Learning Music Theory through Play

Dun Laoghaire Institute of Art, Design, and Technology

DL838 Creative Music Production, BA (Hons)

Professional Project

Ryan Jeffares

How Can Gamification be Used to Enhance Beginner Music Theory Education?

17/05/2021

Dr. Brian Carty

Abstract

The aim of this project is to investigate if gamification - the application of elements from games in other areas - is an appropriate method to enhance music theory education, in particular at a beginner level for children. This is considered valuable research due to the ever increasing consumption of video games and use of gamification, coupled with the importance of online and distance learning since the advent of the Covid-19 pandemic. To investigate the hypothesis, a framework for designing an app that would teach music theory concepts through gamification is derived from research, and an app is designed, developed, and published to the Google Play Store. Players are asked to take a survey examining the effect of the app's gamification on their experience, and the Technology Acceptance Model in combination with a Likert scale is used to quantify the game's perceived usefulness. While the project fails in examining the app's effect with children specifically due to certain constraints, the results from players are overwhelmingly positive, proving the efficacy of the gamification present in it. Further refinement is needed to make the app suitable for younger children, however the power of gamification in musical context and the importance of this kind of accessibility to musical education is verified.

Introduction

Two phenomena that are seen in the world is the increasing importance of online learning[1], and an exponential popularity of video games with increasing acceptance given to the application of games in educational contexts[2]. During the Covid-19 pandemic, the importance of accessible distance learning has been highlighted. It is clear that research and advancements in teaching under these circumstances are invaluable. Considering that the video game industry has overtaken the film and music industries, generating $152.1 billion in 2019[3], and gaming is such a popular hobby for people and children even as young as toddlers, it is likely that combining education and gaming has great potential.

This is not a new concept - the term 'gamification' first appeared in 2008 to describe "the application of game design elements in non-game contexts"[4]. Gamification is used for teaching, training, and marketing at an ever increasing scale. Game design elements such as avatars, badges, leaderboards, and rewards are techniques used to try and engage people in the above contexts and more. Most studies conclude that gamification has positive effects on individuals. In a world that relies on online learning more by the day, this thesis aims to examine how gamification can be applied to music theory at a beginner level with a focus on children.

To investigate this question, a framework on how to design a game with the intention of teaching music theory through gamification will be derived, and a game will be designed and developed using the framework, and ultimately published. Players will be asked to take a survey designed to examine the effectiveness of the game's gamification and usefulness as a teaching tool. Music theory can be a challenging and intimidating subject to a lot of people when it is presented as pure music theory. This game will aim to make it more accessible to anyone interested in learning music with little or no prior knowledge, especially children. Music is a fun and

---

[1] Dhawan, Shivangi. "Online Learning: A Panacea in the Time of COVID-19 Crisis." *Journal of Educational Technology Systems*, vol. 49, no. 1, Sept. 2020, pp. 5, doi:10.1177/0047239520934018.
[2] De Aguilera, Miguel and Alfonso Mendiz Noguero. "Video games and education: (Education in the face of a "parallel school")." *Computers in Entertainment,* vol. 1, no. 1, 2003, pp. 1 - 5.
[3] Stewart, Samuel. "Video Game Industry Silently Taking over Entertainment World EJINSIGHT." *EJINSIGHT*, 2019, www.ejinsight.com/eji/article/id/2280405/20191022-video-game-industry-silently-taking-over-entertainment-world.
[4] Deterding, Sebastian, and Steffen P. Walz. *The Gameful World: Approaches, Issues, Applications*. MIT Press, 2014.

rewarding hobby, with a wide variety of positive mental effects on the participant[5], so an accessible and gamified introduction to it is valuable.

This thesis aims to detail the derivation of said framework, the development and publishing of the game, and ultimately the survey results gathered from the game's players. The results will be used to verify the quality of the framework, and conclude if gamification can enhance beginner music theory education. The survey and research did not raise any ethical concerns - survey participants were given the standard information sheet and debrief document as per IADT ethics guidelines, and were required to give their consent: passive consent for participants under 18 years of age, or active consent for those under 16.

[5] "Music and Health." *Harvard Health*, Harvard Medical School, 2011, https://www.health.harvard.edu/staying-healthy/music-and-health.

Literature Review

To design an effective and gamified app to answer the question of how gamification can aid music theory education, several concepts must be thoroughly understood. A refined definition for gamification must be found and effective means of implementing it should be researched and practiced. Furthermore, an understanding of game design and user experience design must also be achieved. This literature review aims to draw understanding of these aspects of the project from varying disciplines from relevant resources.

A syllabus must also be decided upon, and from this, a target age group can be inferred. A resource used to do this is Trinity College London's "Theory of Music Syllabus" from August, 2017. This institution is an educational charity active since 1877 and is recognised as a leading international exam board. Their Theory of Music Syllabus is used worldwide to design grade based music theory curricula, where a student with no prior music theory knowledge may successfully begin studying at grade one.

This resource can be used as a helpful guide in the current project to decide on what content should be taught in the game, given a student with no prior experience, as this is an internationally recognised syllabus. This resource will not help with game design, but can be used in conjunction with other resources focused on game and level design to create effective levels.

Rovithis et al, in their paper "Educational Audio Gamification: Theory and Practice" (2018) aim to formulate a theoretical framework for the design of audio gamification (AG). Their framework is to be utilised by designers of games using educational AG, so the designer can understand what exactly gamification should achieve. This was done by using the official Program of Music Studies by the Greek Ministry of Education, and the Primary Years Program on learning Arts by the International Baccalaureate Institution to formulate the framework, and then examining three real-world uses of education AG to suggest how it may be incorporated[6].

[6] The list of features devised in the study can be found in Appendix A.

This is useful to the current project as it gives a formulated list of goals that the gamification implemented should achieve, and examples of how this has already been done to inspire level design. While the game examples are only prototypes, the authors state that AG is clearly a valid way to deliver education content, as its inherent features coincide with the globally documented official learning outcomes of musical education. These implementations can therefore influence the current project's use of AG, along with the derivation of a framework

While the previously discussed resource examines how AG can be implemented in an educationally efficient way, Michael Sailer et al aim to validate gamification's goal of fostering human emotion and performance in "How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction" (2017). This is done by investigating the self-motivating power of game design elements, by using a controlled study in an online simulation environment to examine the effects of certain elements of game design on peoples' psychological need for satisfaction[7].

The authors start by giving a more rigorous definition to gamification. They define gamification as "the process of making activities in non-game contexts more game-like by using game design elements."[8] Through their online simulation, they found that badges, leaderboards, and performance graphs all positively increased satisfaction, perceived competence, and perceived task meaningfulness. The use of avatars, meaningful stories, and teammates led to increased experience of social relatedness. These features are therefore important to the current project, along with the authors' finding that it is crucial that the player is aware of the game design elements for the effects of gamification to be felt.

In Maria Roussou's article, "Learning by doing and learning through play: an exploration of interactivity in virtual environments for children" (2004), the author examines how interaction plays an important role in education and engagement with educational experiences, in particular in virtual reality (VR) experiences. Published by University College London, the article begins

[7] Richard M. Ryan & Edward L. Deci. "The Darker and Brighter Sides of Human Existence: Basic Psychological Needs as a Unifying Concept." *Psychological Inquiry*, Vol. 11, No. 4, 2000, pp 319-338, doi: 10.1207/S15327965PLI1104_03

[8] Sailer, Michael, et al. "How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction." *Computers in Human Behaviour*, vol. 69, 2017, pp. 371 - 380.

by giving a helpful definition to human-computer interaction as "the function of input required by the user while responding to the computer and the nature of the system's response to the input action"[9]. It is pointed out that the system should adapt to the user's behaviour; this pertains to Rovithis et al's point that the student's special needs should be adapted to in real time.

The concept of constructivism is outlined, where learners should construct their own knowledge of a topic through experience. The role of a guide is said to be important, and it is noted that successful projects made children feel like they were participating in a group effort. While the article's focus on VR is not relevant to the current project, the article's insights on interaction and how children learn reinforces the goals of the project and gives important points to consider.

A work that can aid in the analysis of the results of the current project is "A novel approach to learning music and piano based on mixed reality and gamification", by Molero et al (2020). The authors conduct a study similar to the current project, wherein they develop an app in an effort to enhance musical education through gamification. Their app gives visualisations layered on top of a piano in augmented reality to instruct the user how to play piano and give feedback on their actions.

Molero et al conducted a survey to quantify their results, involving 18 participants who had used their app. The authors used the Technology Acceptance Model (TAM)[10] and Likert scale[11] to design a survey that would allow them to score the app's perceived ease of use and perceived usefulness. These methods can be used in the current project to gather results, and the authors' interpretations can serve as a guide for the current project.

[9] Roussou, Maria. "Learning by doing and learning through play: an exploration of interactivity in virtual environments for children." *Computers in Entertainment*, vol. 2, no. 1, January 2004, article 1. doi:10.1145/973801.973818

[10] Davis, Fred D. "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology." *MIS Quarterly*, vol. 13, no. 3, 1989, pp. 319–340. *JSTOR*, http://www.jstor.org/stable/249008. Accessed 30 Nov. 2020.

[11] Likert, Rensis. "A Technique for the Measurement of Attitudes." *Archives of Psychology*, vol. 22, no. 140, 1932, pp. 1–55.

Another element of Molero et al's study worth mentioning is their technical analysis. The authors use the same game engine, Unity[12], that is used in the current project. They show graphs of the game's performance and memory usage and explain how maintaining a stable framerate of 60 is important to the user's experience with the app. While the app being designed in the current project is unlikely to be too demanding for this to be achievable on any modern device, it is an important consideration.

Chapter two, "Structure of Games", from "Game Design Workshop: A Playcentric Approach to Creating Innovative Games" (2008) written by Tracy Fullerton, an award winning game designer and professor at the USC School of Cinematic Arts, aims to define what a game is by deriving the shared properties of games. This book is a comprehensive guide for game designers to develop an idea into a finished product.

Fullerton claims the common properties of games are the player, objectives, procedures, rules, resources, conflict, boundaries, outcome, and formal elements, all of which are detailed further in the text. It also explains how engaging the player is achieved through challenge, play, premise, character, story, and drama.

Fig. 1 - The four types of play

[12] Unity is a 2D and 3D game engine that can be used to create games for a variety of platforms. Further information can be found at https://unity.com/.

Relevant to the current project, the chapter also examines puzzles. The text explains that, quite simply, “a puzzle is fun, and has a right answer”[13]. Puzzles put a novel twist on something familiar, inviting the player to be playful. Through the discussion on puzzles, the reader is introduced to the four types of play, shown in figure one above.

The authors clarify that in a single player game, challenge can come from the system. This book does not mention gamification at all, only pure game philosophy. It is still valuable to the current project for its definition of a game and a puzzle and guide to the common properties of a game, while other resources’ explanation of gamification can be laid on top of that to achieve the project goals.

