Music Game to Teach STEM Concept

An Interactive Qualifying Project

submitted to the faculty

of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

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Abstract

There are many important STEM concepts introduced during elementary education. However, traditional approaches to this instruction are not always understood and embraced by students. For some students, STEM topics are too abstract to understand and too dull to maintain their interest. Prior studies show that using video games as a medium to engage students' interest could improve the efficiency of study. While students are enjoying the game, they can learn STEM concepts in an informal way. Other studies show one aspect of improving study efficiency, which is to add creative elements, such as music, into the experience. In this study, our IQP team developed a software-based music game for pre-teens to help teach STEM concepts informally based on a review of the current literature on informal learning, educational games, and STEM education. The prototype contains a water-flowing system by which students control water-flow in and out for various cylindrical containers; the water-flow produces musical pitches in a sequence, and the containers produce a harmonic rhythm to provide the user with aural feedback on their successful attempts to control water-flow. After the prototype was completed, we introduced it to two focus groups of undergraduate students (N=16), and collected feedback about the game. In general, its potential to be an informal learning mechanism, and the participants' level of engagement in the activity. From this, we conducted an analysis of the data and made several recommendations for future research.

Acknowledgements

The members of Team Music Game of STEM Concept would like to thank all the volunteer test players. They actively gave us their suggestions about the gameplay in many aspects. Each of their feedbacks were critical for us to evaluate our current results, and find proper ways to get further improvement of the prototype.

We would like to sincerely thank Professor Vincent. J. Manzo for helping and advising this project. We are grateful that he met with us each week to discuss details about idea, research, implementations and evaluations in the past three terms. Without him, we would not have the chance to collaborate to achieve a satisfactory goal.

We are thankful to Professor Michael. T. Timko for giving patience discussing how to implement steady state concept in the game content properly. We are also thankful to Tao Yang, for providing some software-debugging supports for the prototype.

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Chapter 1: Introduction

Science, Technology, Engineering and Mathematics (STEM) has become few of the most crucial forces in human development. So nowadays STEM concepts have been introduced into elementary school's education. Pre-teens can learn STEMs in school. However, the STEM's topics in lecture is so abstract and boring, that children cannot understand easily or are unwilling to learn.

STEMs should be fun to learn if there's a fun way to learn STEM concept. One way is to learn STEM through game. According to the study done by Denis, G. and Jouvelot, P. (2005), game as a medium can raises children's motivations. The result of their study shows that kid's motivations in video game deal with fun, a potent source of intrinsic motivation. Psychologically, it comes from the combination of feeling of challenge and desire of passing the game (Denis, G., & Jouvelot, P. 2005). To make game more attractive and more efficient to learn STEM, adding music elements is necessary. One study (2009) shows that music, as a medium, can improve sustained attention from children. Within music, children can actively understand and memorize more things than same condition without music (Wolfe, D. E., & Noguchi, L. K. 2009).

We wanted to design and build a music game that can make STEM learning more accessible in an informal way. The music game can visualize abstract and complex STEM concepts to interesting game contents. During the gameplay, the players can learn few basic concepts in STEM while playing the game. After playing the game, they can have vague concepts about physical principles when they see some physical phenomenon in real life. The goal of this project is to create a new learning process, which is easily to be accepted by pre-teens to acquire some STEM knowledges. In order to create a music game, we should figure out

how we should approach the target player through art, music, and the content of our game. The details about that are included in our project notes, which shows game design from basic to improved version, UI and art design, music selection, and raw data from the survey. The notes, which is in Appendix A, shows the development of our prototype.

Chapter 2: Background

In this chapter, we did research about some current games, mostly related to musical and educational ones and analyzed their advantages and disadvantages. Additionally, we compared the informal learning styles and traditional lecture learning methods and analyze and analyze why informal learning styles using new media is better.

2.1 Current Games

2.1.1 Current Music Games

(1) Water Bottle Xylophone

Water Bottle Xylophone is a simple flash game, but it gives us the main inspiration of music games. This game is based on hitting bottles with different water levels and producing different pitches, shown in Figure 1.

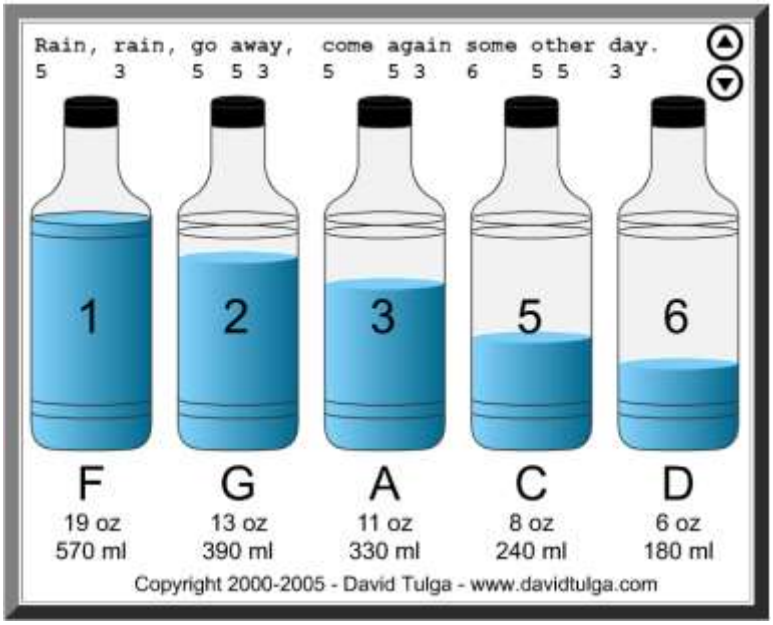

Figure 1. Water Bottle Xylophone

The players are required to tap on empty bottles, which all of them make the same sound. However, when players add different amount of water, the pitch changes overtime. More water produces a higher pitch, and less water produces a lower pitch. Because sound waves travel through liquid, by alternating the amount of water in the bottle, the sound waves are altered as well. Liquid with varying densities will produce different sounds since the sound waves travel through them in varying speed. Likewise, different materials make different sound. Liquid could be orange juice, milk, soda and all kinds of drinks. But with changing of the amount of the liquid in the bottle, it could produce the same sound wave.

(2) Curious George: Splat Symphony

Curious George is a simple music game for children. It requires players to compose music by shooting pigments on canvas. The main interface is shown in Figure 2.

