions on gameplay and distribution.

7.1 User Interface

In general, many of the users with little to no experience with gaming had issues with the controllers, citing that the controllers were cumbersome and took a fair amount of time to learn to use. Since the controllers were modelled after common RPG controllers, we found less distaste with general movement controls, but a fair amount of complaints about the right-click strafing camera. Since the game is targeted at all students that are taking chemistry, we would like to explore a mixture of controllers that will give experienced users intuitive movement while slowly introducing newer gamers. We can do this by adding skippable introductory levels that specifically teach movement and interaction. If the user is comfortable with the controllers, he or she will be able to skip to the next portion, while users that want more practice are able to utilize this low-pressure environment to learn controls and familiarize themselves with movement before entering the game.

7.2 Puzzles

Many of the users thought that some of the puzzles were unclear, citing the lack of obvious visual and audio cues to signal that they had interacted with particular objects. In future iterations, physically-based simulation and graphics should be added to give more intuitive cues. Since chemistry is a natural phenomenon, it would be better to incorporate natural visual and auditory cues for knowledge to transfer. This change in pace can aid in keeping audience attention. Some of the emblems of the cities and humanoid elements. This change in pace can aid in keeping audience attention. Some of the emblems of the cities and humanoid NPC concepts can be seen below. In keeping with stylistic and practical preferences, the concepts all have realistic artwork and obscure the face. This unifies the artistic theme of the game allowing for more immersive play.

7.3 Tangential Learning

Currently, the game is limited to solely teaching chemistry. While there is no singular game model that can be applied to all kinds of tangential learning game, we would like to explore the possibility of creating modular puzzle components. In building our puzzles, there are many core components that are re-used amongst the puzzles. Capitalizing on this modular behavior, further work can be done to make a toolkit of a variety of puzzle components. This toolkit can be made readily available to educators, along with a puzzle editor, to allow for educators to build and create their own puzzles. Thus, instead of creating a full-game, teachers might be able to create modular puzzles for their own classes. This would alleviate the high initial cost to create and code large puzzles that are specific to the desired learning topic. Similarly, this would allow for teachers to create puzzles that are catered specifically to the needs of their students, which could potentially increase the effectiveness.

7.4 Gameplay

The current iteration of the game features a single level for a single player. Much of the system has been designed with scalability in mind; thus, next steps in development include scaling up to encompass group play, where players are allowed to collaborate. Previous studies have shown that collaborative learning can be very effective. Since the main learning mechanism are the puzzles, collaborative play could potentially reduce frustration, by allowing interaction with other players. Similarly, collaborative play could potentially increase learning by having players explain puzzles and concepts to one another in a non-threatening manner. To prevent a particular player or member of the group from solving the puzzles for other members, which could decrease the learning value for the other participants, puzzles could be split in such a way that each member only sees his or her portion of the puzzle. In this manner, communication is enforced and encouraged.

The game would also benefit from a more robust combat system. The current iteration of the game features plug-in points for enemies and combat. However, gameplay could be enhanced by expanding and creating a more robust system to allow for players to engage in combat with each other and with non-player characters. The development of this game considered scalability, so the fundamentals of multiple player views and interaction with the environment and other characters should fit into our current system without much modification.

Finally, gameplay could be enhanced by adding other NPCs and generating an extensive background and world for the game. In looking forward, we have scoped out other potential levels that could be explored by this game. These include: (1) phase-changes, and (2) electrochemistry. Each of these levels can be modeled as its own ruins, with a particular theme and emblem to differentiate among the different cities. Humanoid NPCs can be included to add more interaction in the game to intersperse puzzles and combative elements. This change in pace can aid in keeping audience attention. Some of the emblems of the cities and humanoid NPC concepts can be seen below. In keeping with stylistic and practical preferences, the concepts all have realistic artwork and obscure the face. This unifies the artistic theme of the game allowing for more immersive play.

7.5 Multiplayer

Further analysis could be done on cooperative play and whether it would have a substantial effect on the quantity of tangential learning. Future puzzles could be made to incor-
porate team play, and additional testing could be done with comparison between single and multiplayer mode. With networking infrastructure largely already in place, further development would not be costly and would provide additional data for analysis.

7.6 Distribution

Most of the aforementioned testing was conducted by having participants play on individual team members' machines. While this suffices for testing purposes, proper distribution methods would need to be adopted to allow for educators to adequately use this as a tool. We are currently exploring web exploration via Unity's web exporting tool. In this way, we can host the game online, and distribute a URL for students to access. This could also allow for aggregating and tracking of data and statistics per individual and per class. Currently, we have a rudimentary version of a previous iteration of our game; however, we have found networking and database issues in our previous export that prevented this sort of web distribution for testing. Hosting all of this should preclude most of the issues that have prevented us from distributing via the web.

8. ETHICS

As a supplemental academic tool, the amount of risk the project poses to the user is minimal. It is expected to be used in conjunction with the mainstream, content-base curricula, and, as its main functionality is tangential learning, the puzzles in the project are designed to promote critical thinking and application of concepts. However, its potential may be detrimented by particular cultures and technical infrastructures of the school and facilities. Teachers may need to familiarize themselves with the game and be able to ascertain whether it is appropriate for the curricula and school use. Additionally, game testing need to be extensive, as any number of bugs may be exploited by the students which can skewed the tangential learning aspect of the project. Other factors that need to be considered include the learning curve of the game, the user experience, and amount of content. Producing the game with effective tangential learning has a trade-off in which the amount of work may be disproportionate to the amount of actual learning and thus such a supplemental academic tool may not be marketable.

Additionally, difficulty may arise in the technical infrastructure. Installing the games on predisposed machines and reconfiguration may be required on the school's part. There may be issues in game saving, which may be done locally (where the student must use the same machine in order to resume playing), or remotely. Continuity in game playing is a critical factor of games, and without a secure game saving feature, the game may experience losses in saved data, which may cause frustration in students, especially if they have spent a significant amount of time in solving the puzzles. It may also be possible for the student to already have a firm grasp on the concept, but is forced to play through the game in order to reach the next level, which may cause additional frustration. Additionally, students may spend more time on the game than on the actual, content-base curricula, so a time constraint may be need to put in place, as the game itself is not a substitute for actual, content-base curricula. However, this time-constraint may pose a problem, as each student may need different amounts of time to complete each puzzle. Overall, if used in moderation and content-appropriate, the game may be used as a viable tool for supplemental learning.

9. REFERENCES