Two published examples of audio interaction in games that inspired the current project in the first place, where elements discussed above are seen, are “Two Dots” (2020, figure two) and “Okay?” (2020, figure three). These are both problem solving mobile games, with five and ten million downloads on the Google Play Store, respectively. “Okay?” requires the player to project a ball in the right direction to bounce it between several objects in the scene to hit all of them, each successive hit playing the next note in a major scale. “Two Dots” requires players to connect like-coloured dots in a grid to destroy them, also playing a higher major note for each successive dot connected. Both of these games call on spatial reasoning and logic to move up through the levels.

While these games do not have the goal of teaching music theory, it is their soft aesthetic and large focus on musical feedback that initially inspired the project. “Two Dots” especially sees a huge focus on badges and leaderboards, as already shown to be quintessential. Said game also gives haptic feedback by vibrating the phone on successful moves, contributing to player satisfaction. Many examples of the common properties of games as described by Fullerton et al above can be seen in these games such as conflict against the system and boundaries. The current project can take these games as a primary inspiration for level design and aesthetics, obviously expanding on them to teach further concepts of music theory.

[13] Fullerton, Tracy et al. “Chapter 2: Structure of Games.” *Game Design Workshop: A Playcentric Approach to Creating Innovative Games*, edited by Laura Lewin, Morgan Kaufmann Publishers, 2008, pp. 26 - 48.

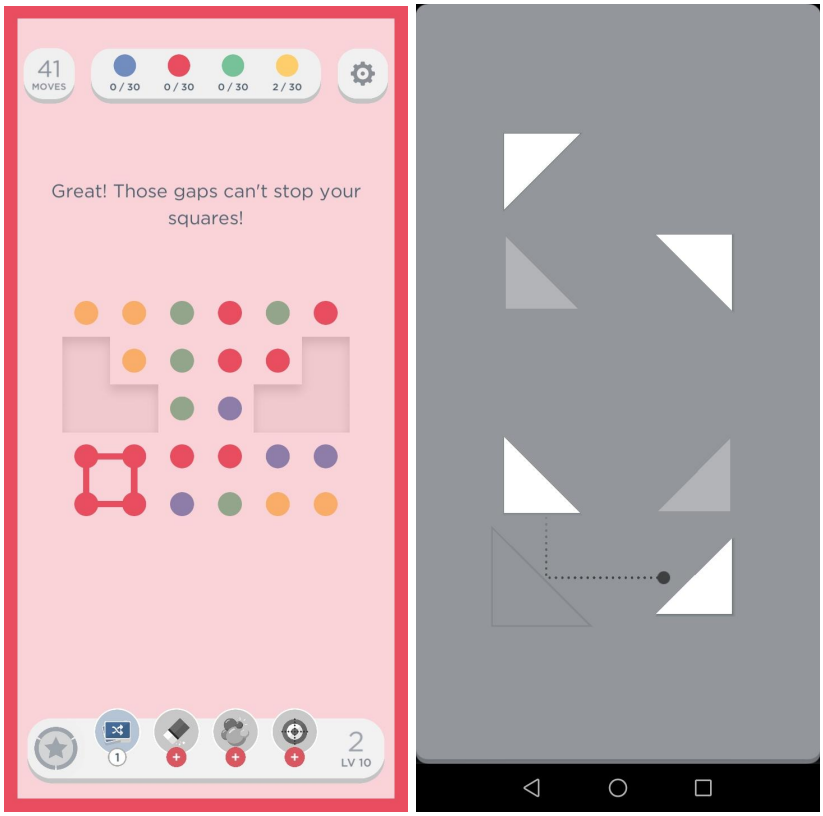

Fig. 2 and Fig. 3 - "Two Dots" and "Okay?"

As well as deciding on the content that should be taught and how the gamification should be implemented, some research is required on how children, the target demographic, actually learn. Stella Vosniadou's booklet "How Children Learn" (2002), published as part of a series on principles of education by the International Academy of Education and the International Bureau of Education, can be used to do this. The twelve principles detailed in this text are based on research that has influenced the design of curricula and techniques employed by teachers worldwide[14].

Some of these principles can be heavily tied to other concepts described in the research here, reinforcing their importance while designing the app. For example adapting to the learner's skill in real time, as mentioned by Rovithis et al, would be an implementation of the author's advice to consider student's individual differences. Likewise, 'meaningful tasks' and 'social participation' have also been emphasised.

[14] These principles, along with Vosniadou's descriptions, can be found in Appendix B.

Some of the principles the author discusses are, however, distinct from the other research undertaken here. Even still, they should be considered while designing the app due to the authority of the author and source. The text explicitly states it does not detail how to incorporate information technology into teaching; however, these principles of education should be universal and enough further research exists in this chapter on how technology can be employed as a learning tool.

To conclude, authoritative resources have been examined in this literature review, each giving insight into some key aspects of the project. Gamification and interaction have been given a more rigorous definition, with some clarification as to how children learn most effectively. Pure game design, with examples, has also been studied. Furthermore, an authoritative syllabus for music theory has been reviewed, giving guidance on the content that the game should aim to teach. It is clear that the project demands consideration from many disciplines including music theory, user experience, programming and game development/design, and education.

Methodology

From the literature studied in the previous chapter, it is clear that gamification and learning through play and meaningful tasks is widely recognised as effective and rewarding for the participants. The methodology chapter of this thesis aims to use this research to derive a framework for designing the puzzles for a game focussed on teaching music theory. The concepts that are to be taught will be derived from the syllabus examined earlier. The development and distribution process of the app will be detailed here too, along with the methods for collecting results.

1. Framework

As mentioned previously, Rovithis et al derived a framework[15] for audio gamification in formal education, which is summarised in Appendix A. Vosniadou's[16] twelve principles of how children learn are listed in Appendix B. Roussou's work[9] is also considered here, particularly her emphasis on constructivism and the use of a "guide" through the learning process. These works were cross referenced to find common points which make up the derived framework.

The derived framework can be found in Appendix C. It abstracts the nine most common talking points from the studied literature into a list, with detail on what these should achieve and how they may be implemented in the context of the app. When designing and developing each puzzle in the app, consideration was given to this framework to ensure none of the points are contradicted. While the framework was extracted from authoritative sources, its effectiveness was unproven without the release of the app, and is up for peer review.

2. Syllabus

The aforementioned syllabus[17] from Trinity College London (2017) was studied in detail to obtain a syllabus for the content taught by the app under development. It quickly became clear

[15] Rovithis, Emmanouel, et al. "Educational Audio Gamification: Theory and Practice." *European Conference on e-Learning (ECEL)*, vol. 17, 2016, pp. 500 - 501.
[16] Vosniadou, Stella. "How Children Learn." *Educational Practice Series 7,* edited by Herbert J. Walberg, International Academy of Education/International Bureau of Education, 2002.
[17] Theory of Music Syllabus. Trinity College London, August 2017

that learning outcomes after grade three were beyond the scope of the project, giving a manageable list of topics to choose from. It was also decided that learning outcomes that directly pertained to the use of a stave and written score would be omitted, as the app should give a more foundational and accessible introduction to music theory, with the written score best left to formal practice.

Each grade's learning outcomes in Trinity's syllabus were divided into pitch and rhythm. It was decided to further divide pitch into melody and harmony, and have these three areas as 'courses', to give more uniqueness to the courses and concision to the lessons. A fourth course, timbre, was also considered, as Trinity's syllabus does also require students (under the pitch section) to identify several different instruments and articulations. This course was ultimately never developed due to time constraints. The syllabus to be used in the current project can be found in Appendix D

Grades one through three are commonly studied by children as young as nine to twelve years old. This was therefore decided to be the target demographic; it was also the intention that while the app would be easily accessible by a child of that age, a user of any age with little to no prior music theory experience could also engage with the app.

3. Development

Development of the app was started early on, as much technical skill with Unity existed previously. Aspects such as the main menu, event systems, navigation through the app, and build properties could be developed without a syllabus decided upon. Once the syllabus and framework were derived, sequential development of the lessons could begin. It was decided that Android would be the target platform, as mobile devices are the more convenient platform for the average user, but iOS would be too costly and time consuming. An Apple Developer's license, costing $99 annually, is required to publish on the App Store, and easy access to an iPhone for testing purposes was not available. Google Play requires only a once-off €25 publishing fee, and easy access to many Android devices was available for testing.

Originally, it was intended to use Rory Walsh's CsoundUnity[18] package for the interactive audio, as much prior experience existed with Csound and it is a powerful tool for sound design and interactive audio. However, after some consultation with Walsh, it became clear that the package was not implemented fully for Android at the time the project commenced development. As Unity's native audio player introduced arbitrary latency, it was decided to use FMOD[19] for playing audio. Some experience using FMOD with Unity existed from the course programme, and it proved to be low latency with high fidelity and required no extra effort to work in an Android build.

Development was generally smooth once navigation and reusable functionality was in place. The project was maintained in a Github[20] repository. The syllabus or goal of the game did not have to be adjusted to accommodate for technical challenges at any point. Emulating rules of music theory in code was challenging at times, as niche algorithms had to be written to understand which note in which octave had to be played, for example, and naming the correct FMOD event to be triggered. Another challenge was writing code that, to the highest level achievable, did not allow for bugs or interruptions in a level's flow. In each level, variables are generally set up to keep track of the user's progress within that level. Interaction with various objects is then only possible if certain conditions are true, removing much ability to break the intended flow of the level.

Consideration was constantly given to the framework previously derived while developing the levels, however not all intended goals were met - detailed analysis of the shortcomings of the game relative to the intentions is found later in this thesis. The player is often encouraged to take as much time as they want to "play" with a new concept - in the form of a playable piano or drum kit, for example - to encourage constructivism in a non-pressured environment.

[18] CsoundUnity is a Unity add-on that allows Unity to use Csound, an audio programming language, to play audio. More information can be found at https://rorywalsh.github.io/CsoundUnity/#/.
[19] FMOD is an adaptive audio engine that can be used in conjunction with a Unity Project to create interactive audio. More information can be found at https://www.fmod.com/.
[20] Github is a version control system that keeps backups of current and previous versions of a coding project. More information can be found at https://github.com/.

Each new concept has a "lesson" section, where the concept is explained, and may have a "puzzle" section, where the player must complete a series of timed challenges on the concept. Upon completing each puzzle, the player is awarded between one and three stars. This is the game's implementation of "badges", a common component of gamification. The stars a player has earned is recorded, and the player may view the earned stars on each completed puzzle at any time. As the player progresses through the levels, new terms are added to a glossary that can be seen at any time, with explanations for the terms - unlocking new terms for the glossary is another form of badge and also helpful educationally. The player is given real-time feedback during the puzzles, and congratulated upon completion, with a message personalised to include the username they set on first opening the game. These are some of the most common talking points of gamification, and have been clearly implemented in the current project.