Figure 2. Curious George: Splat Symphony

The height of shot pigment on canvas determine different pitches. For example, if players shoot the paint higher, it produces higher pitches and vice versa. Also, players can choose different colors, which different playback sounds of various instruments (orange is guitar, and green is viola, etc.)

The colorful and nicely designed UI is one of the most impressive part of the game features. Also, for young players, this UI would more likely becomes interesting and appealing. Therefore, we realized that we need colorful UI on game design.

However, the main game drawback is there is no direct physical connections between the color and music. Therefore, it is not quite realistic implementation. Hence, our direction for game design is to make the game more realistic, and it can show STEM knowledge in a more fundamentally and straightforward way.

2.1.2 Engineering Game

(1) Liquid Measure

Liquid Measure shown in Figure 3 is an interesting engineering flash game. The player can move the water tank into certain positions to hold the water flowing out from the top. The players are also allowed to move the offered pipes to change the path of flowing water.

The idea of this game is to guide players to solve puzzles. In the puzzle, the player must concern about two conditions. Where the water should flow and how much the water should flow to each water tank.

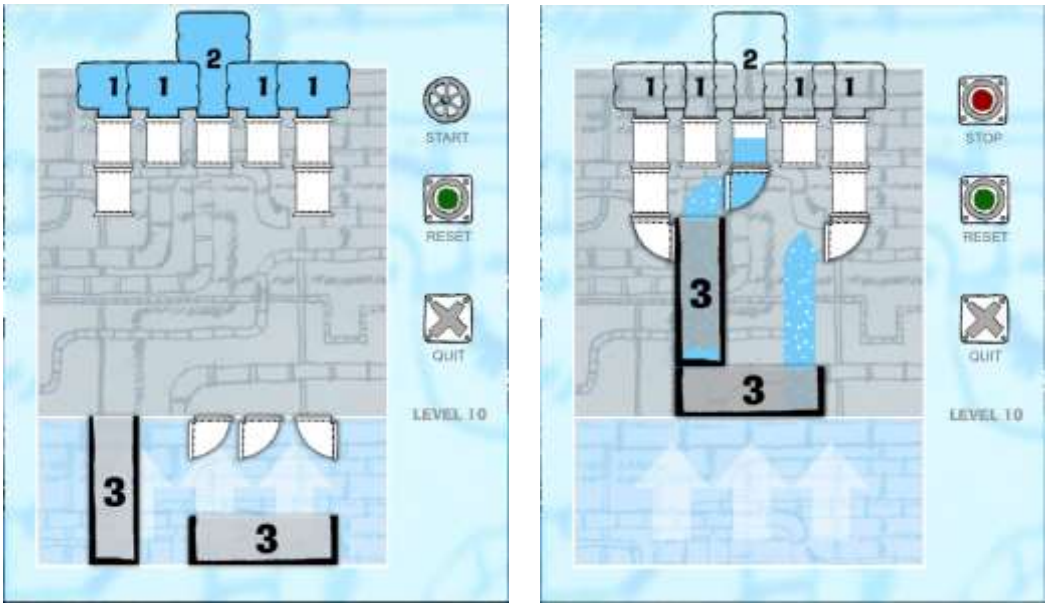

Figure 3. Liquid Measure Interfaces

One of the key features of Liquid Measure is the ramp difficulty levels. The whole game contains 20 levels and each level have increasingly difficulties. In the beginning the players can only play the first level. When they pass it, the second level, which is more difficult one, is unlocked. The players can play any levels which are already unlocked so far. The ramp difficulties are quite appealing for players, since the unlocked features can encourage player, as instant rewards. The increasing difficulties can also challenge the players, making the game increasingly attractive.

Another feature of the game is that it shows the idea of gravity effects on water flowing. In the game interface, when the water is flowing down, the animation shows that there's certain speed on the water flows, and when the water flowing out from pipe in a horizontal way, it forms a parabolic trajectory. The feature is quite inspirational for young-aged player, because they can get some idea of that physical conditions from the game.

(2) Simple Machine Game

Simple Machines Game, shown in Figure 4 is a simple game made for Chicago Museum of Science + Industry. The players are required to build simple machines, such as inclined plane, pulley, etc. to enable the character, a small spirit to access different electronic components.

Figure 4. Simple Machine Game Interface

The key feature of this game is it would provide physical properties of the machines after players pass the level. It is a good approach since players can have some vague understandings about the mechanism. If the game provides physical explanations to guide players to learn the mechanism, it is a pretty effective way to do so. In our game design, we believe it is a good approach to add some verbal explanations on certain phenomenon.

2.1.3 Analysis

Besides the games we have discussed about, we also did some researches on more educational games, generally covering either STEM, or music field. Based on what were observed, we have some basic ideas for game design, which are:

- Our music game on STEM studies need to be more realistic, which can clearly reflect physical phenomenon.
- The UI of the game could be more user-friendly for children, and colorful UI may be a good approach.
- The game mode, which sets multiple levels, is a good approach to increase joy of game. We can consider the modes in our game design.

2.2 Concerns about Traditional Teaching Styles

Nowadays, traditional lecture is the main method of education in school, which is not effective and easy to understand for students. Students could not get a chance to practice and implement the knowledge they have learned from lecture to the real-world problems. Media would more likely make students more motivated and interested during learning process because media can build direct interaction with them. Traditional lecture, on the contrary, makes students feels boring that they could not understand and remember the material taught through class.

These researchers hoped to promote different methods of teaching and studying, which would apply to a more diverse range of differ in learning preference, covering from kindergarten

to college students (Grinder & Bandler, 1976). Though the studies we find out via the music playing and media involved, people are predisposed to learn more effectively. Students normally think themselves as a person, who can understand the material much easier through visual, auditory, or kinesthetic ways.

2.3 Difficulties in Elementary STEM Studies

STEM studies are one of the most important parts in elementary education. However, for some children, the contents of STEM education seem too difficult to learn. Some teachers also argue that the knowledge seems so abstract, which some students can hardly understand although the concepts have explained comprehensively in lecture. Then, the students usually feel frustrated. They would lose interest, and even have negative emotions towards STEM knowledge. This unpleasant scenario is caused by the gap between teacher's oral expressions and understand to children. To solve the problem, there should be a "bridge" on the gap that can show abstract STEM knowledge in a vivid way, which is understandable by children.

2.4 Various Informal Learning Styles and Transferability

With the development of young-aged education, informal learning styles - "learning while playing" is gradually becoming the core value, which is widely accepted by teachers and parents. The learners, especially children, can acquire knowledge actively, and efficiently by playing in a certain way.

Over the years, the educators are pursuing the ways of various informal learning, which

are more accessible for various social units, more efficient to education, and more acceptable by the learners. One of the main stream is to implement game on learning process.

2.4.1 Informal Learning through Games

Games, specifically video games, are a relatively new medium that revolutionizes people's way of entertaining in the last 50 years. Educational game is also becoming a hot trend recently because video games can provide more visualized and more friendly learning conditions. An article published in Theory into Practice points out, that the environment created by video game, is interactive, that enables players learn things are not as they seem but within the context of a controlled and negotiated action. Therefore, game provides a platform that players can understand the logic behind the rules and can also express themselves as individuals through the roles in the game. Educators and scientists ceaselessly return to the research results that games tend to generate a much higher level of students' positive emotional engagement. Thus, making the learning experience more motivating and appealing, improving participation and achievement. Game can provide passive students to contribute more than they would in traditional learning environment.

2.4.2 Informal Learning through STEM Educations

Specifically, on STEM educations, one article published on Science deeply talks about the idea between video games and STEM education. The author, Merrilea J. Mayo, points out that the video games, in theory, are valid pedagogical delivery vehicles and it can reach many more people than lectures. However, the reason that they have not become the main method of education are lack of quality and sustainability. Most of game developers can hardly obtain

assessment data because of the high cost, and some of them don't have enough fund to commercialize their game products to the market. Also, they need to keep updating to form a sustainable business models. Inherently, educational game development is not sustainable since the games affect players during the learning process only, therefore the old audience will unavoidably be flowing out. In both scenarios, the game is unsuccessful in propagating STEM education. To get over the difficulty, the educational game should reach a higher quality and promoted more convincingly. From the article, it claims that educational game is the better way to implement education than traditional education methods, but it needs more entertainment, more information of SETM knowledge that can provide to the players.

2.4.3 Informal Learning through Music

Everyone enjoys music, whether by listening to it, singing, or playing an instrument. But despite this almost universal interest, many schools are having to do away with their music education programs. This is a mistake, with schools losing not only an enjoyable subject, but a subject that can enrich students' lives and education. However, some researches show that, as a media of education, music is known for some positive effects through learning process.

A journal published on Journal of Music Therapy gives a discussion about the effect of music on improving sustained attention. The authors, Wolfe, D. E., & Noguchi, L. K, did an experiment among the children. Children were required to test their sustained concentrations in different conditions. Finally, the conclusion they got is that, music as a medium, can improve children's sustained attention. However, they also point out that people's attention to music wanes significantly after the initial stimulus. The periods may last several seconds to minutes,

depends on individuals, and then the music becomes “background” in their consciousness. Also, the authors remind that an unfocused music listening experience may have minimal educational effect. Bearing that in mind, we believe that it will be a pretty good idea to import the short-lasting musical elements in our game.

Another study on Ohio State University points do the research on children’s recognitions on chord changes. The author, Costa-Giomi, E. concluded that even young children can discriminate harmony and melody, but they cannot disassociate melody from harmony. This gives us more detailed directions on music selections: short, simple and harmonic melody.

2.4.4 Music Games on Education

Interactive music games form a bridge between music and computer science to further the potentials of a musician and educator. Interactive music games can utilize innovative hardware and software to educate and enhance the capabilities of a user in respect to music. Music games are used to improve the musical society. This can range from creating new ways for music to be taught or learned, as well as connecting musician with fans.

Chapter 3: Methodology

The methodology part is shown mainly in two parts about the project: 1) based on our review in the background, we developed a music game prototype that embodied specific aspects of informal STEM games, and 2) tested that prototype with a group of undergraduate students to assess its viability as an informal learning tool.

3.1 Introduction

There are many approaches on developing both STEM educational games and music games for education. However, their combination -- music game in STEM education is a field that does not have many results. Formal research found out, music is able to assist schooled children to learn knowledge in a more active way. Game is also a medium that can appeal them to concentrate on it, and can teach knowledge in an informal way more efficiently than traditional lecturing methods. Therefore, the music game in STEM education, is a new way for schooled children to learn more actively and more efficiently.

In order to design and implement music game in STEM education, one of the main objectives of this project is to show STEM knowledge in an accessible way. This objective was fulfilled by setting up visual and sound elements of the game, and provides a very user-friendly interaction between the game and users. Another main objective of the project was to show STEM knowledge in an interesting way by balancing the reward and challenge in game design. The way this was approached was to set up multiple levels with ramp difficulties. When the users play the game, they can get rewards by passing one level. Meanwhile the next level will become more difficult and more challenging to solve it out.

The STEM topics it covers are sound waves and steady state. Sound wave is an abstract conception. However, lots of studies have made various approaches. They use everyday life objects to show it in more understandable way for education: like to use soap film and candle flame to visualize sound wave. The conception of steady state is quite complex as well: It represents a certain situation in which all state variables are constant in spite of ongoing processes that strive to change them. Despite that, steady state can also be shown in a very simple way: the water flows in and out at the same rate, so the water level (the state variable Volume) stabilizes and the system is in a steady state. In general, these approaches prove that both sound wave and steady state can be shown in a good way, which is very easy to be understood.

In the gameplay, several bottles are placed in orders. In each bottle, there are two valves controlling water flowing in and flowing out. Players are told to control the speed of water flowing in and out, thus creating a steady state phenomenon - a balanced water level in each bottle. Players are also allowed to "knock" the bottle, producing different pitches on different water level. Generally, the game will convey fundamental conceptions of steady state and sound wave to players after playing the game.

To analyze the game's knowledge accessibility and degree of entertainment, users were facilitated to test our game and subsequently take a feedback survey. As shown previously, the design of the project faces to the needs of young-ages students from 8 to 12 years old. That is being said, the users can judge whether STEM can be shown in a very easy-understanding if they are able to stand on children's views. Moreover, in order to get some logical and reasonable feedback, users must have elder age, which enables them to have relative strong reasoning and verbal ability. Finally, the user group is easy to be accessed by research team. Due to these facts,

the study was designed to include and test exclusively users who were undergraduate college students in various majors. The number of group people is 16, which are typical size of two focus groups. The amount of feedback is enough for the purpose of this study. For future studies, however, we should include more user groups in various age to normalize feedback and reveal more drawbacks.