"Quarty" was decided to be the name of the game, a pun on the quarter note found in music theory's rhythmic study. The animated and personified quarter note that is present throughout the game's main menu and levels serves as a guide through the levels, as recommended by Roussou.

The only non-diegetic music that exists in the game is heard at the main menu. "Music for Walking", by Cathal MacRuairí[21], was chosen with consent from MacRuairí for its soothing and "wholesome" tone. It was decided not to include background music in the levels to avoid potential dissonance with notes played as part of the levels. Sound design for the interactive objects in the game was kept limited in scope to aid the foundational intentions. There are sine wave notes with a definite pitch, familiar piano keys, and standard drum kit samples that were kept dry and distinct.

Molero et al[22] explain how stable performance, such as prioritising a refresh rate of at least 60 FPS, is important for the best possible user experience. 60 FPS was targeted and maintained during development, with any time-based operations designed to be independent of frame-rate so as to not interfere with the performance or flow of the game if the frame-rate were to vary.

---

[21] MacRuairí, Cathal. "Music for Walking." *Spotify.* https://open.spotify.com/track/2xi7ql8EEHdgX8uDAHLeny?si=da4ef024218548a9

[22] D. Molero at al. "A novel approach to learning music and piano based on mixed reality and gamification." *Multimedia Tools and Applications,* Sep 1, 2020. doi:10.1007/s11042-020-09678-9

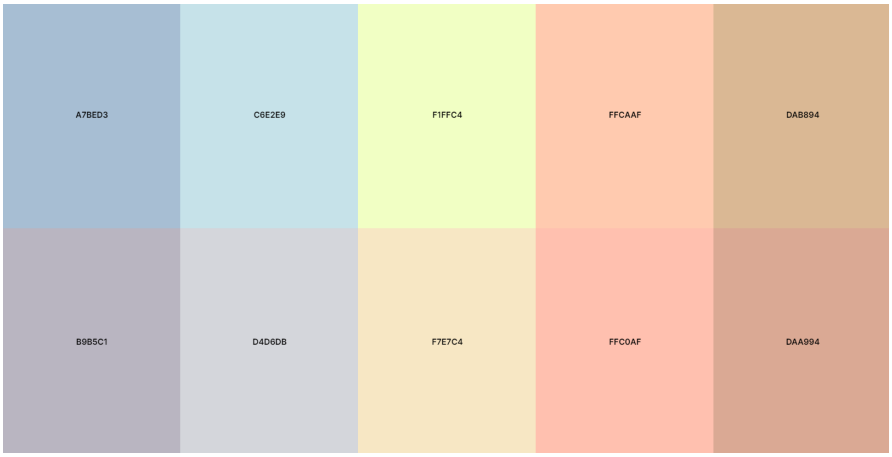

Fig. 4 - Colour Palette used in the game.

User experience and user interface design were extremely important considerations when creating the app, but not an area where much prior expertise existed. A visual communications student was contacted who was willing to pass on some advice and resources that would aid this. Some websites[23, 24, 25] were recommended to help the decision process regarding colour schemes, layouts, and typefaces, and some additional tips were given such as not using more than two fonts in no more than three or four sizes. This advice was employed, giving the levels a consistent look and feel. A colour palette (fig. 4) was made as a loose guide to the colour schemes of the game's levels. Soft, warm, and pastel tones were desired in an attempt to maintain a calm and soothing atmosphere, along with minimal and cartoonish icons.

Most of the icons used in the game, including the quarter note guide, piano keys, buttons, etc., were made using Google Drawings. Icons for parts of the drum kit found in the rhythm section were downloaded from https://flaticon.com[26], and their creators are credited within the game as required. These icons were carefully chosen to match the pastel and cartoon aesthetic found in the rest of the game.

[23] "Adobe Color." *Color.adobe.com*, Adobe, 2020, https://color.adobe.com/create/color-wheel.
[24] Church, Jeremy. "A Visual Type Scale." *Type Scale - A Visual Calculator*, 2013, https://type-scale.com/.
[25] "Figma - the collaborative interface design tool". *Figma,* 2015, https://www.figma.com/.
[26] "Flaticon, the Largest Database of Free Vector Icons." *Flaticon*, Freepik, https://www.flaticon.com/.

4. Publishing

It was decided that to collect the most results and user feedback, the game should be published on the Google Play Store. It is possible to install an app to any Android phone from a third party source, however it involves disabling security features and having access to a link to the download source. Publishing the game to Google Play would allow for a wider reaching player base, and a more trustworthy and simple process for the player.

The publishing process of the game was relatively quick and easy, thanks to the accessibility of the Google Play Store and Developer Console. After the publishing fee was paid, the only other prerequisite is a privacy policy. The game's privacy policy was based on a policy for an app that, similarly, does not collect or maintain any user data[27], and is hosted in the project's public Github repository[28]. After submission on the 17th of April, it took four days for the game to go live on the Google Play Store, and then the result collection could commence.

To gain users, the game was recommended personally to people and shared online. A post was made on a Reddit forum dedicated to music theory, where it received huge interest, resulting in over 600 downloads and large amounts of constructive feedback.

5. Results

Results were gauged using a mixture of qualitative and quantitative feedback from players in a survey. As shown by Molero et al, the TAM can be employed in conjunction with the Likert scale to gauge the app's effectiveness based on user feedback. The two areas that the TAM assesses are Perceived Ease of Use (PEOU), and Perceived Usefulness (PU)[8]: how easy the user found the technology to be, and how useful the user thinks the technology would be for the task, respectively.

[27] Associates, AJ Lester &. "It's Done! App for IPhone, IPad & Android - Privacy Policy." *Privacy Policy*, It's Done!, 13 Sept. 2013, https://www.itsdoneapp.com/privacy.
[28] Jeffares, Ryan. "Privacy Policy for Quarty." GitHub, 25 Apr. 2021, https://github.com/ryanjeffares/Quarty/blob/master/Pirvacy%20Policy.md.

A survey was hosted on Google Forms. Participants were asked to rate on a scale of one to five how strongly they agree with a variety of statements in an effort to quantify PEOU and PU for the game. In the same survey, there were also some qualitative and multiple-choice questions tuned more towards the research goals of the project. They asked the user how they felt about specific components of gamification employed in the project, and how they would have felt about the inclusion of other components of gamification that weren't included in the project. Since Molero et al's study used results from 18 participants, it was decided this was a suitable target for the current project as the analysis methods are similar.

Players are informed of the survey upon first opening the game. The survey is linked through a button in the settings page of the game. Further detail of the results gathered through these methods is found in the analysis chapter of this research[29].

[29] The questions present on the survey, and whether they are designed to assess PEOU or PU (if applicable) can be found in Appendix E.

Analysis

The analysis chapter of this thesis will focus on analysing the game that was developed in its final form, and the results gathered from participants in the survey. This will feature analysis of the steps undertaken in the methodology with respect to the project's goals, a technical analysis of the game with reference to performance and user experience, and an in depth look at the survey's responses.

1. Analysis of Methodology

The development of the framework for designing effective puzzles with gamification, detailed in Appendix C, was an extremely useful exercise at the beginning of the project's timeline. It helped to cement an understanding of the desired aspects of gamification, and what to consider while developing the game. The extent to which some of the principles' implementations were adhered to will be detailed here.

As detailed under "Rewarding and Effective Puzzle Design", the finished game includes several unique types of puzzle with fixed rulesets. The puzzles include dragging circles or squares into the correct order that play a particular note when a moving arrow collides with them, dragging a keyboard into the correct position to play a chord, dragging a piano key into the correct position to play a chord, guessing the correct note value that was played in an audio clip, and arranging pieces of a drum kit in a sequencer to play the desired pattern. These puzzles inherently incorporate concepts from the real world, as they are musical and some pertain to real instruments, however the original intention was to incorporate physics and spatial reasoning into the puzzles. This did not get developed, due to a lack of further creative level design after some designs had been developed. The puzzles give real time feedback, showing text to indicate to the player whether they inputted something correctly or incorrectly.

Similar to what was intended in the principle of "Engagement and Retention", the game's aesthetics are calm, and encouraging messages personalised with the player's set username are given upon completion of puzzles. However, the game does not adapt to the user's skill in real time. This would have been a large technical undertaking, and the time to confidently implement

it was not available. Each puzzle awards between one and three stars based on how many answers a player inputs correctly in a timed puzzle (the number of stars awarded for different amounts of correct answers was decided through play testing).

Constructivism is encouraged with frequent free-play opportunities as new concepts are introduced. No dedicated playground level was developed outside of the game's courses, however users are able to revisit any level.

The aforementioned stars and glossary terms serve as "badges", and the player may view how many stars were received for each level and their glossary at any time. No graphs were developed, due to time constraints during the development. Similarly, no leaderboards are available - developing a networking system was too much of a technical demand to be completed within the project's timeframe. To account for these missing features, questions were placed in the survey asking whether the participant thinks if these features would have benefitted the game.

As instructed by the "Memory Retention" principle, puzzle types are reused and expanded upon. Ear training exercises were, however, never implemented. Once again, this was simply due to not enough development time being available to develop these. One of the rhythm lessons does include ear training, as the user must identify which note value is being played in a sound clip.

The implementations suggested by the "Motor Skills" principle were largely ignored. As previously explained, puzzles based on physics and spatial reasoning never came to fruition. There was an attempt to create a puzzle based on timing and accuracy where the player must tap icons on the screen at a certain tempo, however testing on various devices showed that the latency involved in this was arbitrary. This idea was abandoned to avoid the risk of the level being impossible on some devices due to long input latency.

The game lacks "Social Relatedness". No social aspects were implemented, due to development constraints. Similarly to the lack of graphs and leaderboards, a question on the survey asks the participant if social features would have benefitted the game. World music and audio theory do

not make an appearance in the syllabus - as there was a concern that the game's content would not be universally understood due to the presence of different music theory systems in some cultures, and therefore potentially exclusionary to people from those cultures, a note was placed on first opening the game explaining that some cultures beyond the Western world use different music theory systems, and the user is encouraged to research these. Originally, a section on timbre was planned to be part of the syllabus, which would have described instruments rather than theory, however this had to be abandoned due to time constraints prior to the desired release date.

"Guiding and Building Knowledge" is practiced as per the suggested implementations in the framework. New concepts are introduced as building on what was covered previously, and examples are always played before the user is asked to try it themselves. The aforementioned personified quarter note serves as a guide. The intention was to create a friendlier atmosphere than only text on the screen.

The extent to which "Conciseness" is practiced is debatable. No more than one topic is ever taught in one level. Some lessons have a subsequent puzzle where the user's knowledge is examined, and some do not. It is possible that dissecting a concept into several parts and covering them over the course of multiple lessons before examining the user would lead to greater understanding.

Overall, approximately just over half of the suggested implementations in the framework are practiced in the finished game. Questions were put in the survey to examine if participants would see benefit in some of the missing implementations, which will be discussed further later in this chapter. In a project with more time allotted to it, these implementations could be better examined, however with over half of the implementations present and results on the perceived benefit of the missing ones, adequate research exists to discuss the quality of the framework.

The syllabus for the game that was decided upon proved to be well designed. It was easily manageable within the timeframe of the project - except for the timbre section, as discussed - and the topics lead into one another effectively. The only shortcoming of it that was pointed out by

users with musical experience was the lack of explanation of enharmonics and flat notes. A decision was made early on in the project to purposefully avoid these topics, so as to keep the content foundational. However, users disagreed with this, and many suggested that an explanation would have been beneficial and that formal students do learn key signatures with flats very early on. This decision was therefore possibly a mistake, as to never even mention flats and enharmonics could lead to confusion for the player when they eventually do learn about them.

No issues arose during the publishing process, as careful attention was given to the game's requirements for publishing on Google Play and the questions that must be answered about the game. After sharing the game online in various places, 43 survey results were received, more than twice the desired amount. While the substantial amount of data that existed was a success for the project, there was a failure in that only one survey participant identified themself as being between the ages of 9 - 12, the initial target demographic of the game. People online were asked to involve their children if they had any, and there was an attempt to involve children from a primary school, however seemingly neither of these attempts were successful. Fortunately, many of the users that took the survey were somewhat experienced with music theory and music education, and some commented on its suitability for the stated demographic. Therefore, the results are still very useful, and can be seen as a peer review before further refined testing with a younger audience.

The game was wide reaching; while the majority of downloads came from English speaking countries, considerable traction came from the rest of Europe, South America, and even South-East Asia, showing store listing visitors from 65 countries. The data obtained from the survey likely shows consensus from a wide variety of cultures and backgrounds. Due to the attention from a huge variety of locations worldwide, further research is certainly required into designing a game like Quarty that accommodates different music theory systems from these places.

Country / region	Store listing visitors	Store listing acquisitions	Store listing conversion rate
Selected countries / regions			
All countries / regions vs. previous period	737 -	506 -	68.66% -
Other countries / regions			
United States vs. previous period	327 -	235 -	71.87% -
United Kingdom vs. previous period	52 -	35 -	67.31% -
Canada vs. previous period	45 -	33 -	73.33% -
Ireland vs. previous period	32 -	22 -	68.75% -
India vs. previous period	30 -	20 -	66.67% -
Germany vs. previous period	18 -	15 -	83.33% -
France vs. previous period	14 -	10 -	71.43% -
Australia vs. previous period	11 -	11 -	100% -
Philippines vs. previous period	11 -	8 -	72.73% -
Argentina vs. previous period	10 -	7 -	70% -
Spain vs. previous period	10 -	6 -	60% -

Fig. 5 - A screenshot of statistics from the Google Play Developer console, showing store listing visitors and acquisitions from the top 11 of 65 countries the store page was viewed in.

2. Technical Analysis

The performance of the game, which has already shown to be a large contributing factor on a user's experience with the game and the effectiveness of the gamification can be evaluated while running on an Android device by using Android Debug Bridge[30] in Unity's profiler. It is worth noting, however, that the performance on a user's device will be better than what is measured using this method, as the game must be built in development mode rather than release mode to

[30] "Android Debug Bridge (Adb) | Android Developers." Android Developers, Google, https://developer.android.com/studio/command-line/adb/.

profile[31]. Some analysis was also done on the audio performance, to ensure the audio would not drop out or experience buffer underruns, potentially damaging the user experience. The following profiling was done prior to publishing to ensure a stable 60 FPS can be maintained by the game, and played on an Oppo Reno Z 5G.

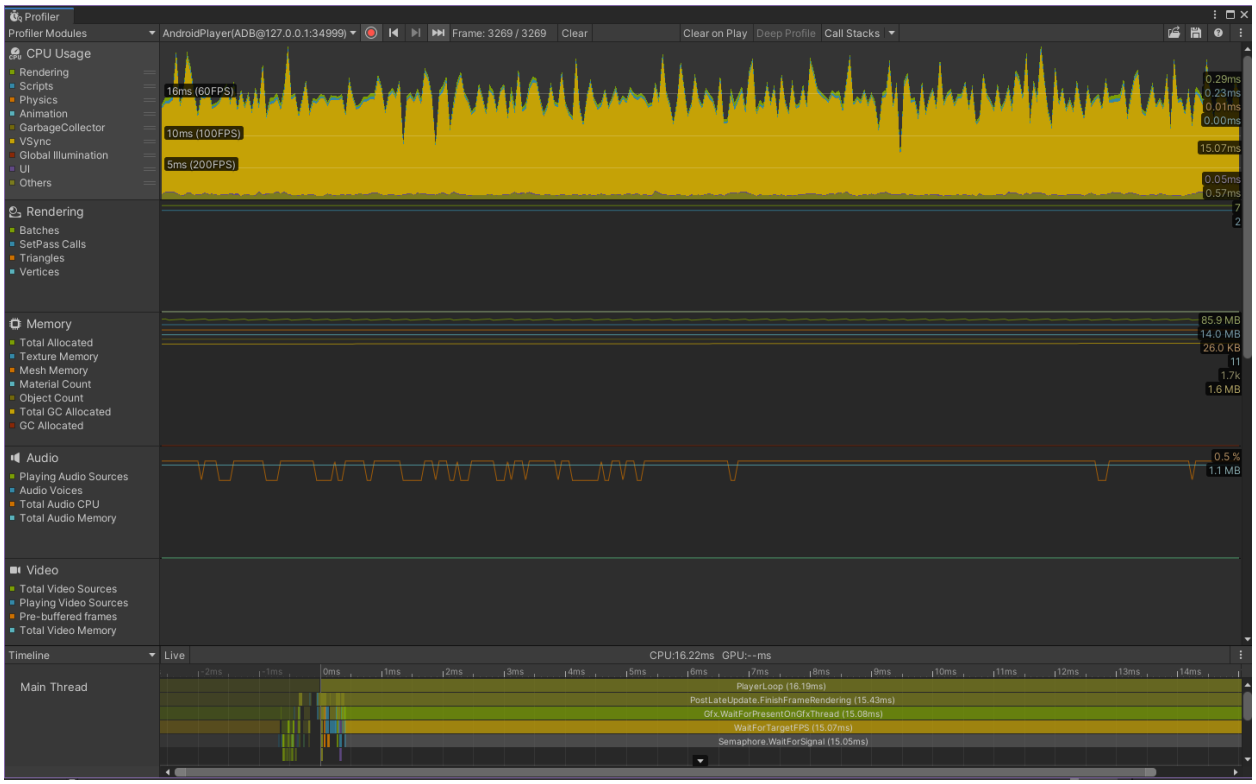

Fig. 6 - Performance profile while sitting idle on the main menu

The above figure is a screenshot of the ADB profiler while sitting idle at the game's main menu. The top graph is the frame times, and what processes compose them. The vast majority is composed of vertical sync - this indicates that the vast majority of the ~16.6 ms that composes each frame is spent simply waiting until the next frame, and not doing any actual processing. This leaves ample time to execute code when handling interaction, physics, and animations - the above screenshot shows an average 0.23 milliseconds spent on script execution, and only 0.01 milliseconds spent on physics simulation. Approximately 86 megabytes of memory is allocated;

[31] When the game is built in "release" mode, as it must be for publishing to Google Play, the code is optimised by the compiler, boosting performance. In "development" mode, the code is not optimised, and also produces logs for the profiler, resulting in slower execution times.

most modern smartphones have four gigabytes of RAM installed, indicating no risk of using too much of the device's memory. The following screenshot was taken during a puzzle, while interaction and audio triggering was being handled.

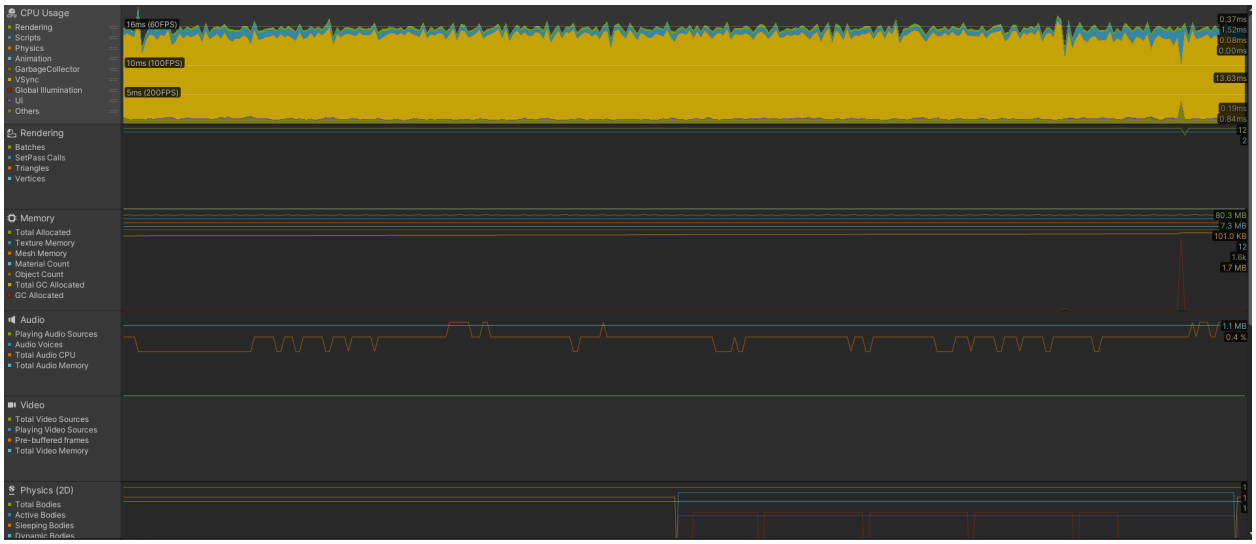

Fig. 7 - During puzzle level while interaction and audio playing was in process.

While frame times are still mostly composed of waiting for vertical sync, noticeably more is spent on script execution - 1.52 milliseconds rather than 0.23 milliseconds - however, it is still comfortably maintaining 60 FPS. No performance concerns were observed in any other levels over considerable lengths of time.