3.2 Hypothesis

Upon completing their research, the group came to the conclusion that users learning basic conceptions about sound wave and steady state in the music game would be more interactive. The learning results will also be more effective and more fun than traditional elementary science lectures about those topics. The purpose of implementing this new way of learning those STEM topics is to discover that music games is an easier and more accessible way to implement young-aged STEM teaching. This study was designed to assist the future implications of developing more comprehensive and various STEM music game prototype upon the feedback collected in the survey. This feedback enable the group to evaluate if the purpose of the game is properly achieved and what are the merits and flaws. Further studies should be considered the ways of improvement based on the feedback data.

3.3 Game Design

3.3.1 Overview

This game is to guide users to control water flowing in and out inside of cylinders in a certain way. Each cylinder will be made of glass, and they will be knocked automatically in some certain beats. By adjusting the water level, the users will get different pitches on each cylinder when it's knocked. The objective of the game is to adjust the knocking pitches until users create a continuous harmonic rhythm when the cylinders are knocked by certain beats.

3.3.2 Development Environment

The first consideration that was addressed during the preliminary research was the choice of development environment used for software design. Finally, the first choice of development environment was Unity 3D. Comparing to other development environment (Android SDK, X Code and Visual Studio etc.), Unity 3D has the following advantages: (1) Good Compatibility: Unity 3D has runtime environment for multiple majority platforms, including mainstream iOS, Android, and VR platforms. (2) User-friendly development environment: The UI is easy to be manipulated, and it allows beginning programmers to create games effectively. (3) Abundant online resources: Unity 3D has an asset store, which have enormous assets that can be accessed. Based on the merits of that, Unity 3D was evaluated as the most effective development environment for this project.

3.3.3 Main Structure of Prototype

There are four phases in the game: Phase 1. Music Preview, 2. Game Interface and 3. Rhythm Testing. The flowchart of the game is shown in Figure 5.

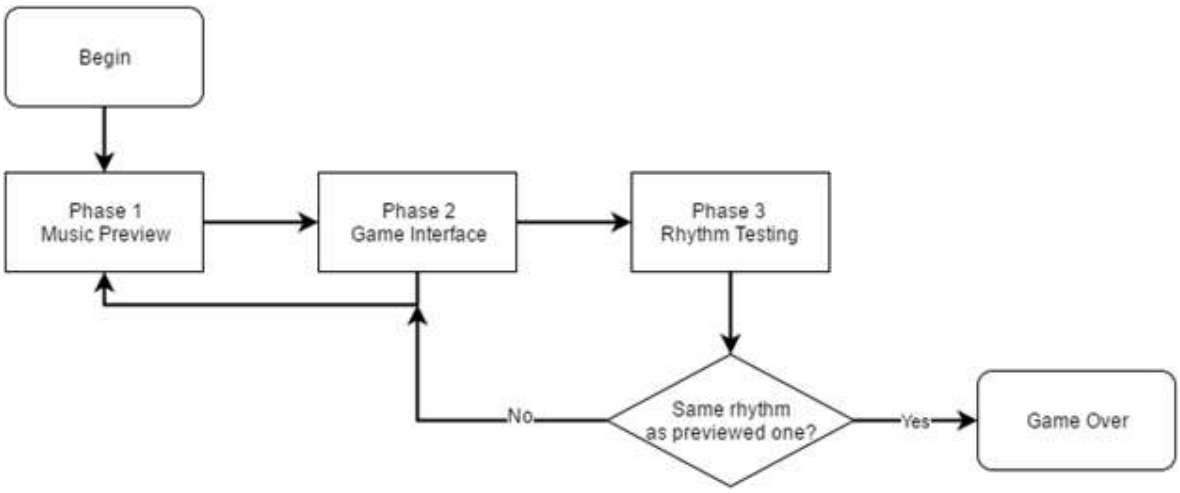

Figure 5. Flowchart of game procedure

3.3.4 Procedure Description

When game starts, the player goes into Phase 1: Music Preview. At the beginning of phase 1, the game will play a short rhythm for the player. Then the player will jump to phase 2.