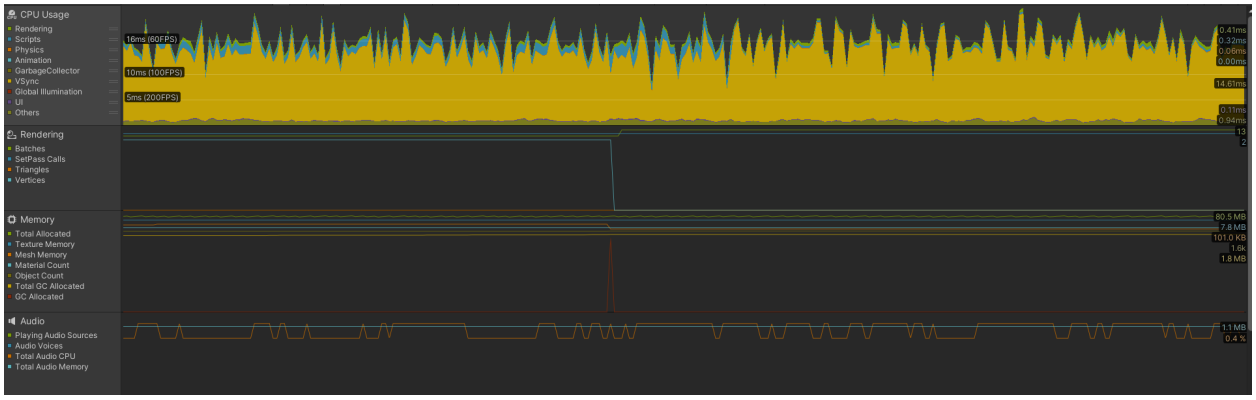

Fig. 8 - Completing a puzzle

The above screenshot was taken upon completing a puzzle. It was a concern that completing a puzzle would lead to a bottleneck in performance, as some logic is done to dictate the player's received stars, and visually spawning those stars on the screen. However, no spike in CPU usage is observed, only an increase in garbage collector[32] allocation, which does not cause any increase in frame-times. No concerning deviation in frame-time is observed.

Fig. 9 - Busy audio playback

Finally, the above screenshot shows the audio performance under a busy load. This does not use more than 1.4% of the CPU, and allocates only 1.1 megabytes of memory. The extremely small load shown above negates concerns of audio drop-outs.

The above technical analysis using the Unity ADB Profiler showed no concerns in performance, and it can be concluded that the game will maintain a stable 60 FPS and high fidelity audio, leaving the user experience uninterrupted by performance issues.

3. Analysis of Survey Results

In this section, the answers received on each question in the survey will be analysed in order, and a conclusion on the data will be finally drawn. The results analysed were obtained between the 17th of April and 3rd of May 2021.

[32] A garbage collector is a background process that deallocates memory that is no longer being used by the program. Unity's "incremental" garbage collector was used which is generally recommended for greater performance - the garbage collector was never observed to increase frame times.

a. Multiple Choice Questions

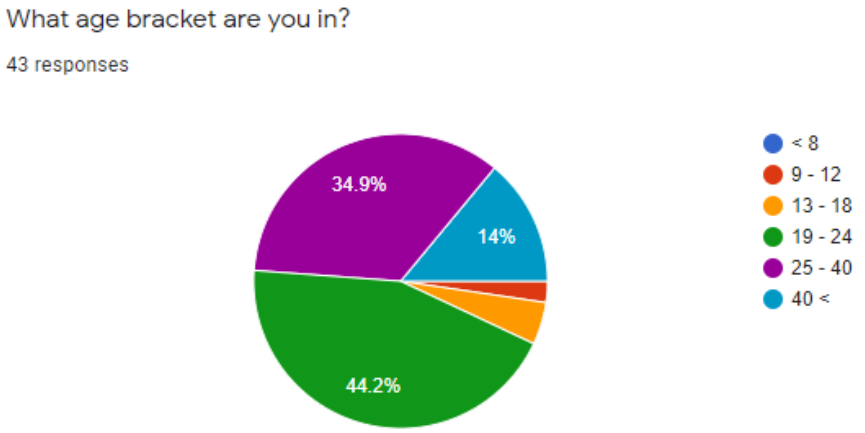

Fig. 10 - Question 1, "What age bracket are you in?"

The first question asked the participant their age. The largest proportion of participants were between 19 and 24, followed by 25 to 40. Some teenagers participated, and only a single participant in the target demographic, as previously discussed.

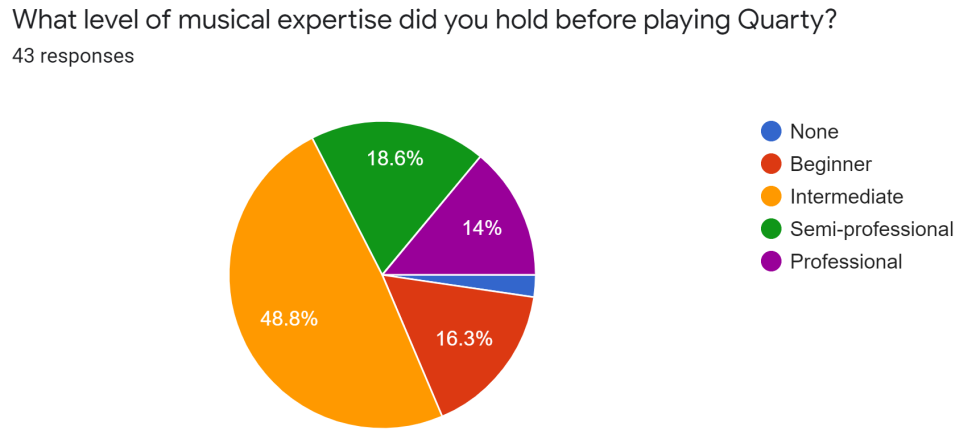

Fig. 11 - Question 2, "What level of musical expertise did you hold before playing Quarty?"

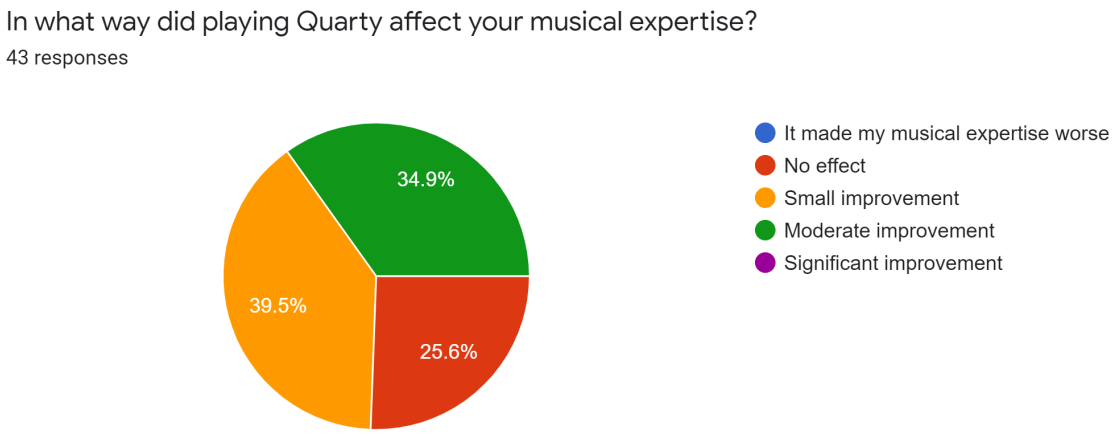

Fig. 12 - Question 3, "In what way did playing Quarty affect your musical expertise?"

The largest proportion of participants identified themselves as having intermediate musical expertise. A sizable proportion were beginners - these participants' data will be useful to gauge how useful beginners found the game as opposed to those with experience. The professionals who answered the survey, making up a similar proportion to beginners, can offer an authoritative peer review.

The vast majority of players found either a small or moderate improvement in their musical expertise from playing the game. While no players found a significant improvement, this can be expected due to the foundational nature of the content and the significant lack of participants with no prior musical experience.

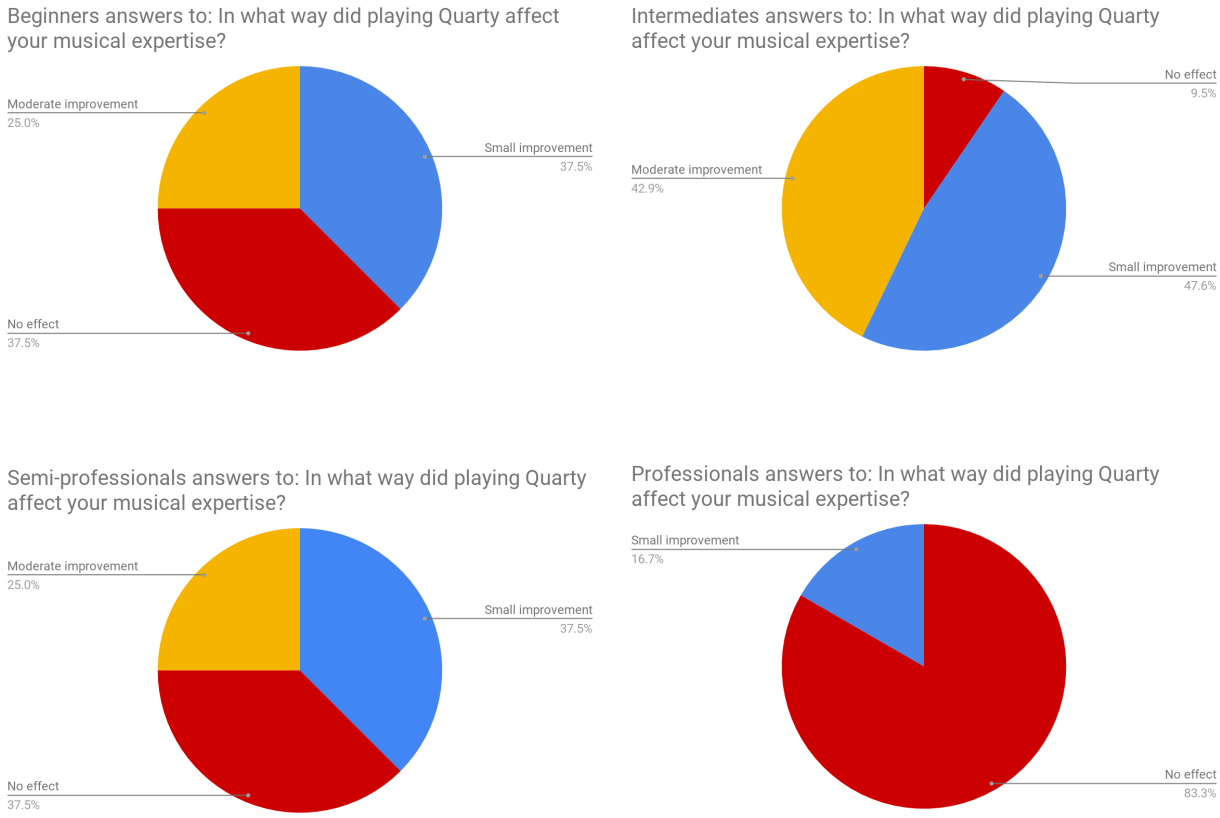

Fig. 13, 14, 15, 16 - Answers to Question 3, "In what way did playing Quarty affect your musical expertise?", categorised by prior musical expertise.