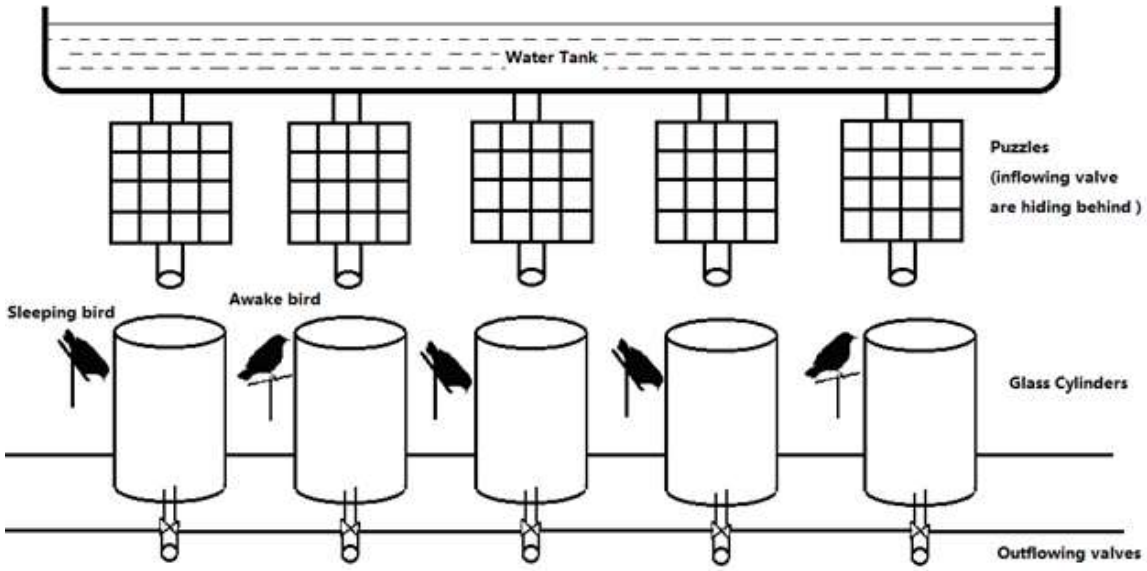

Figure 6. Brief structure of Phase 2

In phase 2, game interface, the player can play the game. The structure of phase 2 is shown in Figure 66. Top structure is a large water tank, which provides the water flowing in. There are certain numbers of pipes and puzzles under the water tank. In the beginning, valves are hidden by puzzles, so the player must solve the puzzles first. If one puzzle was solved out, the brick would disappear and pipe valve is accessible. Then the player could operate pipe valves, which control water's flowing in. Under the pipes and puzzles are five glass cylinders. Each cylinder can be added waters by flowing water in, and can outflow waters by controlling another water valves at the bottom of cylinders. After solving the puzzles, the players can control water flowing in and flowing out, therefore change the amount of waters in each cylinder. In the meantime, the player can knock on certain glass to listen the certain pitch it creates. Besides each cylinder there is one bird standing there. The player can "wake" the bird. If the bird is awake, it will knock on the cylinder in certain beats. If all the birds are awake, they will knock on each cylinder. The integrated beats will form the beats of the short rhythm in preview phase. The player can listen to the beats first, then change the corresponding pitches on each cylinder by inflowing and outflowing water. Usually the player can't remember the whole rhythm, therefore they can jump from phase 2 to phase 1 to listen the rhythm again, then jump back to phase 2 and continue playing the game. If the player think the rhythm created can reappear preview music, they can choose to jump the Phase 3, which is Rhythm Testing.

In phase 3, rhythm testing. There is a program checking if the rhythm is the same as previewed rhythm. If it is, the player wins the game, and game is over. Otherwise they will go back to phase 2 to continue make it right.

3.4 Development

3.4.1 Audio Design

The game audio elements are certain pitches of glass knocking sound. The pitch audios were processed by software, which sound bright and were similar with effects of knocking glass. In the prototype, there are three preview rhythms. Each of them was composed and compiled with Adobe Premiere, an Audio-video after effect software. The complexity of rhythm was ramped up, and were used from level one to level three.

3.4.2 Art Design

For the art design, we got several assets from the Unity 3D assets store, and we designed the user interface by ourselves. Firstly, we chose Unity 3D to give players a better game experience. Basically, 3D background and assets can help players imagine that they are playing game in the reality. The theme we finally decided is Steampunk, shown in Figure 7 and 8.

Figure 7. Steampunk Assets

Figure 8. Steampunk Assets

In the further development of this game, we will consider building this game by using 3D assets, and players may be able to play this game on virtual reality devices. By accessing the Unity 3D assets store, we got the basic features of our game, such as 3D birds, background town and the glasses.

The next thing we need to design is the user interfaces, which include a start scene (Figure 9), a level-selection scene (Figure 10) a music scene (Figure 11) and a main game interface (Figure 12). For user interfaces, we use the same 3D background as it is while playing the game.

Figure 9. Start Scene

Figure 10. Level-selection Scene

Figure 11. Test Scene

Figure 12. Game Interface

In the start menu, we have a start button and a quit button. If players hit start button, the level-selection menu will show up. After selecting a certain level, the music menu will show up with a piece of music. A continue button is needed for the music menu. The most important interface is the main game menu, which contains a test button, a listen button and a quit button. In order to make the button distinct from the dark background, we used bright red square images for level buttons and bright blue square images for other buttons.

3.4.3 Animation Design

Our game had to feature animations to implement basic functionalities of main objects. The most fundamental objects were dynamic water effects. The water could not only splash in the glass cylinders, but also flowing in and out through the pipe. Another animation is the spinning valves. Acting as a response for players, each pipe could spin in both directions if it was manipulated by players. The third animation from main object is bird motion. When the birds are not “wakened” (shown in Figure 13), they could keep stable; but when they are “wakened” (shown in Figure 14), they have effects of “knocking” the glass with their beaks.

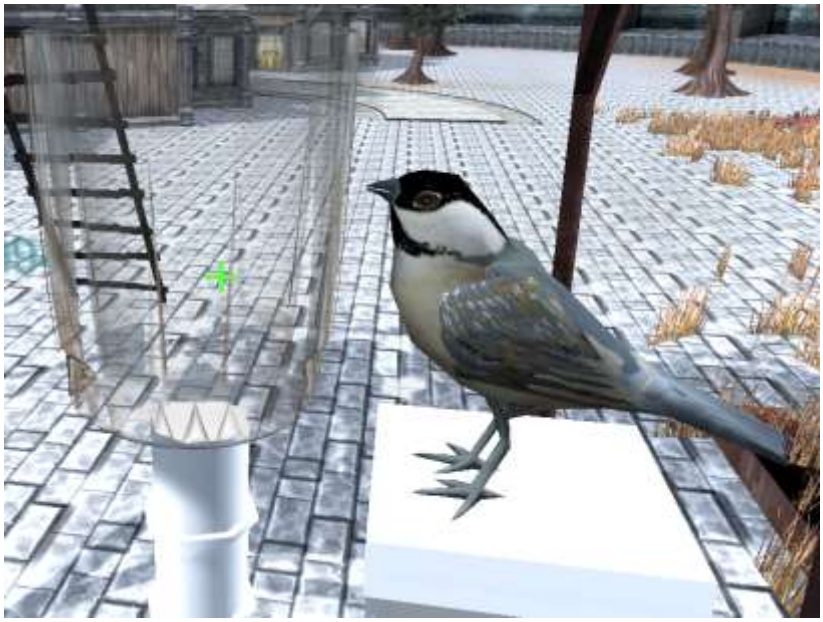

Figure 13. When the bird is not "wakened"