As can be seen above, it was actually participants that identified themselves as intermediate who found the greatest benefit to their musical expertise, with only a single participant citing no effect and the rest either a small or moderate improvement. Over a third of beginners found no effect, yielding the exact same results as semi-professionals, with professionals largely finding no benefit. Further research is required as to why beginners found less benefit, however it can be assumed that the content in the game is less foundational than initially intended, and actually benefited players who already had the basics covered.

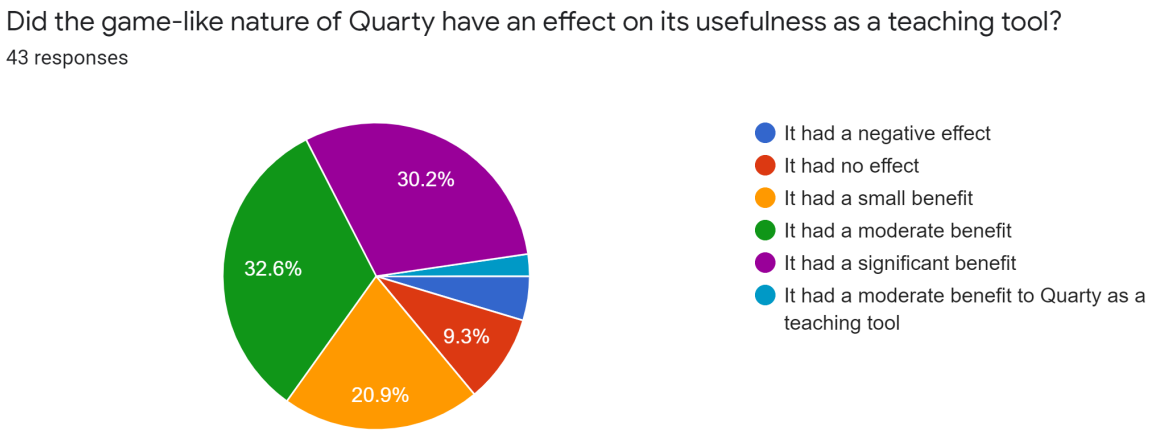

Fig. 17 - Question 4, "Did the game-like nature of Quarty have an effect on its usefulness as a teaching tool?"

Here, while some users disliked or were indifferent to the game-like nature, most thought it gave at least a moderate benefit with almost a third of participants citing significant benefit. This shows that gamifying the concepts was well received by most players, and that gamification in this context is largely considered positive.

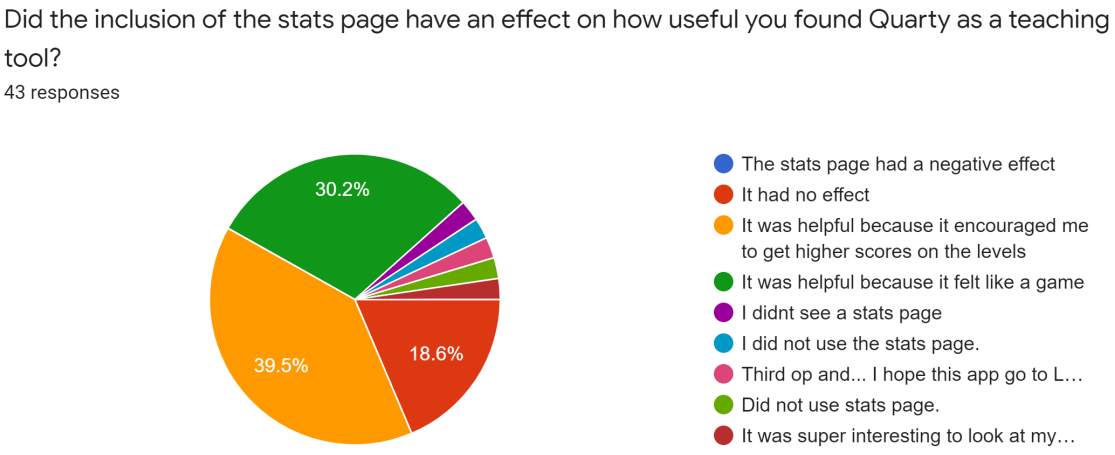

Fig. 18 - Question 5, "Did the inclusion of the stats page have an effect on how useful you found Quarty as a teaching tool?"

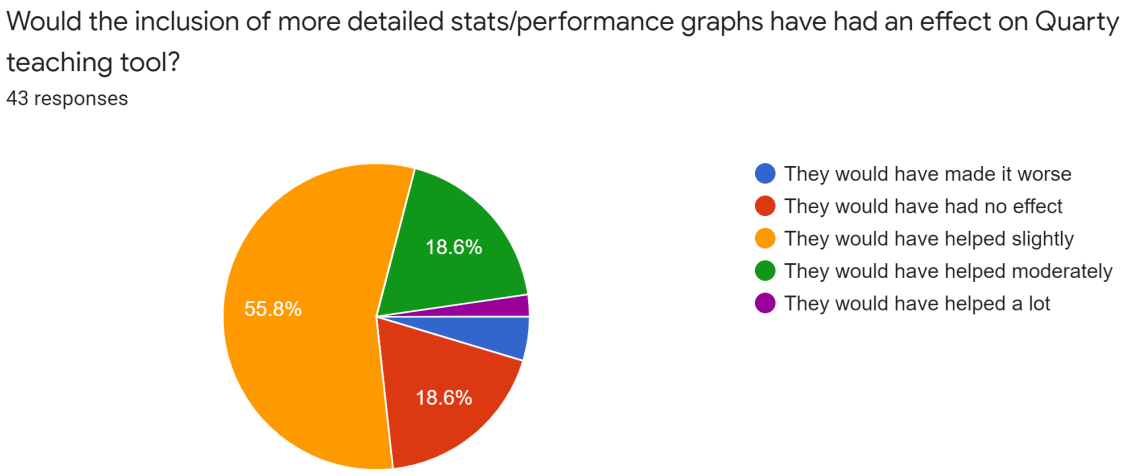

Fig. 19 - Question 6, "Would the inclusion of more detailed stats/performance graphs have had an effect on Quarty as a teaching tool?"

Here, the effect of badges and stats is measured, and the potential of the missing stats features such as performance graphs that are often discussed with respect to gamification are investigated. The largest proportion of participants stated that the stats encouraged them to get higher scores on the levels, which would in turn solidify the music theory concepts being taught. Over 30% of participants said it was helpful because it felt like a game - indicating the stats page caused more enjoyment in the game by making it feel as such.

The former question was given an option for participants to give their own answer - some stated they did not see the stats page, indicating the feature was not labelled clearly enough. Another stated "It was super interesting to look at my own scores. I'm not motivated to grow because of it, but I do enjoy learning what my strengths and weaknesses are." While not directly affecting this player's motivation in the game, it benefited the player in their own self-evaluation.

The majority of participants stated that only a slight benefit would be granted by more detailed stats, with some thinking it would have been a negative inclusion. These results were contrary to what is often discussed with respect to gamification - further research is required here into how different players value detailed stats such as performance graphs.

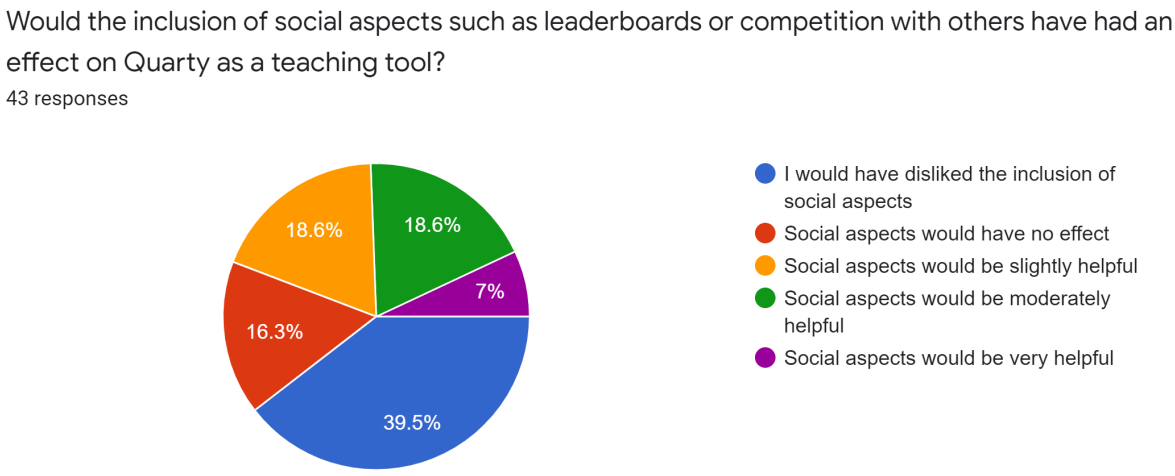

Fig. 20 - Question 7, "Would the inclusion of social aspects such as leaderboards or competition with others have had an effect on Quarty as a teaching tool?"

The final multiple-choice question sought to investigate how players would have taken to social aspects, another commonly stated feature of gamification. Surprisingly, and much on the contrary of previous studies of gamification, the largest proportion (just over a third) of participants would have disliked this. The smallest proportion would have found it very helpful, with the rest evenly split between moderate, slight, or no effect. It is possible that while social aspects aid gamification in other disciplines, it would not be applicable in music. It is also possible that a younger audience of the originally intended demographic would have answered differently here - further research is required to investigate the effect of social features in musical gamification specifically.

b. Perceived Ease of Use/Perceived Usefulness

This section aims to analyse the results of the questions in which the participant had to state how strongly they agreed with a statement on a scale of 1 to 5. The TAM is employed here to quantify the PEOU and PU of the game. The mean and mode for each question is calculated - it was decided that the median and interquartile range were not relevant due to the small number of answer options. The mean scores for questions targeting PEOU and PU are also calculated

separately to examine how well the current project was implemented as opposed to the perceived value of the idea of the project as a whole.

Question	**Identifier**	**Mean (to 2 d.p.)**	**Mode**	**Standard Deviation (to 2 d.p.)**
I find it easy to understand how to complete the puzzles	PEOU1	4.07	4	0.92
I find it easy to understand the music theory concepts	PEOU2	4.07	5	1.15
I find it easy to physically interact with the interactive objects in the game	PEOU3	3.91	4	1.05
I find it easy to hear the musical concepts the game is referring to	PEOU4	4.26	5	1.04
I find it easy to navigate through the game	PEOU5	4.16	5	1.08
I find it useful for learning music	PU1	4.09	5	0.98
I find it motivates me to learn	PU2	4.09	5	1.01
I feel comfortable playing the game	PU3	4.47	5	0.95
I think a game is a useful way to teach music theory	PU4	4.58	5	0.81

Type	**Pooled Mean (to 2 d.p.)**	**Mean of the Mode**	**Mean of the Standard Deviation (to 2 d.p.)**
PEOU	4.09	4.6	1.05
PU	4.31	5	0.94

Overall, the results here are positive. The questions with the lowest mean result was PEOU3, indicating that the game's interaction and accessibility should be refined. This question, along with PEOU1, were the only questions that did not score a mode of 5, indicating that physical interaction and explanation of the puzzles has greater room to improve than every other aspect examined. The highest was PU4 - this question also had the lowest standard deviation - indicating that the premise of the game is widely considered useful, and with further refinement of its content, would be beneficial. The question targeting PEOU with the highest mean result was PEOU4, showing the musical concepts are demonstrated clearly and audibly. The highest standard deviation found from a question was just 1.15 (to 2 d.p.), showing that there was a strong element of agreement.