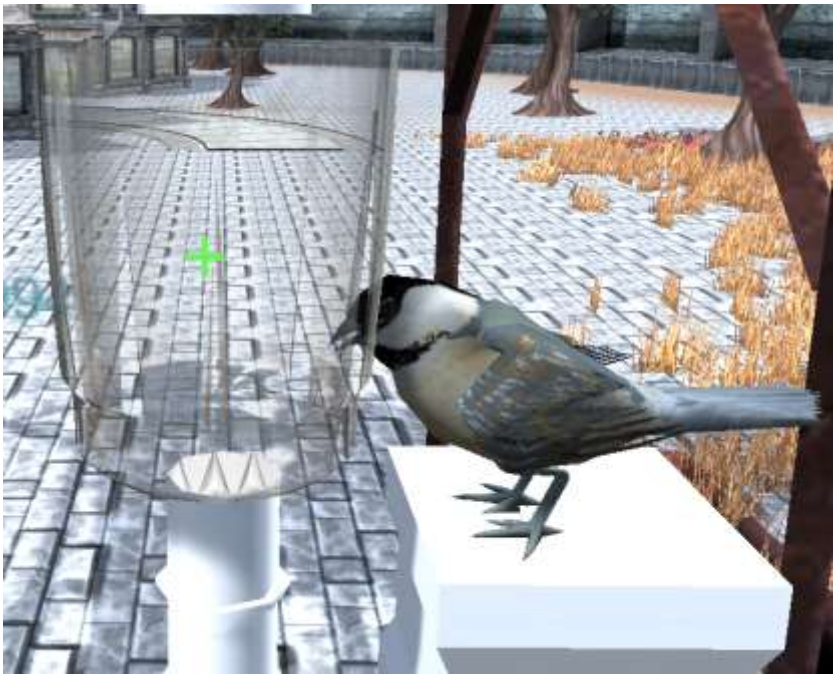

Figure 14. When the bird is "wakened"

Besides main objects, there are also some animations in the scene. In order to create a dynamic atmosphere, we added some animations on the sandbox environment: The black smoke (shown in Figure 15) will randomly appear from chimneys. In order to make the whole scene more vivid, we also set up some wind effects, which trees and grasses can move along the random wind (shown in Figure 16).

Figure 15. Smoke Effect

Figure 16. Wind Effects

3.4.4 Programming Design

The game was developed in Unity 3D, which is a highly-integrated SDK. So, it would be easy to use and required only minor programming experience.

One main feature we implemented in program is to link different scenes (states). Using effects of button, we enabled different states, which are start state, level selection state, main game interface and game over states, to jump from one to another logically.

Another main feature is to determine the relationship between water level and velocities of flowing in water and flowing out water. We defined three variables: water level y, velocities of flowing-in water V_{in}, and velocities of flowing-out water V_{out}. And their relationship is shown in Equations 1.

$$y = \begin{cases} 0, & when\ \ y\ attemps\ to\ lower\ than\ 0 \\ y_o + \int V_{in}(t) - V_{out}(t)\,dt, & when\ y\ is\ in\ the\ range\ of\ 0\ to\ 7.5 \\ 7.5, & when\ y\ attempts\ to\ higher\ than\ 7.5 \end{cases}$$

Equation 1. Dynamic Water Level Characteristics

Note that y_o represents the water level at the beginning, and in our game design we defined $y_o=0$, as there is no water in the cylinder when game started. The water level, y is constrained in the range of 0 to 7.5. In our program design, this range represents from lowest water level and highest water level of cylinder.

For the function of water velocities, we defined both V_{in} and V_{out} as two independent integers. Their range are both from 0 to 5, and they can be adjusted by water valve objects. Players can adjust the water flowing in and flowing out velocity on the valves, which are mapped from 0 to 5. Taken the numbers to equation 1, we can see that the water level y won't change if

V_{in} (t) and V_{out} (t) are the same values. This case represents “steady state” because the water level is dynamically balanced in certain period.

The last main feature we implement is to map sound and animation effects to water level variable consistently. The knocking sound is the pitch from C0 to C1. Then we evenly mapped the corresponding frequency ranges from 0 to 7.5. We also implemented the water effect animation in similar way: Adjusting the height of water level animations in certain range, and then we mapped the data from 0 to 7.5 as well. After those jobs done, the water animation and knocking sound effects will follow the variable to change as it changes.

3.4.5. Program Debug and Maintenance

After the whole design is done, we tested the game out by playing the game ourselves. We fully tested all the functionalities and passed all the levels. We were satisfied for most parts, but there are some minor bugs needed to be fixed: For example, the background scene cannot be loaded sometimes or and the pitch won’t follow the change of water level. We did some fixings by optimizing code and update Unity Runtime Environment. Finally, we fixed almost all of them and the game can be played normally.

3.5 Prototype Testing

3.5.1 Objectives

The objective of inviting players to test out our game was to get more feedback about user experience. So, we designed a survey for target groups to get following information in details:

1) Highlights of the game.
2) Satisfaction about interaction, art design and sound effects.
3) If the idea is suitable to teach conception of wave and steady state in this informal way.

3.5.2 Survey Design

After The game design and implementations, the final part of the methodology was to test the prototype among a group of selected test users and get the feedback for future improvements. This was accomplished by two 8-person focus groups, which was totally 16 college students in various grades and degrees, completing a conversational survey after completion of the music game prototype. An email was sent to the WPI mailing list with the brief instructions of the game and an appointment form. Shown in Appendix B. To appeal more volunteer users, a raffle was also prepared for all participants and one of them can win the reward, which is the 25$ Amazon gift card for each focus group. Each user's conversation was recorded during the survey for keeping the completed raw data. To protect user's privacy and follow the idea of anonymous survey, volunteers were guaranteed that their audio recording would be deleted after the conversations were transcribed. The focus group starting questions, shown in Appendix C, has 7 open-topic questions. This survey served to provide a general and more qualitative idea of evaluation, which, in specific, are six aspects on the game design: visual,

sound, control, Target group, STEM concepts, and entertainment. Moreover, the survey could get feedback of additional trivial feelings, which was another source needed to analyze exclusively for future use. Further studies could include test users with a wider varieties of age range. It could also include comparative studies, which was to test and analyze the differences between learning STEM with the music game and with traditional learning methods.

Chapter 4: Data Analysis

From the survey from 2 focus groups, we received feedbacks from 16 test users. After arranging those feedbacks, we got the following evaluations mainly from game design, control performance, UI design, sound effects, target users and STEM concepts.

4.1 Game Design

For game design, they have mentioned following ideas. First, one player said “you can fly and walk around. It is amazing that you can get underground”. The game environment we set up is allowing the player to move around freely. The player could move around the town and exploring the world. This idea made the game interesting to them, since they are able to explore the game.

The second point they have mentioned about is the houses and the view were beautiful. The model we chose and the world we set up was nicely modeled. Beautiful UI and game environment would make the player being more enjoyable to play the game. With beautiful models, the game becomes more interesting.

Third, the music itself was beautiful. Although we only set up three stages for the testers to play around, the rhythms we have chosen were varied from one to another. The complexity of each rhythm is increasing. Therefore, it is important to have a beautiful music piece for the player listen to and play with. The tester said, it was going to be boring if we do not have a beautiful music because they should listen to it in multiple times.