PU questions scored higher on mean, mode, and standard deviation on average. It is clear that users consider a gamified approach to learning music theory useful, however the implementation of the current project has not quite met that potential.

To conclude the analysis of the survey results gathered, it is clear the project was largely a success, and a gamified approach to learning music theory is valuable and well received. Unfortunately, no data exists on its effectiveness in the originally intended age bracket of 9 to 12, so further research is required here. However, the older users that did play the game mostly found at least some benefit from it. This shows that while the project may have failed in its initial intention of investigating its benefit for children, it is still helpful for adults and teenagers, even up to an intermediate level of prior musical experience. Gamification enhanced their experience, and further expansion on the idea would be welcomed.

Discussion

The discussion chapter of this thesis will demonstrate the learning gained from undertaking the project, and highlight interesting points from the project. The achievements of the project will also be discussed in relation to its original goals.

A substantial amount of technical knowledge of the Unity game engine and the C# programming language was gained during development of the game. This includes how the code executes with respect to frame updates, detailed understanding of how the IL2CPP scripting backend works[33], and how to effectively target the Android platform. This understanding is invaluable in future game design and Android app projects; a detailed understanding of the technology that is being used, especially its limitations, allows for more informed decision making in the design process of any technical project. C# is a highly used language, with wide employment opportunities[34], so knowledge of it is valuable.

Data analysis skills were practiced while analysing the results of the survey. The data was put in a CSV file on Google Sheets, where graphs could be created and mean, mode, and standard deviation calculations could easily be made. These calculations then had to be interpreted to produce the analysis earlier in this thesis. The process was insightful, and a highly valuable skill in any technology related field.

The process of publishing a game to the Google Play Store was experienced first hand, an important thing to understand for a career in game or software development. The process itself is simple, however several prerequisites relating to the game's technical qualities were discovered. The game had to be rebuilt several times to target Google's minimum Android API requirement, and to do so, an updated version of the Android SDK had to be installed. These are surprisingly non-trivial operations that provided detailed insight into the Android development process.

[33] To enhance performance of a game when it is built, Unity's IL2CPP scripting backend can be used to convert the developer's C# code used to script the game into C++, a higher performing language.
[34] Ramel, David. "C#, .NET and SQL Server Make List of Top In-Demand Programming Skills." *Visual Studio Magazine*, 14 Jan. 2020, https://visualstudiomagazine.com/articles/2020/01/14/dice-skills.aspx.

Here, it is worth framing the project in a commercial context, and examining the value of a game like it in the industry. The app was intentionally left free and without ads, so as to not distract from the educational intention and attract the most players. One user's review of the game stated:

> "This is a high quality, fun and educational game. I would highly recommend it for children, as it is family friendly and helps them learn music theory. I'm thrilled at the quality for a free app!"

Another user remarked as an additional comment on their survey response:

> "I hope this app goes to Latin America, my people don't have money to pay a teacher and I think this app may be a really good alternative."

It is clear that the game's accessibility at a free price point is appreciated. The game serves as a contribution to free sharing of knowledge, and an opportunity for people to engage with music who could not afford to otherwise. This was possible due to the only cost of publishing to Google Play being a once-off €25 payment - if a much larger recurring payment was required, for example on the iOS App Store, the game would need to run ads, request donations, or require payment. Further research is required here on how much people would value this type of software monetarily. Furthermore, it is worth investigating the viability of expanding the concept of the game to teach more advanced music theory, even up to a professional level. With more time and resources behind the project, and refined implementation of gamification, game design, and teaching, a game like this could potentially serve as a viable option for education at much higher levels.

A major success of the project was sharing the game on a music theory dedicated Reddit page. The post received over 700 upvotes and two awards resulting in 676 total downloads and an average rating of 4.6 stars out of 5, with scores of comments giving positive and constructive feedback. No crashes or bugs were reported, showing the technical integrity of the game.

Among the most common points of feedback was that the section early on about scales did not provide enough explanation. Here, the derived framework's principle of conciseness should be better exercised, explaining the topic in greater detail, possibly with more examples.

Some users also commented that the target demographic of 9 - 12 years old was ambitious, and they would expect children of a secondary school age to engage with it. Some users commented that it was difficult to obtain three stars on some levels, and that children would find that hard too, indicating that adapting to the user's skill in real time would have been a welcomed feature. It is clear that not enough research was done into how children of the target demographic learn, and what content would appeal to them. Despite this shortcoming, the project was a success with older age brackets. One user commented:

> "I've always had trouble memorizing scale patterns but the visual lay out and practice exercises helped me retain the information better than ever."

What came out of the project was not, after all, a foundational introduction to music theory, but instead a valuable tool for beginner and intermediate users to retain and practice their prior knowledge. Nevertheless, more attention should have been given to the pedagogical aspects of the project with respect to its specific goals. In future projects with more time, this process can be refined.

Some other users' comments pertain very strongly to frequent talking points of gamification, thus showing the positive effects of gamification were achieved and are indeed useful.

> "The game aspect made learning music theory more enjoyable. The level based system of unlocking knowledge really incentivised learning."

> "The timer made me think faster for the reward of stars."

> "The matching games were excellent practice. It was a good mix of learning and practice."

> "Motivational responses and feedback for correct interactions."

> "It made me more motivated to retry the training exercises, boosting my speed and knowledge at selecting the correct answers."

Game design elements such as badges, rewards, and puzzles clearly benefited these players with their educational experience. Gamification was successfully implemented, and the commonly stated benefits of it were experienced, verifying its ability to enhance music theory education.

The framework derived during the project can also be verified here. As the game scored so highly in PEOU and PU with its players, the principles of the framework which were adhered to are most likely important. The principles which were not so strongly adhered to include Social Relatedness, which was eventually shown in the survey results to be unwanted by many users. Adapting to the user's skill, as well as further conciseness, has been shown to be most likely beneficial. As for practicing motor skills, further research is required.

Conclusion

In conclusion, the project was a successful and insightful experience. A wide variety of skills in many disciplines were practiced, and a large amount of work was done with relatively little left unachieved. While the project's intentions of investigating gamifications effect on enhancing music theory education in children aged 9 - 12 specifically is left unanswered due to a lack of research in education at that age group and unsuccessful result gathering from that age group, results unanimously showed it was successful in older age groups regardless. Gamification enhances music theory education, even at intermediate levels, and has welcomed potential throughout the world.

Quarty will continue to receive updates, addressing user feedback and hopefully expanding the syllabus to include timbre, enharmonics, and further refinement of techniques of gamification. The game will retain its free price point going forward, as this has proved to be appreciated. Users' supportive comments and lovely reviews provided lots of encouragement going forward. The project was a highly valuable practice for future projects in both software and game development, education, and academia.

The project was an opportunity to tie together many aspects of the course program. Music theory, audio for games, audio programming, and sound design were brought together in the larger context of education. Not only was the project an enormous success in achieving its goals with respect to the course program, a published and well received game exists indefinitely in the market, benefiting people and kick-starting a career.

To see strangers take genuine joy and personal benefit from one's own creation is a heart-warming and, at times, unbelievable experience. The value of music in our lives, and the importance of freedom to education, has never been so large. The current project has served as a small, but very real contribution to that, and hopefully this research can aid others in aiding all of us.

Bibliography

"Adobe Color." *Color.adobe.com*, Adobe, 2020, https://color.adobe.com/create/color-wheel.

"Android Debug Bridge (Adb) | Android Developers." Android Developers, Google, https://developer.android.com/studio/command-line/adb/.

Associates, AJ Lester &. "It's Done! App for IPhone, IPad & Android - Privacy Policy." *Privacy Policy*, It's Done!, 13 Sept. 2013, https://www.itsdoneapp.com/privacy.

Church, Jeremy. "A Visual Type Scale." *Type Scale - A Visual Calculator*, 2013, https://type-scale.com/.

Davis, Fred D. "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology." *MIS Quarterly*, vol. 13, no. 3, 1989, pp. 319–340. *JSTOR*, http://www.jstor.org/stable/249008. Accessed 30 Nov. 2020.

De Aguilera, Miguel and Alfonso Mendiz Noguero. "Video games and education: (Education in the face of a "parallel school")." *Computers in Entertainment,* vol. 1, no. 1, 2003, pp. 1 - 5.

Deterding, Sebastian, and Steffen P. Walz. *The Gameful World: Approaches, Issues, Applications*. MIT Press, 2014.

Dhawan, Shivangi. "Online Learning: A Panacea in the Time of COVID-19 Crisis." *Journal of Educational Technology Systems*, vol. 49, no. 1, Sept. 2020, pp. 5, doi:10.1177/0047239520934018.

D. Molero at al. "A novel approach to learning music and piano based on mixed reality and gamification." *Multimedia Tools and Applications,* Sep 1, 2020. doi:10.1007/s11042-020-09678-9

"Figma - the collaborative interface design tool". *Figma,* 2015, https://www.figma.com/.

"Flaticon, the Largest Database of Free Vector Icons." *Flaticon*, Freepik, https://www.flaticon.com/.

Fullerton, Tracy et al. "Chapter 2: Structure of Games." *Game Design Workshop: A Playcentric Approach to Creating Innovative Games*, edited by Laura Lewin, Morgan Kaufmann Publishers, 2008, pp. 26 - 48.

Jeffares, Ryan. "Privacy Policy for Quarty." GitHub, 25 Apr. 2021, https://github.com/ryanjeffares/Quarty/blob/master/Pirvacy%20Policy.md.

Likert, Rensis. "A Technique for the Measurement of Attitudes." *Archives of Psychology*, vol. 22, no. 140, 1932, pp. 1–55.

MacRuairí, Cathal. "Music for Walking." Spotify. https://open.spotify.com/track/2xi7ql8EEHdgX8uDAHLeny?si=da4ef024218548a9

"Music and Health." *Harvard Health*, Harvard Medical School, 2011, https://www.health.harvard.edu/staying-healthy/music-and-health.

Okay? 4.06. Philipp Stollenmayer. Kamibox. 16 July 2020. Video Game.

Ramel, David. "C#, .NET and SQL Server Make List of Top In-Demand Programming Skills." *Visual Studio Magazine*, 14 Jan. 2020, https://visualstudiomagazine.com/articles/2020/01/14/dice-skills.aspx.

Richard M. Ryan & Edward L. Deci. "The Darker and Brighter Sides of Human Existence: Basic Psychological Needs as a Unifying Concept." *Psychological Inquiry*, Vol. 11, No. 4, 2000, pp 319-338, doi: 10.1207/S15327965PLI1104_03

Roussou, Maria. “Learning by doing and learning through play: an exploration of interactivity in virtual environments for children.” *Computers in Entertainment*, vol. 2, no. 1, January 2004, article 1. doi:10.1145/973801.973818

Rovithis, Emmanouel, et al. “Educational Audio Gamification: Theory and Practice.” *European Conference on e-Learning (ECEL)*, vol. 17, 2016, pp. 500 - 501.

Sailer, Michael, et al. “How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction.” *Computers in Human Behaviour*, vol. 69, 2017, pp. 371 - 380.

Stewart, Samuel. “Video Game Industry Silently Taking over Entertainment World EJINSIGHT.” *EJINSIGHT*, 2019, www.ejinsight.com/eji/article/id/2280405/20191022-video-game-industry-silently-taking-over-entertainment-world.

Theory of Music Syllabus. Trinity College London, August 2017.

Two Dots. 6.10.1. PlayDots. 24 October 2020. Video Game.

Vosniadou, Stella. “How Children Learn.” *Educational Practice Series 7,* edited by Herbert J. Walberg, International Academy of Education/International Bureau of Education, 2002.

Appendix

A - Framework for Audio Gamification in Formal Education

Rovithis, Emmanouel, et al. “Educational Audio Gamification: Theory and Practice.” *European Conference on e-Learning (ECEL)*, vol. 17, 2016, pp 500 - 501.

1.	Exciting players’ interest, Motivating towards knowledge, Applying modern learning theories
2.	Raising players’ self-esteem, Reducing negativity
3.	Guiding players to experiment and realize their musical ideas, Creating platform for music composition and improvisation
4.	Introducing players to musical concepts without prerequisites, Guiding players to identify sonic properties, Employing mechanics that target specific musical skills
5.	Focusing on the sense of hearing, Excluding distractions, Gaining players’ attention and retaining it over time, Increasing concentration, Enhancing immersion
6.	Promoting collaboration among team members
7.	Sonifying non-musical data
8.	Facilitating the exploration of complex patterns, Enhancing analytical thought, Managing complex sets of data
9.	Enhancing memory
10.	Enhancing dexterity at fine movements and manipulation of complex tools, Improving hand-eye coordination
11.	Allowing freedom for interpretation, Releasing fantasy
12.	Employing a familiar technological medium of modern culture
13.	Carrying emotional content

B - Twelve Principles of How Children Learn, Compared with Other Findings

Vosniadou, Stella. "How Children Learn." *Educational Practice Series 7,* edited by Herbert J. Walberg, International Academy of Education/International Bureau of Education, 2002.

Principle	**Description**	**Related Points in Other Research**	**Implementation**
Active involvement	Learning requires the active, constructive involvement of the learner.	Constructivism	Involvement and non-passive learning inherent in puzzles
Social participation	Learning is primarily a social activity and participation in the social life of the school is central for learning to occur.	Social relatedness (Sailer et al), participation (Roussou)	Multiplayer tasks/mode
Meaningful tasks	People learn best when they participate in activities that are perceived to be useful in real life and are culturally relevant.	Perceived task meaningfulness (Sailer et al), meaningful activities (Roussou), base puzzles on real life (Fullerton)	Base puzzles on real life things, emphasise importance of music theory when learning an instrument
Relating new information to prior knowledge	New knowledge is constructed on the basis of what is already understood and believed.		Each new skill is shown in context with the previous skill. Have a playground type situation prior to each section where players can experiment freely with sounds.
Being strategic	People learn by employing effective and flexible strategies that help them to understand, reason, memorize and solve problems.		Show an example of new types of puzzles being completed.
Engaging in self-regulation and being reflective	Learners must know how to plan and monitor their learning, how to set their own learning goals and how to correct errors.	Performance graphs (Sailer et al)	Performance graphs, leaderboards, and badges. After lessons, ask the player open ended questions: "What do you think would happen if…" "Why did you think…"
Restructuring prior knowledge	Sometimes prior knowledge can stand in the way of learning something new. Students must learn how to solve internal	Teach fewer topics in greater depth (Huynh et al)	Teach fewer topics in greater detail. Show examples from history of people being wrong on their beliefs to show it is ok.

	inconsistencies and restructure existing conceptions when necessary.		
Aiming towards understanding rather than memorization	Learning is better when material is organized around general principles and explanations, rather than when it is based on the memorization of isolated facts and procedures.	Constructivism (Roussou)	Inherent in puzzles.
Helping students learn to transfer	Learning becomes more meaningful when the lessons are applied to real-life situations.		The text states the previous principle helps this. Show how theory helps to learn an instrument.
Taking time to practice	Learning is a complex cognitive activity that cannot be rushed. It requires considerable time and periods of practice to start building expertise in an area.		Do not rush through topics, repeat puzzles on the same topic. Playground idea is reinforced here. Possibly implement an entire practice mode.
Developmental and individual differences	Children learn best when their individual differences are taken into consideration.	Adapting to skill in real time (Rovithis et al, Roussou, Huynh et al)	Adapt to the user's skill in real time.
Creating motivated learners	Learning is critically influenced by learner motivation. Teachers can help students become more motivated learners by their behaviour and the statements they make.	Badges and leaderboards (Sailer et al)	Give rewards and positive feedback. Show leaderboards and performance graphs.

C - Framework for Designing Musical Puzzles with Gamification

Principle	**Goal**	**Implementation**
Rewarding and Effective Puzzle Design	Puzzles should engage the player in a balanced and steady level of challenge. They should be rewarding and intuitive.	Several types of puzzles with unique, fixed rulesets will be reused. Puzzles will incorporate concepts from the real world, and give real time feedback.
Engagement and Retention	Balance of challenge and fun keeps the player engaged. Player's self esteem should be boosted and their interest spiked.	Difficulty will adapt to the player's skill in real time. Aesthetics will be inviting and calm. Players will be rewarded and encouraged.
Constructivism and Practice	Players should be encouraged to form their own understanding of concepts. Players should be given time to practice concepts and learn through doing and playing.	Learning through doing is inherent in puzzles. A playground level will be available prior to each lesson. A playground mode will possibly be available outside of lessons.
Badges and Leaderboards	Players should be rewarded for their progress. Psychological need for satisfaction and self regulation is encouraged.	Players will be rewarded badges for their achievements. Players can see graphs of their own performance. Players can see themselves on leaderboards.
Memory Retention	Players' memory retention should be exercised. Players should be encouraged to use their memory, not to answer questions but to solve problems.	Reusing puzzle types will call on this. Intermittent ear training exercises, with the option to practice outside of tests, will be included.
Motor Skills	Puzzles should exercise players' hand eye coordination, hand ear coordination, and spatial recognition.	Puzzles based on physical space/positioning will be included. Some puzzles will rely on timing and accuracy.
Social Relatedness	The app should encourage social participation, social relatedness, and a feeling of inclusion.	Leaderboards will introduce a social aspect. Multiplayer modes, whether cooperative or competitive, can aid this. Concepts of world music/audio theory and not just western music can allow users of all backgrounds to relate.
Guiding and Building Knowledge	Knowledge should be built on top of prior knowledge. Players should understand strategies to complete puzzles.	New concepts will be shown in context of previous concepts. Examples of how to complete new puzzle types will be shown. A guide in the form of a character will bring the player through new concepts.
Conciseness	The app should not aim to teach too many concepts too quickly, so as to encourage a genuine understanding of the subject matter and not rudimentary understanding.	The app will teach fewer topics in more detail. Multiple levels will be designed to cover the same topic.

D - Syllabus for the Current Project

Course	**Lesson List**
Melody	1. Notes 2. Tones And Semitones 3. Major Scale 4. Major And Perfect Intervals 5. Minor Scale 6. Minor Intervals 7. Melody Writing
Harmony	1. Triads 2. Major and Minor Sevenths 3. Suspended Chords 4. Keys 5. Chord Progressions
Rhythm	1. Tempo 2. Time Signatures 3. Note Values 4. Combining Rhythm with Melody and Harmony

E - Survey Questions

1. What age bracket are you in?
    a. < 8
    b. 9 - 12
    c. 13 - 18
    d. 19 - 24
    e. 25 - 40
    f. 40 <
2. How did you find out about Quarty?
    a. Online/Social Media promotion
    b. Personal recommendation
    c. Suggested in Google Play Store
3. What level of musical expertise did you hold before playing Quarty?
    a. None
    b. Beginner
    c. Intermediate
    d. Semi-professional
    e. Professional
4. In what way did playing Quarty affect your musical expertise?
    a. It made my musical expertise worse
    b. No effect
    c. Small improvement
    d. Moderate improvement
    e. Significant improvement
5. Did the game-like nature of Quarty have an effect on its usefulness as a teaching tool?
    a. It had a negative effect
    b. It had no effect
    c. It had a small benefit
    d. It had a moderate benefit
    e. It had a significant benefit
6. If so, in what ways did the game-like nature of Quarty achieve this?

7. Did the inclusion of the stats page have an effect on how useful you found Quarty as a teaching tool?
    a. The stats page had a negative effect
    b. It had no effect
    c. It was helpful because it encouraged me to get higher scores on the levels
    d. It was helpful because it felt like a game
    e. Other (please specify)
8. Would the inclusion of more detailed stats/performance graphs have had an effect on Quarty as a teaching tool?
    a. They would have made it worse
    b. They would have had no effect
    c. They would have helped slightly
    d. They would have helped moderately
    e. They would have helped a lot
9. Would the inclusion of social aspects such as leaderboards or competition with others have had an effect on Quarty as a teaching tool?
    a. I would have disliked the inclusion of social aspects
    b. Social aspects would have no effect
    c. Social aspects would be slightly helpful
    d. Social aspects would be moderately helpful
    e. Social aspects would be very helpful

PEOU/PU Questions (participant is asked to rate how strongly they agree with the statement on a scale of 1 - 5):

Question	**PEOU/PU**
I find it easy to understand how to complete the puzzles	PEOU1
I find it easy to understand the music theory concepts	PEOU2
I find it easy to physically interact with the interactive objects in the game	PEOU3

I find it easy to hear the musical concepts the game is referring to	PEOU4
I find it easy to navigate through the game	PEOU5
I find it useful for learning music	PU1
I find it motivates me to learn	PU2
I feel comfortable playing the game	PU3
I think a game is a useful way to teach music theory	PU4