At last, one of the players mentioned that it was going to help music students to study the nodes. Instead of using instrument to learn, the water is going to help them to have a better

understanding. Most of the tester really liked our idea that using the water and glass to teach students how to make music with those items. The way of tester seeing it was that our game was using some brand-new concepts to lead the players studying STEM concepts, which was entertaining and unique. This idea could benefit our game well.

4.2 Control Performance

First, some testers mentioned that the control did not make sense at first place, and the input and output of the water were hard to understand. When the first time the testers were playing the game, they were confused because they didn't know what they should do as well as they have no idea what is going to happened in this game. Therefore, one of the tester suggested us that the game could have more detailed tutorial and guide the player to went through the first level, so the player could avoid making mistake. In our perspective, we are going to have a tutorial stage to teach the player what to do. This is going to help to increase the gaming experience.

Second, the transparency of the cup was too clear to be shown obviously. The glass model we chose was too transparent. We are going to do the improvements by changing the transparency of glass model.

At last, they mentioned that it was hard to control the water in a steady state. We are planning to improve the way of control the valves. Instead of only showing players percentage of valve is opening, we are going to show the amount of water coming in and going out to help the player control the water in a steady state.

4.3 UI Design

For UI design, there is one main contribution and three defects in the game. The contribution is the user interface is beautiful in general. The color and style of the UI suits the game style and world created. The UI we created is helping the player to have a better playing experience, which emphasizes the user action and the processes of the game play. However, the drawbacks of our UI are obvious as well. First, there were not welly integrated between the music theme and the background UI. The style of music we have was different from the style of UI and the world. The music was with a peaceful rhythm, but the background UI was in Industrial punk style. We plan to change the background UI be more peaceful rather than the metal like. Second, the color of the water-level indicators was too dark to see. The display of the water level is not clear enough, because the words are dark and the background is distracting people. Third, It was hard to figure out which bird should peck the glass first. It would be better if we could assign a number next to each bird to indicate the order of birds. And the birds were distracting people from focusing on the music as well.

4.4 Sound Effects

The overall sound effects are decent, but there still have space to improve. The testers gave us three suggestions to improve the sound effects. First, we can add low volume background music into the game. The game was getting a little bit boring without a background music. The background music should in a low volume, that it wouldn’t disrupt the main rhythm. The diversity and the Layering of the sound is a good way to improve the playing experience. Also, background music would make the player feel less boring when they enter the menu or the setting menu. Second suggestion was that we could separate each node, so that players can

choose to listen a particular one. In this way, the game is going to be easier and the player could concentrate on the single node instead of the entire rhythm. When the difficulty increases in higher levels, the player could have a much better performance and experience. The last one is the example melody should keep the same all the time. The example melody would change sometimes, when the player tests the water glasses. We have fixed this bug from every level of the game.

4.5 Target Users

For target users, we didn't give hints for the players. Mainly their feedbacks are based on two aspects.

For some people, they thought it was more suitable and more enjoyable for young-aged school children, who were similar with the target user we originally design in our goal -- pre-teen.

Also, few audiences also thought the music game may be also enjoyable for music learners: the easy stages are suitable for beginning music learners. If later levels have ramp difficulties, the game can also be designed for people with music background, or be designed as a tool for musician training. Those suggestions could be considered in the software's further development.

4.6 STEM Concepts

This survey question concerned about which STEM concepts were learned by users and how much they learned from the game. During the survey, some audiences found that, the more water was in the container, the lower pitches of the sound were made when the contained was

hit. This finding showed that users can learn the conception of sound wave while playing the game.

Conversely, no one found that he or she learned the concept of steady state in the game. But we didn’t regard the result as a drawback because the idea of steady state is less conspicuous than that of sound wave in the gameplay.

There were also some extra findings that beyond our expectation. For example, one audiences said the game gave her idea of ideal gas law, which is pv = nrt. Another student founded the deflection effect of the light: the light deflection on the cylinders changed as the water level went up.

4.7 Other Comments

For the last open-ended question, we didn’t collect some constructive ideas because the previous survey questions were already covered almost every aspect of the information we wanted to know.

Chapter 5. Conclusion

The music game prototype that we implemented is a good try to explore the informal ways of learning. This game successfully integrated the merit of the music elements into educational game. When the pre-teens, enjoy playing it, they get to understand some conceptions of STEM, precisely sound wave and steady states. In this method, the STEM concepts will become more vivid, easier to be understood, and more interesting rather than what they learned in traditional lectures.

After implementation and the survey, we got some feedback that properly evaluated our prototype. However, the feedback is less ideal than we planned, and the errors are shown below.

For the STEM concept, 1) the concept of "steady state" is less obvious than that of "sound wave". And for the gameplay, 2) there are some minor bugs coming out during the gameplay. For UI design, 3) the whole map in the sandbox is so big that players sometimes miss he game objects and had to find it again. For the runtime environment, 4) Unity 3D supports multiple platforms but not very stable on Mac.

Due to the limitation of time and capability, we will no longer work on the project, but the future work that can do, we will suggest that 1) the game can provide simple tutorials at the start of gameplay. 2) After passing each level, the small window will pop out and show the small tips about the STEM concept. 3) Also, the upcoming teams should continue testing the game and debugging. 4) Moreover, The UI design can be smoothed more beautiful. 5) If the Unity 3D doesn't provide stable runtime environment in the future, the upcoming teams can recompile the program on another stable development platform. 6) For the survey, future teams can take more

samples and thus getting more comprehensive feedbacks by doing the surveys for more focus group in various ages.

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Appendix A: Design Document

A1: Sketches of Layout Design:

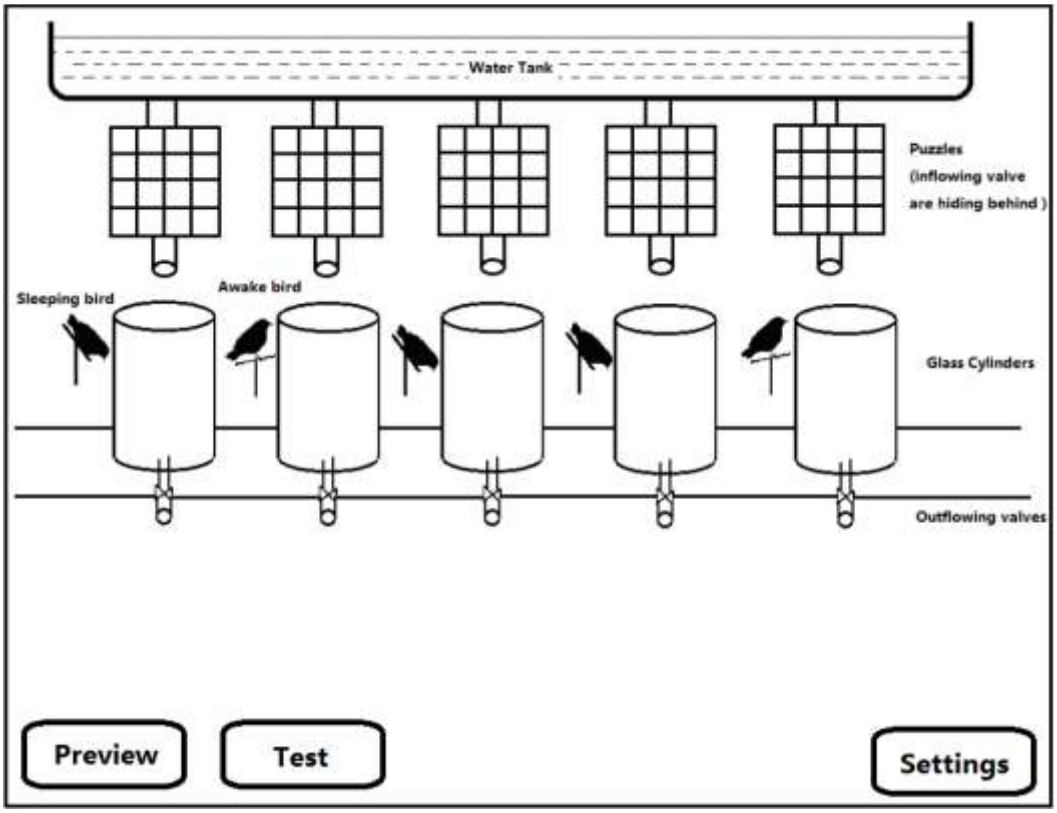

Figure 17. Sketch of Main Interface

Figure 18. Sketch of Music Preview Scene

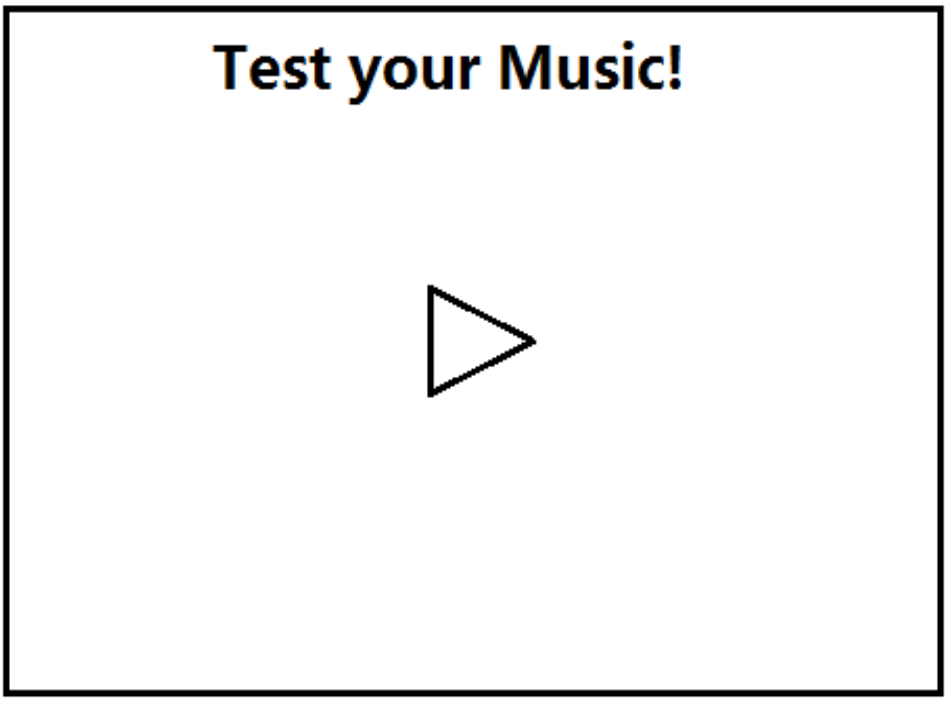

Figure 19. Sketch of Music Test Scene

A2: Game Preview

Figure 20. Game Interface in Level 1

Figure 21. Game Interface in Level 2

Figure 22. Game Interface in Level 3.

Appendix B: Invitation Email Template

Subject: IQP Volunteers Needed – Chance to win a $25 Amazon gift card

Email Body:

Hello everyone,

Our IQP team is currently looking for undergrad students to participate in a 25 to 40-minute gameplay session of a music game we've developed.

This is a music game related to STEM, which is designed for primary school students, which are from 8 to 12 years old. The objective of the game is to convey STEM concepts to learners through a musical activity during the game play. As players complete the levels, they should informally learn and reinforce fundamental concepts about pitch and frequency in the physical field, and steady state in chemical fields.

If you are interested in participating, feel free to fill in the appointment form: **[Link of Appointment Form]** and we will email you back as soon as possible confirming your participation. The study will be taking place in the **[Room Number]**.

Every participant will be entered for a chance to win a $25 Amazon gift card. Thank you very much.

Best Regards,

IQP Team of Music Game for STEM Teaching

Appendix C: Focus Group Survey Questions

1. What are the most interesting aspects of this game?
2. How do you feel about the ways that the controls contribute to the engagement of the gameplay?
3. In what ways to did the user interface contribute to or detract from the enjoyment of the experience.
4. How did the music and sound effects contribute to or detract from the overall game experience?
5. What age groups or demographics, if any, do you feel would enjoy a further developed version of this game?
6. Which, if any, STEM concepts do you feel were referenced while playing this game?
7. Do you have any other comments or suggestions about this game that can help us improve it in future versions?

Appendix D: Download Link of Prototype

Link: https://drive.google.com/file/d/0B49jk_zudCRbdkJYUXVjbk9zX3M/view?usp=sharing